

CRYOMODULE TEST FACILITY

Overall Scope of Work
and
Proposed Areas of Responsibility

August 22, 2011

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1. APPROVALS

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2. REVISION HISTORY

Revision	Date	Section No.	Revision Description
1.0	August 22, 2011	All	Initial Release

3. INTRODUCTION

Fermilab in collaboration with the Indian Institutions of the IIFC is building a Cryomodule Test Facility (CMTF). This installation will be used as a research and development facility for accelerator technology, in particular, the testing and validating of SRF components. Currently, U.S. High Energy Physics envisions two possible SRF based machines, Project X and in the longer term future, ILC. CMTF is intended to be a flexible cryomodule test facility, configurable in different ways to meet the needs of either of these projects or other potential future users.

CMTF is located in a new set of buildings adjacent to the New Muon Lab. It provides the necessary test bed to measure the performance of SRF cavities in a cryomodule (CM). The facility will include two liquid helium refrigerators, two Cryomodule Test Stands (CMTS), a test area for RF components, a clean room, and all related support equipment. The first test stand, CMTS1, is designed for 1.3 GHz cryomodules operated in a pulsed mode (PM). The second test stand, CMTS2, supports testing of 650 MHz cryomodules in Continuous Wave (CW) mode. Associated with each test stand are the cryogenic transfer lines, connection "boxes", mechanical supports, vacuum systems, instrumentation, RF power sources and controls required for operation. The information exchange between Fermilab and Indian Institutions would be useful in setting up desired CMTF in India.

The Project X design is still evolving and it is likely that other frequency cryomodules, operating at 1.3 GHz sub-harmonic frequencies such as 325 MHz, need to be tested in CMTF. Wherever practical, sufficient flexibility shall be designed into the components of the CMTF to allow for a possible upgrade to other frequencies. Depending on the particular components this upgrade could involve either the full removal/replacement of existing equipment, extensive modifications, or more simply the adjustment of operating parameters. In all cases, the trade off between cost and flexibility shall be considered.

This document provides the general scope of work and proposed associated responsibilities for the design, fabrication, installation, commissioning and acceptance testing of the various parts of the Cryomodule Test Facility. There will be individual documents specific to each subsystem that will provide additional details.

4. DEFINITIONS/ACRONYMS

CMTF – Cryomodule Test Facility

CMTS – Cryomodule Test Stand

CW – Continuous wave operating mode

IIFC – Indian Institution – Fermilab Collaboration

FRS – Functional Requirements Specification

PM – Pulsed operating mode

TRS – Technical Requirements Specification

TD – Technical Design

5. SCOPE OF WORK/AREAS OF RESPONSIBILITY

Requirements and Specifications

- Fermilab will be responsible for generating the approved Functional Requirements Specification (FRS) and Technical Requirements Specification (TRS) for each subsystem of the CMTF. Once the TRS is approved and accepted, the Technical Design (TD) will be developed. If an existing Technical Design exists, the FRS and TRS documents can be simplified but are still required to assure that the specific requirements of CMTF are met by the chosen design. However, in this case, the fabrication of the components is essentially “build to print”. In cases where a new design is required, the design will be a collaborative, team effort between Fermilab and the Indian Institutions with the Indian Institutions at the forefront of the design effort for components for which they have primary responsibility.

Reviews and Approvals

- The design and fabrication efforts for CMTF will follow the approved Fermilab Engineering Process, see Reference [5]. This process includes specific steps for design reviews, formalized approvals and documentation. In all cases, the

reviews and approvals will be set up so as to satisfy both the Indian Institution and Fermilab prescribed processes for approval.

CMTF Buildings

- Fermilab is responsible for the construction and outfitting of the CMTF building. Requirements that the building or its infrastructure impose on the technical components will be clearly listed in the applicable TRS.

