A NEW ELECTROPOLISHING SYSTEM AT ANL FOR SUPERCONDUCTING QUARTER-WAVE RESONATORS

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Abstract

A new electropolishing (EP) system at Argonne National Laboratory has been used with six quarter-wave resonators to be installed in the ATLAS superconducting ion linac. This energy upgrade (7 QWR's, 1 HWR) will increase the output energy of the ATLAS 68 cavity array by ~30%. These cavities are the first to be processed in the new Superconducting Cavity Surface Processing Facility (SCSPF) built jointly by Argonne National Laboratory and Fermi National Accelerator Laboratory. This EP system reduces costs by electropolishing each cavity as only two major subassemblies prior to the final electron-beam closure weld. The uniformity of the polishing is improved through the use of a custom rotating cathode that also stirs the acid over the entire length of the cavity, minimizing temperature gradients in the electrolyte.

INTRODUCTION

An energy upgrade at the ATLAS superconducting ion linac at Argonne National Laboratory (ANL) uses a cryomodule of 7 quarter-wave resonators (QWR) and 1 half-wave resonator (HWR) to boost the output energy of ATLAS by ~30% [1]. These 6 new QWR's (the 7th QWR and the HWR are previous rare isotope beams prototypes) were the first to be processed at the new SCSPF. Nearly 50 identical QWR's would form most of the front end for a proposed U.S. rare isotope beams facility, where cost minimization will be critical to the viability of the project. By electropolishing the QWR's as two subassemblies rather than four, EP manpower is cut from 8 to 4 man-days per cavity, while maintaining a good EP surface over the entire cavity.

SCSPF

The SCSPF was commissioned in December 2006 by processing of one of the QWR dome ends (see Figure 1.), one of the two major QWR subassemblies. This facility consists of two separate chemical processing rooms, a class 1000 anteroom, and two separate class 100 clean rooms. Each chemical room shares a large 3000 cfm exhaust fume scrubber, and an ultrapure deionized water system supplies water to all of the chemical and clean rooms [2].

Dome Electropolishing

The smaller dome subassemblies were processed using an EP setup like those used with many other similarly flat geometries, including spoke-cavity and split-ring end walls. With such geometries the niobium part forms the bottom of a container of electrolyte with a coiled aluminum cathode placed just over top of the part (anode). We used a "birdcage" design, with a bottom high density polyethylene (HDPE) plate, and a top HDPE cylinder that seals to the dome with a Viton gasket. The seal is ensured by tightening the nuts on the threaded rods. The cathode/heat exchanger was made from 3003-O series aluminum tubing, and a HDPE propeller, attached to a 50 RPM AC/DC right angle gearmotor, was used to stir the acid.

NEW QWR EP SYSTEM

The new QWR's to be used in the ATLAS upgrade were chemically processed as two major subassemblies; the dome end and the housing/center conductor/toroidal end, seen in Figure 2. This is a change over the prototype QWR, which was processed as four separate pieces. This change was due to the desire to cut down on the costs associated with the procurement and disposal of the EP solution, along with an attempt to minimize the total time involved in processing each cavity. Because of this change, a new EP system was designed to process the larger of the two subassemblies.

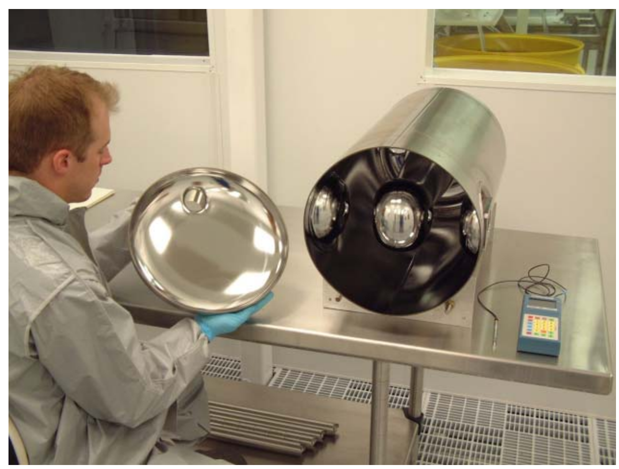

Figure 1: QWR subassemblies after an EP procedure.

