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CRYOGENICS FOR THE SUPERCONDUCTING RADIO-FREQUENCY MODULES

Klebaner A. L., Theilacker J. C.

Fermi National Accelerator Laboratory, Batavia, IL, USA

Fermilab is constructing a superconducting cryomodule test facility. The facility will be used to support research and development (R&D) of superconducting radio-frequency (SRF) cryomodules for the International Linear Collider (ILC), an upgraded Photoinjector for accelerator physics, and the Proton Driver (PD). Four major SRF test areas are being constructed to enable vertical and horizontal cavity testing, as well as cryomodule testing. The existing Fermilab cryogenic infrastructure is being modified to service SRF R&D needs. The system overview, cryogenic capability, current status and challenges of the project are described in the paper.

INTRODUCTION

Fermilab has started an R&D program on superconducting radio frequency (SRF) elliptical and spoke cavities for use in future accelerators such as ILC and High Intensity Neutrino Source, formerly known as the PD. These potential projects place increasing demands on the performance of SRF components, and on the ability to produce them in large quantities at lower costs. Four test areas for testing SRF components have been constructed at Fermilab.

The largest of these test areas is located at a New Muon Lab and could have an electron beam capability to allow full evaluation of the ILC RF unit. Vertical testing of the elliptical cavities will be done at the Industrial Building 1 (IB1), also known as Fermilab Magnet Test Facility (MTF). Horizontal testing of the elliptical cavities and the majority of the research of spokes cavities will be conducted at the Superconducting Module Test Facility (SMTF), which is an experimental area being constructed inside the Meson Detector Building at Fermilab

SUPERCONDUCTING MODULE TEST FACILITY

Liquid nitrogen and liquid helium are supplied to the Meson Detector Building (MDB) through vacuum insulated transfer lines from the Cryogenic Test Facility (CTF). CTF is located about 500m southwest of MDB and was formerly known as Meson Central Cryogenics [1]. The refrigeration system is comprised of three Tevatron Satellite style refrigerators operating in parallel. Each refrigerator is capable of providing 625 W of refrigeration at 4.5 K when operated in refrigerator mode and approximately 4 g/s of 4.5 K liquid helium in a liquefier mode.

Test areas in this facility are divided into three test caves – Horizontal Test Cryostat (HTC), Spoke Resonators Vertical Test Cryostat (SRVTC), and a front end for the High Intensity Neutrino

Source (HINS). The first two test caves can operate down to 1.6K, where the HINS low energy front end operates in the 4.5 K range. All three test caves could operate simultaneously depending on the operating requirements for specific tests.

Currently, the Capture Cavity II (CCII) test cryostat has undergone tests at 4.5K and 1.8K. RF testing, including gradient and frequency measurements, is underway.

To achieve superfluid in this facility, a modified liquid ring and roots blower vacuum pump system is used. The skid has capacity of approximately 10 g/sec of helium at 1600 Pa inlet pressure, which corresponds to 1.8K saturation temperature.

The vacuum pump skid (see Figure 1) was originally designed and fabricated at Thomas Jefferson National Accelerator Facility in 1993, and has since been refurbished and altered for continuous helium service at Fermilab. Most significant modifications include controls and instrumentation upgrade, variable speed drive for the blower, and the addition of dual helium guarded dynamic shaft seals for both pumps.

During initial skid commissioning high levels of vibrations were observed. It was determined that the vibration was caused by an imbalance in the blower rotors. The imbalance was due to oil getting inside the ventilated hollow rotors. Under normal circumstances, the service does not require an oil injection, and as a result there is no chance for imbalanced rotors. For helium service, an oil injection is used to compensate for the high heat of compression. The original ventilated caps on the hollow rotors were replaced with sealed caps in order to avoid oil getting in the lobes.

Figure 1 MDB Vacuum pump skid

The HTC is designed to facilitate timely testing of dressed 1.3 GHz or 3.9 GHz cavities prior to their assembly in a SRF cryomodule. It is manufactured by U.S. industry and is expected to be delivered to Fermilab in July, 2006. The cryogenic distribution system, including controls and connections to the warm pumping system, is currently being installed. It is expected that the HTC will be operational in the summer of 2006.

The SRVTC (see Figure 2) is being designed to test SRF spoke cavities and their associated helium vessels, RF couplers, tuning mechanisms, and focusing solenoids [2]. The cryostat would have enough room to test triple spoke cavities with a quadrupole magnet, as well as quarter wave resonators developed in Argonne National Laboratory. It has capabilities to test the spoke resonator at 4.5 K or 2 K. Procurement of the cryostat is scheduled for July, 2006. It is expected to start operation of the SRVTC in the beginning of 2007.

