SRF HIGHBAY TECHNICAL INFRASTRUCTURE FOR FRIB PRODUCTION AT MICHIGAN STATE UNIVERSITY*

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Abstract

Abstract: Michigan State University (MSU) is establishing a new 2,500 m^2, high bay building to house the Superconducting Radio Frequency (SRF) infrastructure for the Facility for Rare Isotope Beams (FRIB) production requirements. The construction has been completed and beneficial occupancy began in May 2014. The new SRF highbay includes over 373 m^2 of cleanroom and chemistry facility space, automated cavity etch tools, ultra pure water systems, cold mass component inspection area, hydrogen degassing furnace, SRF testing capabilities for three vertical test Dewars and two horizontal cryomodule test caves with a dedicated helium refrigeration system. The status of the design, installation and commissioning will be presented.

INTRODUCTION

The SRF technical infrastructure is operated by the FRIB SRF Department, which has developed and will mass-produce four types of SRF cavities, coldmasses, and cryomodules for the FRIB linac. The linac requires a total of 330 certified cavities for installation into 49 cryomodules.

The SRF highbay will house all FRIB SRF-related activities except for cryomodule assembly, which will occur elsewhere. This infrastructure will support the FRIB baseline SRF cavity processing requirements [1]. Detailed coldmass component processing and testing workflows have been developed to define equipment requirements and optimize the work center layout (Fig. 1).

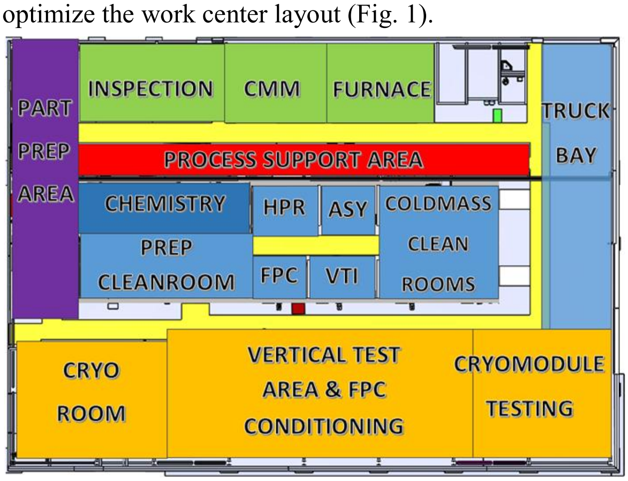

Figure 1: SRF highbay work center layout.

Coldmass production will require 36 months, with an average process rate of 12.5 cavities per month. It is assumed 20% of the cavities will be reprocessed. This rate, coupled with maintenance downtime considerations, yields a required throughput of one cavity per weekday.

The SRF highbay was completed in 13 months, in May 2014. The highbay includes a 30 ton overhead crane, four 1.5 m diameter x 4.9 m deep Dewar shafts, and a roof structure designed to handle the load of eight 113.6 m^3 helium gas storage tanks.

PROCESSING FACILITY

Cleanrooms

The new 372 m^2 SRF cleanrooms were designed using lean manufacturing principles to streamline work flow and minimize cross-contamination by creating separate work centers for each major activity. Critical procedures including final rinsing and cavity and coldmass assembly are performed in an ISO 5. Less critical processes take place in an ISO 6 area. A central walkway minimizes interference between work centers, which are divided by transparent air return walls increasing visibility and flexibility for expansion. The layouts (Fig. 2) are identified as follows: 1) ante room, 2) part washing 3) power coupler assembly, 4) insert hatches, 5) coldmass pump down and leak checking, 6) coldmass assembly, 7) cavity drying and assembly, 8) high pressure rinse, 9) chemistry room pass through and 10) chemical etching room.

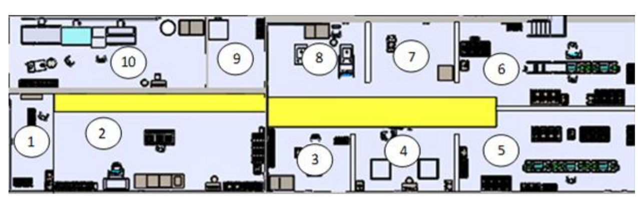

Figure 2: Cleanroom layout.

The new cleanroom has passed all vendor and independent certification tests and is fully commissioned. Processing work is now ongoing in the new cleanroom.

Chemistry Facility

The SRF cavity chemical etching facility includes state-of-the-art process equipment designed for safe and reliable performance. Sophisticated safety interlocks and alarms were implemented to eliminate the possibility of exposure to buffered chemical polish (BCP) or toxic chemical vapors. The process equipment (Fig. 3) is composed of an SRF cavity etching cabinet optimized for the FRIB cavity designs, a chemical fume hood capable of storing three 200 L drums of BCP, a niobium parts etching fume hood

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featuring hands-free acid fill and drain cycles, and a touch-screen enabled control cabinet programmed with automated cavity etching recipes.