Cryogenic Plants

- Fermilab will procure, install, and commission the two liquid helium cryogenic plants including all compressors, support equipment, instrumentation and controls.
 - CTI-4000 Plant (FNAL)
 - Linde Superfluid Plant (FNAL)

Indian Institutions would be offered an opportunity towards cryogenic plant's design and commissioning. This would be helpful in overall CMTF work in India.

Cryomodule Test Stands & Cryogenic Distribution

- The cryogenic functional requirements of the test stands are covered in Reference [3]
- CMTS1 – Indian Institutions shall provide the cryogenic boxes (feed can, feed cap, end cap, bayonet cans and associated transfer lines) for this test stand. Fermilab shall provide all of the remainder of the equipment and components required to make the test stand operational.
- CMTS2 – Indian Institutions shall provide the cryogenic boxes (feed can, feed cap, end cap, bayonet cans and associated transfer lines) as well as the instrumentation, controls, RF power equipment, and safety systems consistent with the requirements and the CMTS2 installation.
- Valve Box – The valve box is the connection between the cryogenic plants and the test stand systems. Fermilab will be responsible for the design of the valve box and the Indian Institutions shall be responsible for its fabrication.

- Fermilab shall be responsible for the installation and commissioning of both test stands including the construction of the test caves and shielding. Indian Institutions are encouraged to participate in this work so as to gain experience for their project.

RF Power Equipment

- The RF functional requirements of the test stands will be covered in the FRS specific to those subsystems.
- Fermilab will provide all of the 1.3 GHz power equipment for CMTS1. Much of this equipment has already been procured. Indian Institutions are encouraged to participate in this work so as to gain experience for their project.
- Indian Institutions will have responsibility for and provide the 650 MHz power and distribution system for CMTS2. Working closely with Fermilab's RF Group, the Indian Institutions will develop a technical design that meets the requirements of the FRS and TRS. Depending upon the requirements, technology choices available, and schedule there may need to be two different systems developed; one that meets short term needs and another that is geared towards future application. Fermilab will work closely with the Indian Institutions as once again there is existing equipment available. Integration of the RF Power systems into the existing power environment is essential.

Instrumentation & Controls

- The instrumentation & controls functional requirements of the test stands will be covered in the FRS specific to those subsystems.
- Indian deliverables for CMTF instrumentation and controls include RF protection interlock systems, LLRF systems, cryogenic temperature monitoring systems, and other diagnostics (to be specified) for CMTS2. All the sensors are to be provided by Fermilab.

- Fermilab has designs and/or prototypes for each of these systems. The technology transfer will be based on visiting engineers and scientists from the Indian Institutions.
- A seamless integration of the instrumentation systems is mandatory. Interfaces are physical (cable connectors, racks, etc.), electrical (signals levels and ranges), and logical (DAQ towards the control system). On the global controls level, CMTF will be controlled by the Fermilab ACNET control system. Therefore, drivers, timing and DAQ interfaces for ACNET / EPICS must be provided. Further, VME, VXS and VXI are the preferred electronics hardware platforms.

Mechanical Supports

- Mechanical supports integral to the components supplied by Indian Institutions shall be provided with the equipment. Fermilab will be responsible for all other required mechanical supports and fixtures. In particular, the support structure on which the cryomodule sits while in the test stand will be provided by Fermilab.

Shipping and Customs

- Indian Institutions shall be responsible for transportation and delivery of their equipment to Fermilab. Fermilab will be responsible for all customs charges and import fees.

6. KEY ASSUMPTIONS, INTERFACES AND CONSTRAINTS

- (a) The necessary building, civil structures and utilities are available prior to the delivery and installation of the CMTF equipment. The current completion date for building construction project is October 2011. Civil drawings and information will be provided to the Indian Institutions by Fermilab when available. See Reference [2] for current detailed information.
- (b) Cryogenic plants are capable of operating at their appropriate rated capacities and will be connected in such a way as to provide sufficient cooling to each of the test stands for any given mode of operation.

