ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB400

DEVELOPMENT OF HELIUM VESSEL WELDING PROCESS FOR SNS PPU CAVITIES

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Abstract

The Spallation Neutron Source Proton Power Upgrade cavities are produced by Research Instrument with all the cavity processing done at vendor sites with final chemistry applied to the cavity to be electropolishing. Cavities are delivered to Jefferson Lab, ready to be tested. One of the tasks to be completed before the arrival of production ready PPU cavities is to develop a robust helium vessel welding protocol. We have successfully developed the process and applied to three six cell high beta cavities. Here, we present the summary of RF results, welding process development and post helium vessel RF results.

INTRODUCTION

The Proton Power Upgrade (PPU) project at Oak Ridge Spallation Neutron (SNS) currently being planned will double the proton beam power from 1.4 to 2.8 MW by adding 7 additional cryomodules each containing four 6-cells high beta (HB), β = 0.81, superconducting radio frequency cavities. Some modifications were made on both cavities and helium vessels based on the operating experience of earlier SNS cryomodules and one of the prototypes currently installed in the linac. Some of the modification are the absence of higher order mode ports, the end groups are made from cavity grade niobium, and some design change in helium vessel [1]. One of the tasks to be completed before baseline qualifications of production ready PPU cavities is to develop a robust helium vessel welding protocol. Jefferson Lab received three 6-cells HB cavities with earlier design to develop the helium vessel welding protocol. All three cavities were processed at Jefferson Lab and vertical test at 2.1 K was carried out. Typical processing steps includes the 600 °C heat treatment for hydrogen degassing for 10 hours followed by ~ 30 μm buffer chemical polishing in JLab's closed chemistry system. The cavities received first 2 pass HPR, pre-assembly and additional 2 pass HPR before the final assembly to test stand. Cavity HB-046 was subjected to additional low temperature baking at 120 °C for 24 hours in UHV before the vertical test. The cavities were tuned to ~804 MHz at room temperature for fundamental mode with all pass band frequency being measured. The field profile measurements were recorded with the field flatness of > 90%.

INITIAL VERTICAL RF TEST RESULTS

The cavities were tested with typical Jefferson Lab cooldown procedure with residual magnetic field < 20 mG along the cavity axis. The Q_0 vs E_{acc} for all three cavities were measured at 2.1 K. The final RF test results are shown in Fig. 1. All cavities encountered multipacting starting at ~ 10 MV/m, typically observed for this cavity shape. The multipacting was able to be processed with high rf power. All three cavities reached above the PPU specifications in gradient and quality factor. The cavities were kept under vacuum and transported to the helium vessel welding work station for tanking.

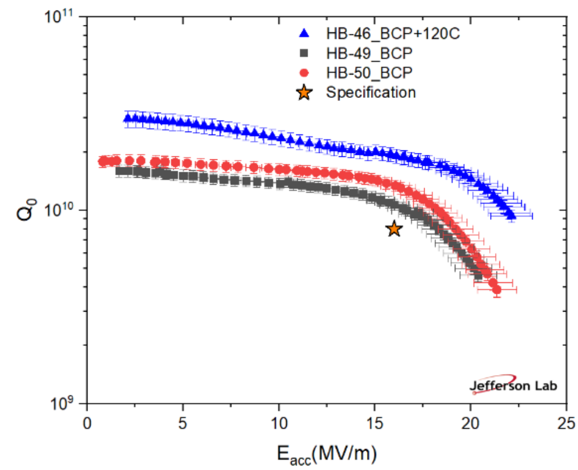

Figure 1: RF test summary of developmental cavities before helium vessel welding at 2.1 K.

HELIUM VESSEL WELDING

The cavity was placed horizontally with support posts on the end flanges. The welding of the titanium helium vessel started with the tack weld of the first head, followed by the cylinder. A three-arm spider was then bolted at the center of the cavity and then welded to the cylinder. The spider was used to support the cavity against transversal forces. The second helium vessel head is then tack welded to the cavity end dish and to the cylinder. The cavity was then welded, using skip-welding technique. The full welding was not done since the cavities were only used for the process development. Passband frequencies were recorded after each crucial step. The schematic of the helium vessel welding process is shown in Fig. 2. For production cavities, each helium vessel will be equipped with one heater and two temperature diodes. Additionally, in one helium vessel per cryomodule, two liquid level probes will be installed to measure the superfluid helium level during operation. A small, systematic drop in frequency was observed after the final welding as shown in Fig. 3.

