FIRST FRIB β = 0.53 PROTOTYPE COLDMASSS BUILD*

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Abstract

The β = 0.53 coldmass consists of eight Superconducting Radio Frequency (SRF) β = 0.53 cavities, eight Fundamental mode Power Couplers (FPC), and one 8 T solenoid. This is the first coldmass with this version of cavity and it has brought new challenges to overcome. The Facility for Rare Isotope Beams (FRIB) contains 18 cryomodules with β = 0.53 cavity coldmasses, and this type of coldmass is the highest power and most produced ones in FRIB. During the final cleaning stage and the cavity assembly, particle detection equipment is used to verify the cavity cleanliness levels for cavity certification test and for coldmass assembly. This method allows for cleanliness detection of specific areas inside the cavity at any time a vacuum flange is off. The fixtures, techniques and procedures used to build the β =0.53 coldmasses will be presented.

INTRODUCTION

The FRIB linear accelerator consists of 3 β = 0.041 coldmasses, 11 β = 0.085 coldmasses, 12 β = 0.29 coldmasses, and 18 β = 0.53 coldmasses. Coldmasses of each type have been assembled except for the β = 0.29 variant at this time. All of the β = 0.041 coldmasses have been assembled and are being installed into cryomodules. Three β = 0.085 coldmasses have been fully assembled with two tested. The last β = 0.085 cryomodule was tested with no field emission increase from vertical test.

The β = 0.53 coldmass took over a year to complete from the first cavity arrival. The design and process were based on a prototype cryomodule previously built, but new fixtures and procedures were developed with new designs to successfully build the coldmass.

FRIB BASELINE CAVITY PROCESS

Incoming Cavity Process

All cavities and coldmass components are subject to inspection through an Acceptance Criteria List prior to processing. Critical dimensions are measured with a Coordinate Measurement Machine. Machined mounting surfaces are measured to ensure proper placement of the cavity on the alignment rails. Other inspection includes surface finish quality test, and detection of scratches, dings, and inclusions.

Cavities are degreased after inspection to remove any residual grease and oil from the fabrication process. A 1% solution of Micro-90tm detergent is used in an ultrasonic cleaner at 100°F for 60 mins.

Cavity Etching and Heat Treatment

The β = 0.53 cavity is etched with buffered chemical polish to remove 120 microns. This process is also used to tune the cavity. For this purpose, the process is divided into several steps [1]. A final etch cleans up the surface by removing 30 microns of material. After etching the cavity goes into the cleanroom and 150 minutes high pressure rinsing takes place with 93 bar water. The high pressure rinse robot manipulates a wand that enters into the 7 ports on the cavity.

After the bulk etch process is completed, the cavity is placed in a vacuum furnace. This furnace operates at 600°C for 10 hours to remove the deposited hydrogen on the surface of the niobium.

Cavity Assembly

After the high pressure rinse, the cavity is dried overnight in an ISO 5 cleanroom. The cavity ports are covered with clean plastic caps to prevent particles from entering during assembly. The assembly starts on the bottom of the cavity and goes up to reduce the contamination from handling hardware above open ports. The vertical test setup includes a matched radio frequency power coupler and the cryomodule diagnostic pickup loop coupler. Cavities and vacuum components are verified to be clean with a surface particle detector to less than 0.2 0.3μm particles/cm^2.

The cavity is mounted on a vertical test insert with a flexible coupling to make the vacuum connection (Fig. 1). The vacuum system on the insert allows for manual slow pump and purge processes to pump out and purge at 1 mbar/s. A helium mass spectrometer is used to verify the seal and weld leak rates before cooled down to 2 K with liquid helium.

Figure 1: β = 0.53 cavity for vertical test on test insert with Fundamental mode Power Coupler (FPC).

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Vertical Test

Figure 2 shows field emission onsets of the β =0.53 cavities during certification testing in a test cryostat. Seven of the eight cavities do not operate with field emission below the operational gradient during vertical test. Figure 3 shows the quality factor of the cavities. True validation of the processing and assembly techniques after the cryomodule test is completed. Testing of a β = 0.085 coldmass proves that our standard cleanroom practices can be successful in maintaining the field emission onset gradient after cryomodule assembly.

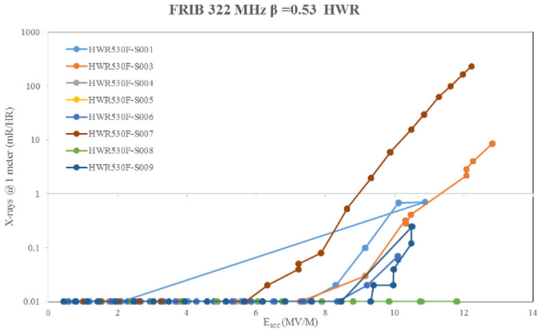

Figure 2: Field emission vs. E_{acc} for β = 0.53 cavities.

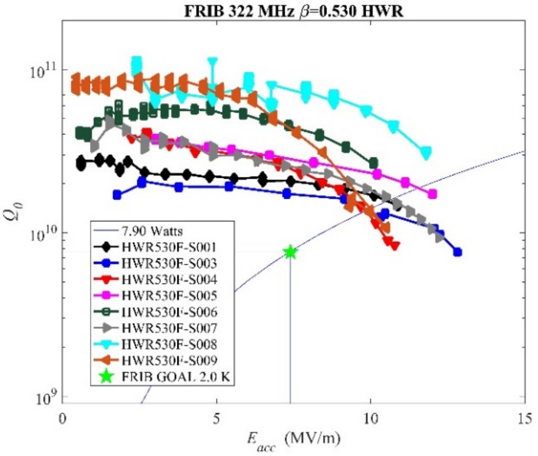

Figure 3: Q_0 vs E_{acc} for β = 0.53 cavities.

