

# 1.3 GHz RF Nb CAVITY TO Ti HELIUM VESSEL TIG WELDING PROCESS AT FERMILAB\*

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## Abstract

Fermilab has developed an electron-beam (EB) and TIG welding procedure that will attach a 9-cell 1.3GHz niobium (Nb) cavity to a titanium (Ti) helium vessel. These welds were designed to meet ASME Boiler & Pressure Vessel Codes, Division 1 and are full penetration welds. The cavities produced will be used in Japan's S-1 Global cryomodule, Fermilab's Project X cryomodules, International Linear Collider and the current Type IV cryomodules. Discussion in further detail will include: Setting up electron beam weld parameters for Ti transition rings for the cavities, TIG welding parameters, tooling requirements for assembly and alignment of the cavity to the helium vessel. Settings that are applied to the glovebox environment to produce the best quality TIG welds, and what test measurements are taken throughout the process to monitor the cavity for excessive cell deformation due to the heat loads from TIG welding?

## INTRODUCTION

The procedure for dressing a 1.3GHz cavity with a helium vessel entails 5 steps with seven welds in the following sequence: (1) Two electron-beam welds with overlaps of a Ti transition ring to the Nb55Ti conical disk on the main coupler end of the cavity, (2) two EB welds with overlaps of a Ti transition ring to the Nb55Ti conical disk on the field probe end of the cavity, (3) one circumferential full penetration TIG weld of the Ti cavity transition ring to the main coupler end of the helium vessel, (4) one circumferential full penetration TIG weld of the Ti cavity transition ring to the field probe end of the helium vessel, and (5) final circumferential full penetration TIG weld that seals the helium vessel volume to the field probe end of the cavity through a Ti adapter ring which is custom fabricated for each cavity depending on its length. Weld joint geometry is shown in Figure 1. Backing rings were incorporated on all TIG welds to avoid vapor or weld debris deposition on the exterior surface of the cavity cells that would potentially degrade cavity performance.

## EB WELD PARAMETERS

Weld samples were developed to generate final EB weld parameters, starting with 152mm long linear samples and concluding with conical samples that duplicated each of the EB weld joints. Each sample was cut, polished and etched. Figure 2 shows a final sample of the EB weld joining the Nb55Ti conical end disk of the cavity to the Ti transition ring. The ring is welded from both sides to ensure complete joint fusion to meet ASME code.

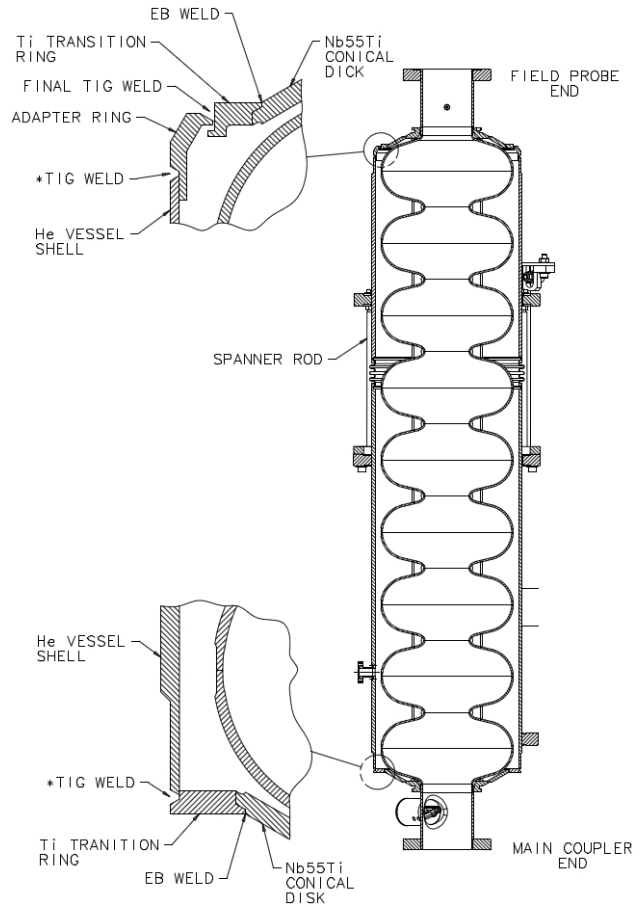


Figure 1: Section view of dressed cavity showing the weld joint geometry.