- (c) Test parameters are still being developed as the Project X design continues to evolve. Current test parameters for the 1.3 GHz pulsed and 650 MHz CW tests are as follows

Pulsed mode

RF power only, no beam
Rep rate - 5 [Hz]
 $Q_0 \geq 1.0E10$
Maximum accelerating gradient $E_{acc} = 35$ [MV/m]
RF flat top 1000 [μ sec]
Operating temperature $T_{op} > 1.80$ [K]

CW mode

RF power only, no beam
Rep rate - Continuous wave
 $Q_0 \geq 2.0E10$
Maximum accelerating gradient $E_{acc} = 20$ [MV/m]
Operating temperature $T_{op} > 1.80$ [K]

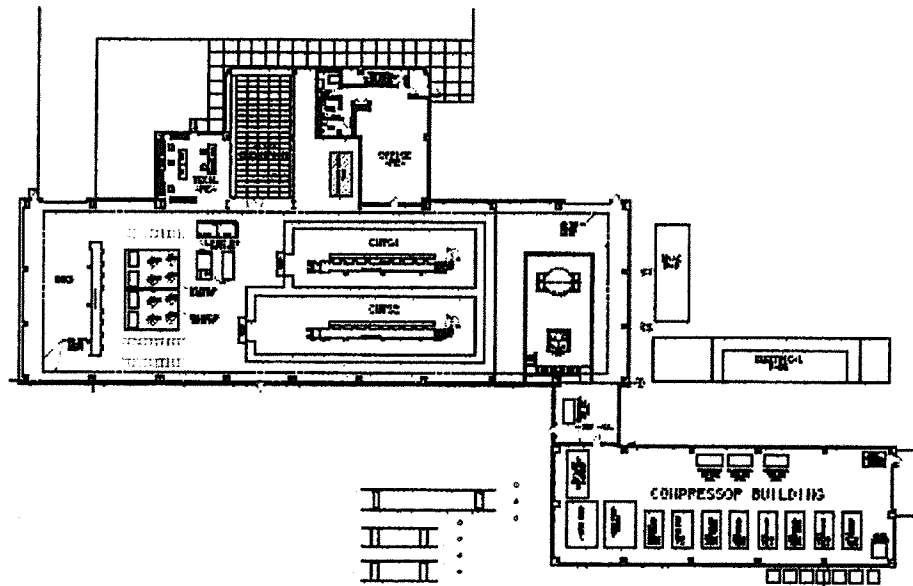
7. GENERAL REQUIREMENTS

- (a) All systems shall meet the applicable codes and safety requirements necessary for operation at the Fermilab facility. The system and its components are subject to compliance with the Fermilab ES&H Manual (FESHM), in particular those policies associated with pressure vessels, cryogenics and electrical power aspects of the systems.
- (b) The test stand systems are expected to operate for at least 20 years with an estimated 12 tests per year per stand.
- (c) Control systems used in CMTF shall be compatible with Fermilab's ACNET controls to allow easy integration into the existing system. System control and instrumentation shall be integrated into the existing NML control system.

- (d) The test cave's ODH classification shall not exceed ODH class 1 as defined in the FESHM 5064. Fermilab will be responsible for assuring this classification.
- (e) The CMTF system will be manufactured using industry accepted QA procedures and standards. ISO accepted testing procedures and standards shall be used for system and component tests.

8. REFERENCES

- 1) Holmes, S. "Project X - Reference Design Report", Fermilab, November 2010.
- 2) Leibfritz, J. "CMTF Building Details", Fermilab, August 2010.
- 3) Klebaner, A. "CMTF Cryogenic Functional Requirements Specification", Fermilab, October 2010.
- 4) Klebaner, A. "Cryogenic Functional Requirements Specification – Supplementary Details", Fermilab, September 2010.
- 5) Fermi National Accelerator Laboratory "Engineering Manual", Fermilab, 2010.



Current CMTF Layout