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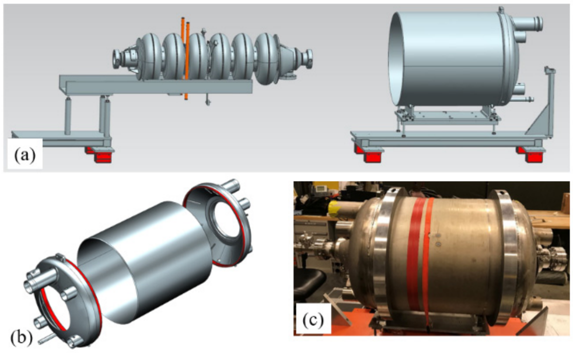

Figure 2: (a) The schematic of the He vessel welding fixture with cavity on rail, (b) schematic of helium vessel and (c) the cavity after completed welding.

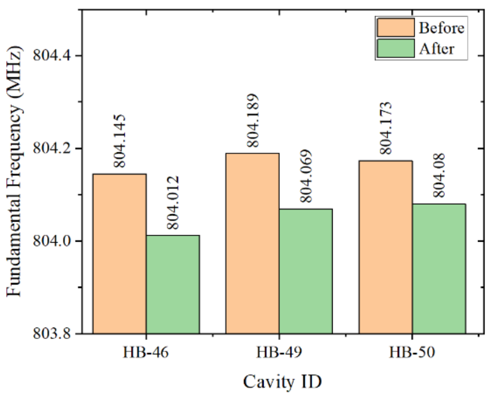

Figure 3: The fundamental frequency before and after the HV welding.

FINAL VERTICAL RF TEST

After the completion of helium vessel welding, the cavity was externally cleaned with isopropanol wipe down and removing any particulate with nitrogen. The cavity HB-46 was cooldown without any active pumping while HB-49 and HB-50 were actively pumped during the cooldown and RF test. The results of the vertical test for all three cavities at 2.1 K before and after helium vessels are shown in Fig. 4. Cavities HB-46 and HB-50 showed a small decrease in quality factor, likely due to the high residual magnetic field in the Dewar during the cooldown. No significant change in accelerating gradient was observed as a result of the helium vessel welding. The summary of RF results is presented in Table 1.

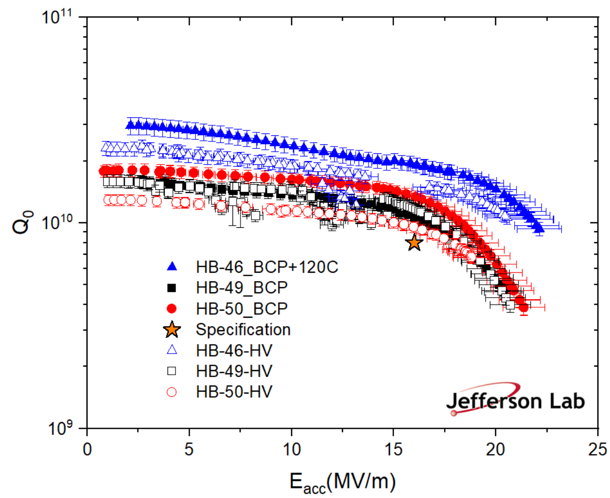

Figure 4: Summary of RF test before and after HV welding at 2.1 K.

Table 1: Summary of Developmental Cavity Performances

Cavity ID	Status	E_{max} (MV/m)	Q_0 at E_{max}	Q_0 at 16 MV/m	Limitation	Field Flatness (%)
HB-46	Bare	22	9.3×10^{9}	2.1×10^{10}	Quench	95
HB-46	HV	20.54	1.1×10^{10}	1.9×10^{10}	Quench	91
HB-49	Bare	20.3	4.6×10^{9}	1.1×10^{10}	RF Power	96
HB-49	HV	20.7	4×10^{9}	1.2×10^{10}	Admin	93
HB-50	Bare	21.3	4×10^{9}	1.3×10^{10}	RF Power	95
HB-50	HV	18.8	6.8×10^{9}	9.6×10^{9}	MP/Quench	95

SUMMARY

Prior to the work start on the production cavities, three high beta cavities were successfully processed at Jefferson Lab with all cavities exceeding the PPU specification in accelerating gradient and quality factor. The helium vessel welding process was developed for the production cavities without any significant change in the RF performance. After seeing the systomatic frequency drop we learned to preload the vessel length to accommadate weld shrinkage (~3 mm). This helped to reduce frequency drop for production tanking. The developed process is currently being applied to the production cavities.

ACKNOWLEDGEMENTS

This manuscript is authored by Jefferson Science Associates, LLC under U.S. DOE Contract No. DE-AC05-06OR23177. We would like to acknowledge JLab SRF staff members for the technical and cryogenic supports.

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