## TIG WELD PARAMETERS

In order to qualify our TIG welding process, weld joints for ASME conformity and welders, exact weld samples of each joint were fabricated. These samples were welded using the same processes as the real cavity/helium vessel. Upon completion, these samples were sent to an independent company for X-ray inspection and were processed in accordance with ASME Section VIII, Division 1. Sections of the samples were cut, polished, etched and examined. Once a "Golden Sample" of each joint was achieved the next step in the assembly process was approved.

## CAVITY TO HELIUM VESSEL ALIGNMENT

After all the components are properly cleaned the cavity and helium vessel are mounted in the assembly fixture shown in Figure 3. This fixture function is similar to the design that inserts a cavity string cold mass into the

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vacuum vessel. The cavity is mounted on a long boom arm and is attached to the survey rings on the end groups.

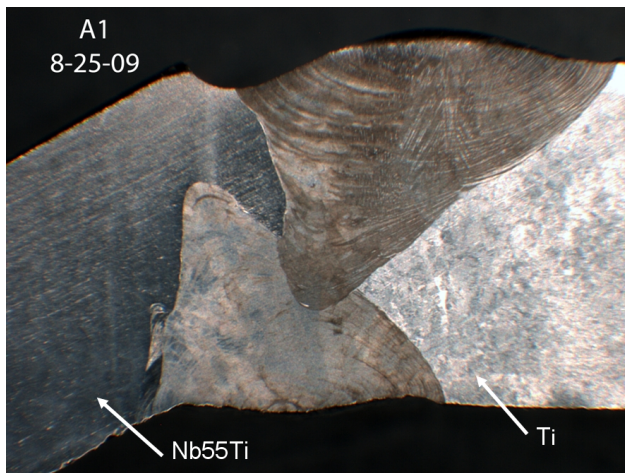


Figure 2: Polished and etched EB weld sample.

The main coupler is aligned in the horizontal position and parallel to the moving cart using a bracket that engages the coupler flange. The helium vessel is mounted to the cart supported by the bearing lugs and travels along a rail track with bearing rollers. This fixture enables us to adjust and achieve the cavity coupler flange to the helium vessel lugs perpendicularity requirement.

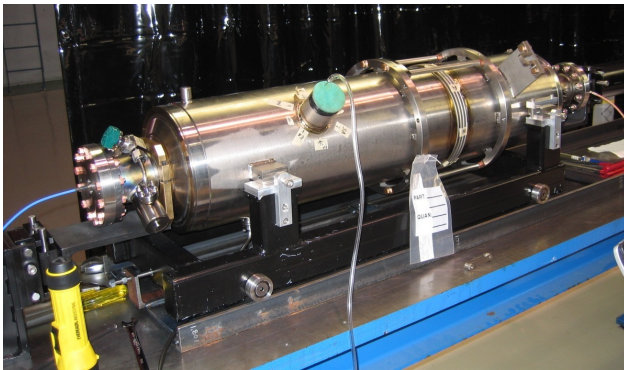


Figure 3: Assembly and Alignment Fixture.

The helium vessel is slid over the cavity until there is engagement of the vessel to the cavity transition ring on the main coupler end. The adjustable adapter ring at the field probe end (installed over boom prior to mounting the helium vessel) is slid into place. Using a micrometer the root weld gap is set for the two circumferential TIG welds of the helium vessel marked with an asterisk (\*) in Figure 1. These root weld gaps were determined using formulas from the ASME Boiler & Pressure Code entitled: "Attachment of Pressure Parts to Form a Corner Joint." Once these gaps are set the fixture is locked to prevent shifting of the parts. RF cables are attached to special flanges on the end groups to monitor the frequency spectrum, an argon gas line is attached to the helium fill port on the vessel and an oxygen monitor device is

plugged into the stub of the 2-phase pipe, all shown in Figure 3. This completes the set-up requirements prior to welding.