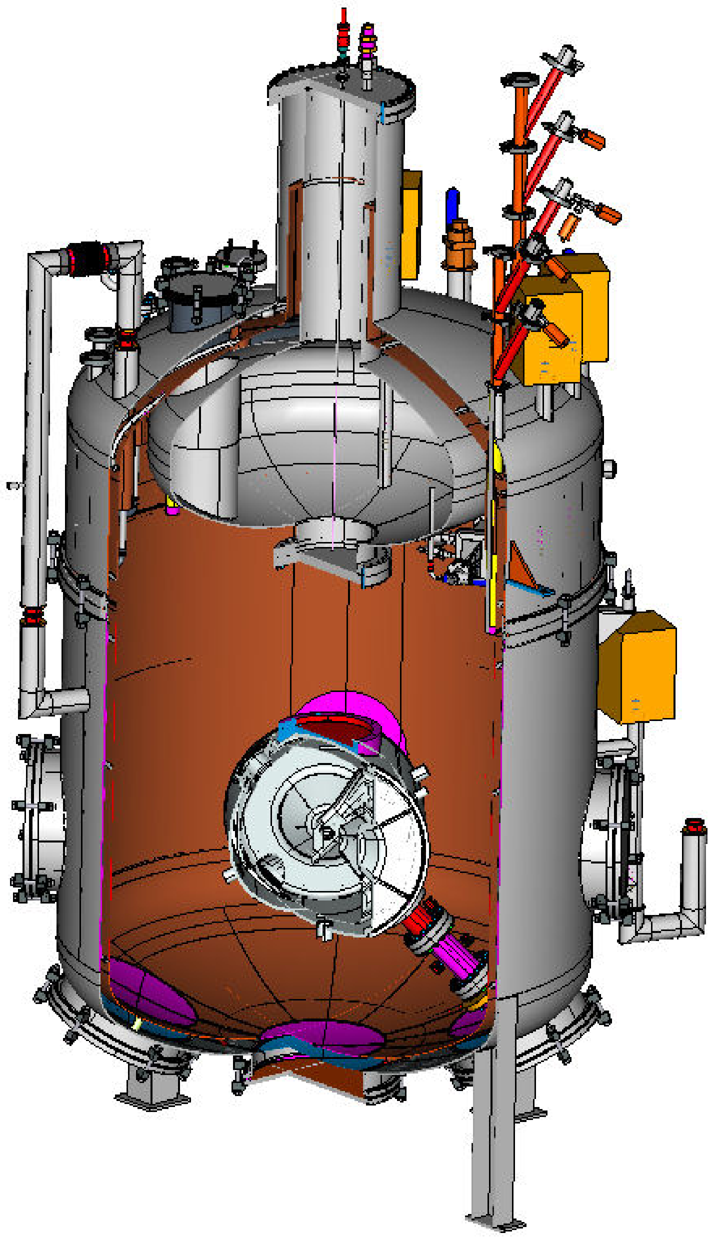

Figure 2 3-D Model of Spoke Resonators Vertical Test Cryostat

VERTICAL TESTING AREA

An ILC vertical test cryostat is being procured to allow undressed cavity testing in the IB1. The vertical testing of a cavity is required to ensure acceptable cavity performance following surface processing and prior to being enclosed in a helium vessel. The cryostat is part of the Fermilab MTF cryogenic system. The cryogenic system is based on a 1500 W refrigerator and a warm pumping system. The refrigerator operates in a liquefier mode during testing and is capable to produce approximately 9 g/sec of liquid helium. The vacuum pump system consists of two skids with a total pumping capacity of a 4 g/sec at 1600 Pa [3].

NEW MUON LAB TEST AREA

An ILC cryomodule test area is being constructed at Fermilab's New Muon Lab (NML). The area could have an electron beam capability to allow full evaluation of the ILC RF unit with beam. Each RF unit consists of three eight cavity cryomodules. The center cryomodule includes a quadrupole magnet with HTS leads. An electron beam could be supplied from an existing Photoinjector. The injector would be relocated and upgraded by adding CC II.

The NML cryogenic system will initially consist of a Tevatron satellite refrigerator operating in a liquefier mode. Operation at superfluid temperatures is achieved with a warm helium vacuum pumping system of the same type used at MDB. Provisions are being made to add a second satellite refrigerator to allow for operation at ILC repetition rate.

The system in the initial configuration is being installed and is expected to be operational in spring 2007. Several components of the system are being procured from the U.S. industry. One ILC cryomodule is expected per year over the next three years to be added to the NML RF unit.

CONCLUSIONS

An international panel has recommended adoption of SRF technology to accelerate the electron and positron beams of the International Linear Collider. Nearly all new initiatives for electron, ion and proton sources incorporate superconducting cavities. These projects place increasing demands on performance of SRF, and the ability to produce SRF components in large quantity at lower cost.

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