All waste produced in the equipment is neutralized in an automatic system before being pumped to the sanitary sewer, and all acid vapors produced during etching are neutralized with a 0.94 m^3/s NOx scrubbing system. The etching facility also includes an ISO 7 pass-through area to maintain cavity cleanliness during transport to the high-pressure rinse work center. All chemical equipment commissioning will be complete by October 2014.

Figure 3: Automated chemical etch tools.

High Pressure Rinse Systems

The existing SRF high pressure rinse (HPR) was disassembled, moved and successfully recommissioned in the new cleanroom. This facility provides a water pressure of 83 bar at a flow rate of 7.6 L/min. The rinse nozzle consists of eight 0.5 mm diameter orifices. Two jet-holes are located on the nozzle at 87.17° angle to clean the short plate region. Six jet-holes are located around the periphery of the nozzle; two point upwards at a 45° angle, two point down at a 45° angle, and two spray horizontally. The cavity rotates at five rpm and the wand assembly translates on a linear actuator with speeds varying from about 0.1 cm to 10 cm/s. An automated HPR system more suited to a production environment has been specified and bids received from vendors. This system will provide 83 bar water pressure and utilize a multi-actuator wand system. It is designed to HPR rinse all four cavity types and reduces the personnel effort required to complete the process by over 1300 people-hours. The multi-wand feature reduces human interaction and handling, minimizing risk of contamination and improving repeatability and cleanliness. The new system should be operational by late 2015.

Ultra Pure Water System

The SRF ultrapure water (UPW) system is designed to deliver ASTM 5127-13 Type E-1 water to the cleanroom and chemistry room points of use and ASTM laboratory grade Type E-4 water to the part prep area. The UPW has a reverse osmosis (RO) makeup capacity of 20 L/min feeding the E-4 system. The E-4 system feeds the E-1 system at 15 L/min through microelectronics grade virgin resin deionization tanks. Both systems polish water at 58 L/min. The E-1 and E-4 systems both have a 1900 L storage tank. Type E-4 water is specified for use as solutions, such as Micro-90 in ultrasonic cleaners. The E-1 water is microelectronics grade with resistivity of 18.2 Mohm-cm and total organic carbon (TOC) at < 15 ppb. Type E-4 water is >0.5 Mohm-cm with TOC at 18 ppb. The UPW system is commissioned and in use. Independent water sampling confirmed specified water quality.

Degassing Furnace

The SRF high temperature heat treatment furnace has been decommissioned and moved to the SRF highbay. The furnace will be commissioned in fall 2014. The furnace can reach a maximum temperature of 1350ºC and a chamber vacuum of $1x10^{-8}$ Torr. Vacuum is achieved using a combination of a mechanical pump and two 20 in. cryogenic vacuum pumps (9,700 L/s – Air). The furnace hot zone dimensions are 0.61 m x 0.61 m x 1.5 m. Vacuum quality and contamination are monitored using an RGA. The FRIB cavities are fired for 10 hours at 600°C, while maintaining vacuum less than $5X10^{-6}$ Torr.

COMPONENT INSPECTION

The SRF coldmass component inspection area includes equipment to perform incoming RF measurements, internal surface optical inspection, vacuum leak checking, and dimensional measurements. A new coordinate measuring machine (CMM), the Global Performance 12210, has been purchased and will be installed in early September 2014. A clean zone will surround the CMM to reduce the dust on sensitive components. The machine has a 1200 mm x 2200 mm x 1000 mm measurement envelope and a maximum measurement error of (MPEe) 2.9 + (3.0 x L/1000). The CMM is capable of performing acceptance inspection of all coldmass components, including internal measurements of the QWR drift tube concentricity and inner conductor dimensions. The programmability of the CMM will reduce measurement time of a cavity from two days to two hours.

RF TESTING

The RF test areas are used to certify SRF subcomponents and completed cryomodules prior to installation in the FRIB linac. This area includes a Vertical Test Area (VTA) consisting of three Dewars installed in shafts in the high bay floor, a Cryomodule Test Facility (CMTF) consisting of two cryomodule test caves, and a Fundamental Power Coupler conditioning area (FPCCA). The three Dewars share a movable shielding block to provide radiation protection for personnel, while the two test caves share a sliding steel shielding door. Each test area has its own RF, controls, and diagnostic instrumentation systems.

The RF system for the VTA provides for testing at both 80.5 MHz and 322 MHz, utilizing wide-band 50 W amplifiers. Signals from the Dewars are multiplexed to a LLRF controller that can operate at both required frequencies. Each Dewar insert is instrumented with pressure gauges, liquid Helium level sensors, insulating vacuum gauges, and thermometry.