## TIG WELDING

Before the aligned cavity and helium vessel can be moved into the glove box, tack welds are performed to further lock the alignment. A boiled-off argon gas from a cryogenic dewar purge is started at a rate of 20cfm. The oxygen level inside the helium vessel is monitored until a level less than 20ppm is achieved. This will ensure that no contamination will occur inside the helium tank during welding. Open air tacks are performed using a shielded cup on the TIG torch with an argon flow at the cup of 20cfm. Approximately eight tacks are applied on the two circumferential weld joints discussed earlier.

After the tack welds have cooled the assembly is ready to be moved to the glove box. Using a crane and a special lifting fixture, the jacketed cavity is carefully inserted into a 360 degree rotation cage inside the glove box. The vessel is attached to this cage by the four bearing lug mounts and secured with clamps. Figure 4 shows the glove box configuration.

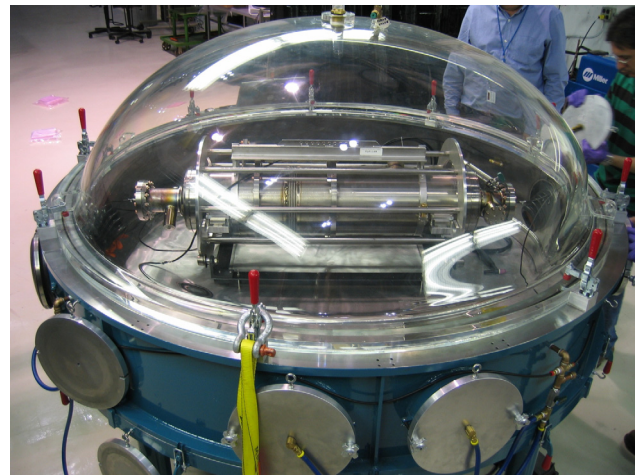


Figure 4: Glove box with cavity installed for TIG welding.

The TIG welding done inside the glove box is operating on three separate argon purge lines. One line is dedicated for the dome purge; a second line has a purge flow inside the helium vessel and the third line is for torch purge and torch cooling. The cables for monitoring the frequency spectrum of the cavity are also attached and connect to feedthrough ports inside the glove box. Once the oxygen level is below 20ppm and humidity levels below 15% are achieved, welding can begin. TIG welding progresses in segments to avoid overheating and plastically deforming the cavity. A cool down period of about 20 minutes is allowed after each TIG weld segment. The continuous flow of argon inside the helium vessel helps facilitate cooling. Figure 5 shows a typical weld being applied inside the glove box. The frequency spectrum of the

cavity is monitored after every step of the welding process to insure the elastic limit of the cavity is not exceeded. Figure 6 shows a plot of the frequency response during

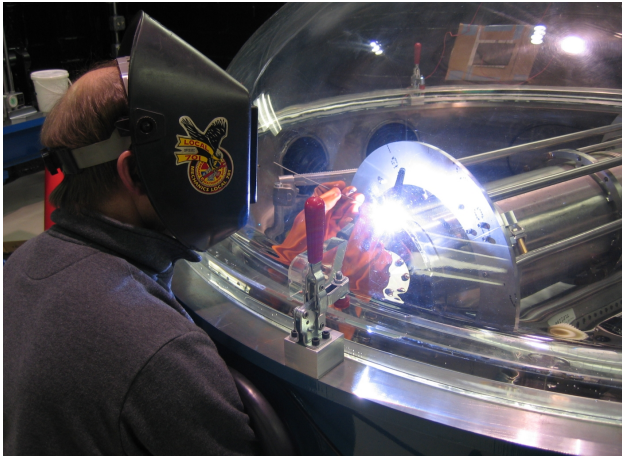


Figure 5: Typical TIG weld performed in the glove box.