Design

The design of the new QWR EP system is also a birdcage design, and incorporates an 1100 series high purity aluminum cathode that runs the entire length of the housing. All the wetted materials are made of (HDPE), 1100 series aluminum, 2024-T4 series aluminum, Viton, and Teflon. The two small HDPE flanges used to seal both the acid space and the water jacket are bolted in place using stainless steel threaded inserts that were first coated with epoxy and then screwed into the large bottom HDPE flange. The large top HDPE flange and cylindrical extension were joined using a HDPE plastic weld. The top and bottom ¼" aluminum reinforcement plates are installed to prevent the flex of the top and bottom HDPE flanges once the cage of stainless steel threaded rods and nuts have been tightened. The anode connection to the cavity was made using a 1" x 3" piece of copper braid sandwiched in between the cavity housing and a block of aluminum. The aluminum block was attached directly to the positive output of the power supply, and the whole copper braid/aluminum block assembly was held in place with a large hose clamp around the cavity housing.

Cathode

The heart of the QWR EP system is the newly designed cathode. The cathode is made from 1100 series aluminum in the form of a four-bar cage, with the four bars, top disk, and bottom ring being held together with ¼"-20 2024-T4 aluminum screws. The cathode runs the entire length of the cavity housing, surrounding the center conductor, and is evenly spaced between the center conductor and housing. A thin Teflon ring was attached to the bottom ring of the cathode to prevent any scratches to the center conductor during the insertion and extraction. The cathode also includes 20 "fins", with five fins on each of the four bars. These fins are also made from 1100 series aluminum, and each is attached to the four bars using two 6-32 screws made from 2024-T4 series aluminum. As the cathode rotates, the fins circulate the acid, minimizing temperature gradients in the electrolyte and improving the uniformity of the polishing. The cathode can be seen in Figure 3.

The rotation of the cathode is possible due to the use of a high current rotary contact. This rotary contact is manufactured by Meridian Laboratory, Inc., Model No. MC-750, and is rated for 750 amps. The cathode is chain driven, with a 20 tooth sprocket mounted to the rotary contact and a 10 tooth sprocket mounted to a 50 RPM AC/DC right angle gearmotor. The final drive speed of the cathode is 25 RPM.

Water jacket

In addition to the rotating cathode, a water jacket is also used in order to minimize the temperature gradients in the acid. This jacket (green cylinder in Figure 2.) is made from a 30 gallon HDPE cylindrical tank. The bottom of this tank was cut off, and the cylinder was affixed in the groove of the large bottom HDPE flange using RTV. A heat exchanger made of aluminum tubing was constructed by wrapping the tubing around the housing along with a section running into and back out of the center conductor. Once the EP system is ready for a procedure, the water jacket is filled with water and a 10 kw water chiller forces chilled water through the aluminum heat exchanger. This chills the water in the water jacket, which in turn chills the acid through conduction through the niobium.

Water testing

In order to ensure the system is leak tight once assembled, an extensive water test is completed within 24 hours of each procedure. Due to the design of the system, a leak could introduce acid into the water jacket. Therefore, weep holes were incorporated into the two small HDPE flanges that seal the acid space and water jacket. To check for leaks, the acid space is filled with water and the plug in each weep hole is removed. If a leak into the water jacket is present, the water will seep out of the weep holes. Once the system is found to be leak tight, the plugs are threaded back into the weep holes, the water is drained from the acid space, and the water jacket is filled. As a precaution, the level of the water in the water jacket was marked so that a leak from the acid space into the water could be noticed by the operator.