COLDMASS ASSEMBLY

After the cavity certification test in a test Dewar, the cavity is cleaned on the test insert and is moved to the cleanroom. There, the cavity is leak tested to ensure no leaks developed from thermal cycling. Surface particle checks are made of the exposed ports after removal from the test insert to ensure cleanliness in the beamline to be less than 0.2 0.3μm particles/cm^2. The cavities are stored inside the cleanroom until they are ready for installation on the coldmass.

Traditional methods of Superconducting Radio Frequency (SRF) cavity string assembly include the use of a slow purge of a dry clean gas. Cavity strings for FRIB are unable to be purged with a gas during the assembly process due to the assembly sequence. To counter the potential for contaminate to enter the clean vacuum space, diligence is done on cleaning the flange and bolt holes prior to disassembly. A HEPA filtered vacuum cleaner is used to remove loose contaminate. A saturated polyester wipe with isopropyl alcohol is also used to remove stuck-on contaminate. This procedure has been validated during vertical testing of cavities and β = 0.085 cryomodule tests.

The coldmass is broken into three major segments. The first cavity to go onto the string is in the second cavity position on the entry rail. The cavity is lowered onto the rail and aligned and a linear guided bearing assembly to allow for thermal shrinkage. The surrounding two cavities are placed next. This is the same procedure for the exit rail. The center rail is built with the solenoid first then the outer two cavities next. The rail segments are pushed together to make the final connection between cavities.

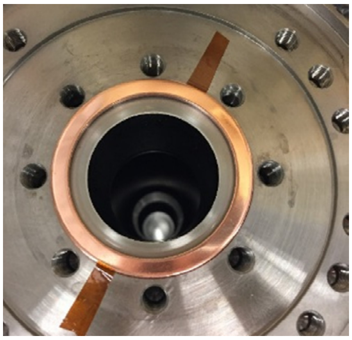

Figure 4: Kapton® tape securing gasket to cavity flange.

A flexible coupling is connected between adjacent cavities. It is first installed to the cavity on the rail, then a piece of Kapton® tape is applied to the connected cavity (Fig. 4). Since the low profile nature of the beam line flanges does not allow for the use of gasket clips, FRIB developed a procedure to use two small pieces of tape to hold gaskets in place. Kapton® can be sufficiently cleaned for the low particulate needs of the cavities, while being also radiation resistant for the insulating vacuum.

A single 8 T solenoid is placed in the center of the coldmass. Along with the shoulder bolt and slider bearing assembly the solenoid has an additional adjustment mechanism for alignment. A yaw adjustment screw allows the beamline to be moved across the coldmass to center the beamline. Custom length bellows were used to connect the solenoid to the adjacent two cavities. The solenoid was first installed with the bellows attached, then the same tape method for holding gaskets was used again.

Multiple FPCs were tested on cavities to verify the design and function. Standard processing was to test FPCs on a copper RF Cavity at room temperature, and then to condition them for use on a SRF cavity and coldmass. These FPCs followed similar processing as other beamline vacuum components and were ultrasonic cleaned in ultrapure water after being degreased.

The end plates for the coldmass include a pressure gauge and burst disc or a pressure gauge and an ion pump. Gate valves are used on both ends to seal the coldmass during transport and maintenance. These end plates are mounted temporarily to the coldmass with a mechanical adjuster to allow for the precision placement of end assemblies during the installation of the coldmass to the cryomodule base plate. A comprehensive work instruction was created in collaboration with the mechanical design department for the coldmass assembly to ensure components are installed properly. This work instruction was designed to ensure the cleanest assembly procedure to produce qualifying coldmasses.

FPC installation

Special tooling was created to interface with the FPC to install to the coldmass. The FPC would not fit through the rail while attached to the cavity and had to be installed after the cavity was on the rail. Every effort was made during the tooling design to be particulate free to prevent contamination to the FPC and cavity during installation. In Fig. 5, the FPC is installed to the cavity on a spring adjusted fixture. The springs allow consistent pressure to be applied to the FPC to keep a particle seal against the cavity during fastening.

Figure 5: β=0.53 cavity ready to install on coldmass and FPC installation to coldmass.

FINAL PREPARATIONS

The coldmass was attached to a clean pump manifold that runs a turbo molecular pump and backed with a scroll pump. The pump manifold uses a right angle hand valve and a pressure sensor on the outlet of the valve to control the pump out rate. The desired pump out rate is determined to be 0.125 mbar/s. This rate is based on Reynolds laminar flow calculations to prevent particle migration inside the coldmass. Figure 6 is the completed coldmass with an attached pump station.

The coldmass was rolled out of the cleanroom into the adjacent truck bay in the highbay while maintaining vacuum under battery power. Rigging was installed to the coldmass rails to lift it onto a flatbed truck. The coldmass was secured to the truck and moved across the parking lot to the cryomodule assembly team.

SUMMARY

The β = 0.53 coldmass was built in the FRIB SRF Cleanroom. The first prototype β = 0.53 module will begin cool down near the end of 2016. The results of this test will verify the coldmass assembly procedure before production starts on the remaining β = 0.53 and β = 0.29 coldmasses. The procedure laid out here reflects the typical path for a cavity to undergo before it is installed into a cryomodule.

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REFERENCES

[1] I. Malloch, *et al.*, "SRF Cavity Processing and Chemical Etching Development" in *Proc. 17th Int. Conf. RF Superconductivity*, Whistler, BC, Canada, Sept 2015.

Figure 6: Assembled coldmass in cleanroom.