TIG welding of the helium vessel to a cavity. Once the first two circumferential welds are fully completed and cooling period achieved, preparations begin for the final weld shown in Figure 1. For the final weld, serious consideration of vessel shrinkage was examined. At this point the cavity is fully welded to the vessel at the main coupler end. The adapter ring, shown in Figure 1 was designed with a gap incorporated on the Ti transition ring at the field probe end. This gap will allow up to 2mm of shrinkage of the helium vessel with respect to the cavity.

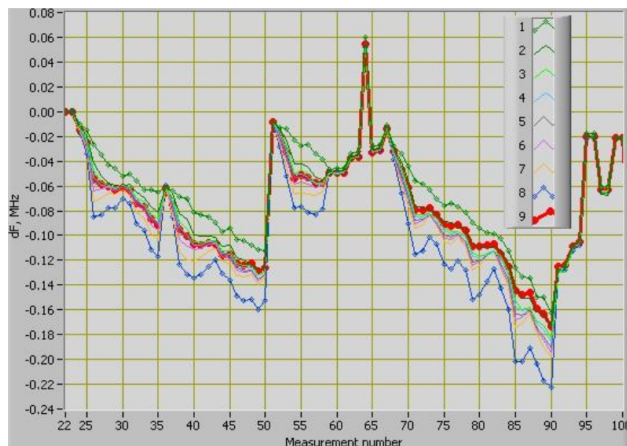


Figure 6: Frequency spectrum of cavity recorded during TIG welding. The horizontal axis is time.

To eliminate stresses on the cavity and possible de-tuning effects, it was determined that the bellows in the center of the vessel was the appropriate mechanical device to take up the shrinkage. To do this, prior the final weld, the spanner rods were loosened that support the bellows and support brackets clamping the vessel lugs to the 360 degree rotation cage were also loosened. This allowed the helium vessel to shrink towards the bellows. Once this

weld was completed and sufficiently cooled, the spanner rods and vessel lug clamps were tightened. Figure 7 shows minimal cavity frequency change after all welding has been completed. Figure 8 shows a close-up view of the cavity with the helium vessel after the TIG welding was completed.

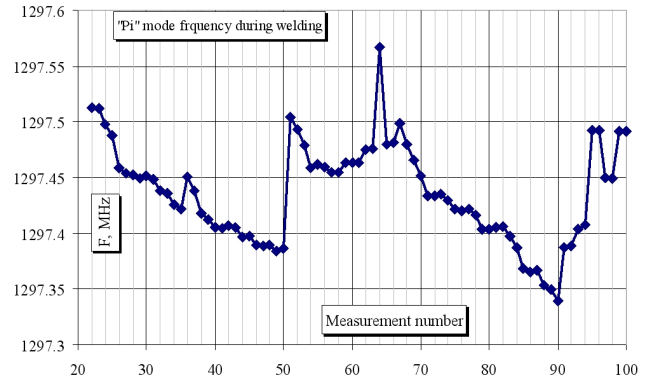


Figure 7: Cavity frequency during welding.

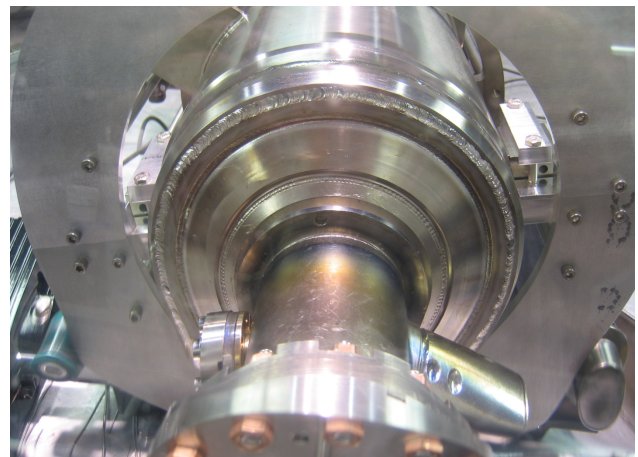


Figure 8: Close-up view of cavity with helium vessel after TIG welding is complete.

## CONCLUSION

Fermilab's electron-beam and TIG welding processes had no significant effect on the tune of the cavities. This result is typical for cavities that were welded following the procedure described in the preceding section.

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