The CMTF includes sets of high–power amplifiers for each test cave operating at 4 kW 80.5 MHz and 8 kW 322

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MHz. The amplifiers are mounted on the roof of the CMTF, with RF lines penetrating into the test caves below. The RF line from each amplifier will be manually switched between cavity RF feeds from the roof of the CMTF test caves, negating the need to open the shielding door when testing the next cavity. As in the VTA, each test cave is configured and instrumented to allow independent readout of cryomodule and process instrumentation.

Radiation from X-rays produced during testing of cavities will be monitored using detectors placed in strategic locations in the test caves and on top of Dewar inserts. Additional detectors mounted inside and external to the test caves, and on the moveable VTA shielding blocks, will be used to monitor personnel exposure to radiation and interfaced with the RF interlock system.

The coupler conditioning area (FPCCA) consists of a set of high-power amplifiers operating at 322 MHz with a maximum power output of 20 kW, allowing high-power conditioning of the FPCs for the half-wave resonators. Couplers are mounted and evacuated in a cleanroom on a bakeable connecting waveguide which is instrumented with vacuum gauges. The couplers themselves are equipped with vacuum gauges, arc detectors and thermometry which are then interfaced with the FPCCA RF system interlocks.

Software for control and data acquisition is implemented using Control System Studio (CSS) with all process variables read out and available via EPICS channels. Software is being developed to provide control functionality (RF power, tuner operation, valves) and data acquisition and logging capabilities.

The VTA is being designed to accommodate a test rate of one cavity test per day, while the CMTF is designed to test two cryomodules per month, with one module undergoing RF testing for two weeks at a time. The FPPCA is designed to provide a throughput of 4 couplers per week.

The RF testing and controls systems reside in an array of 38 equipment racks and cable trays. Equipment installation is ongoing and expected to be completed in early 2015.The first cavity test is planned for fall 2014 using a temporary RF system to allow commissioning of the first Dewar. The VTA will be fully operational by September 2015, and the CMTF ready in December 2015.

HELIUM REFRIGERATION

A dedicated SRF cryogenic system, which includes helium refrigerator, warm compressor, subcooler, storage Dewar, purifier, 2 K pump and cryogenic distribution system will be installed to support the 4 K and 2 K simultaneous operations of the VTA and CMTF. The helium refrigerator, (Linde LR280) is capable of generating 900 W refrigeration power at 4 K. Three 2 K pumps (Oerlikon Leybold Vacuum Roots Pumps) are specified to meet the VTA and cryomodule throughputs. Each pump can maintain approximately 2 g/s (50 W refrigeration power) at 2 K. Figure 4 shows the SRF highbay cryoplant flow diagram.

The VTA test Dewars are filled using saturated liquid helium from the 5000 L Dewar at 1.4 atma. This feature allows filling the test Dewar(s) quickly independent of the cryoplant refrigeration capacity. Cryomodules are filled using supercritical helium at 4.6 K, directly from the cryoplant after going through the subcooler Dewar. The 2 K vacuum pumps achieve the superfluid condition in both the VTA and CMTF. The gaseous helium discharged from the 2 K pumps is compressed by the 20 g/s recovery system compressor, and fed into a full-flow 60 g/s purifier system, then discharged into the gas storage tank.

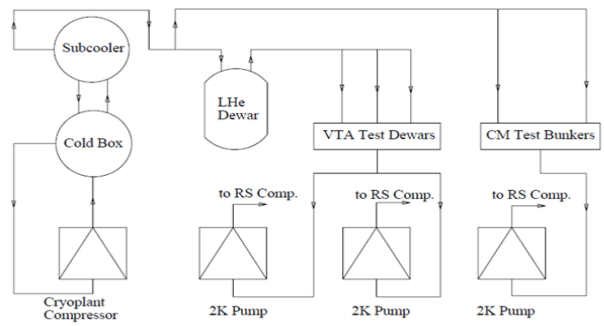

Figure 4: SRF Highbay cryoplant flow diagram.

Helium system contamination is monitored at multiple points of detection throughout the cryoplant using a Linde Multi-Component Detector (MCD), with standard measurement ranges 1-30 vpm for CxHy, 1-100 vpm for N2 and water, and 1-250 ppb for oil aerosol.

Currently the cryoplant compressor, purifier, recovery compressor, and 5000L LHe Dewar have been received and installed. The first of three 2 K pumps will be delivered at the end of September 2014 with the cold box and subcooler following shortly thereafter. The warm gas piping, cryogenic transfer lines, VTA and CMTF valve boxes design continues and specifications for these systems are being developed for submittal to vendors.

SUMMARY

The purpose of the SRF highbay is to meet the SRF production needs for the FRIB cryomodules. The installation of the technical equipment is ongoing and will be ready to produce cryomodules for the FRIB linac.

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