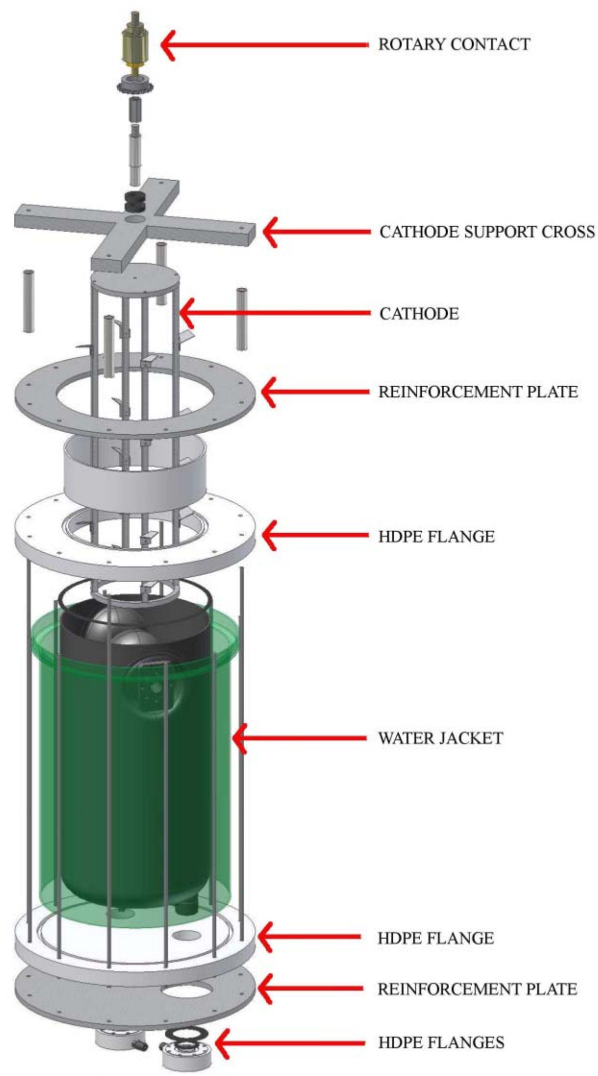

Figure 2: An exploded view of the QWR EP setup.

EP RESULTS

Most of the large subassemblies were marked in four distinct locations along the housing axis. These marks were used to make ultrasonic thickness measures before and after EP procedures. Mark "A" is located at the top of the toroid end, "B" is 1" down from the toroid/housing joint, "C" is at the housing midpoint, and "D" is below the re-entrant beam port assembly. On four of the

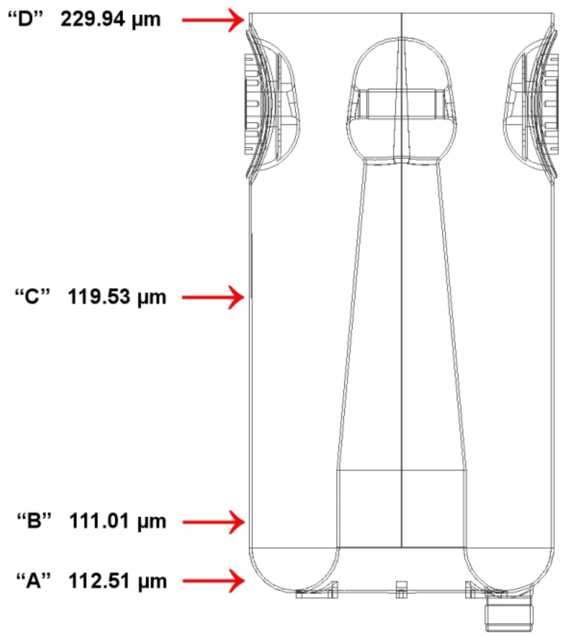

Figure 3: Average post-EP material removal.

Figure 4: QWR EP system ready for procedure.

subassemblies, this pattern was repeated three more times around housing axis, 90 degrees apart.

The average material removal rate for the "A" region of all the cavities was 0.525 μm/min, 0.523 μm/min for the "B" region, 0.557 μm/min for the "C" region, and 1.079 μm/min for the "D" region. The average material removal was 112.51 μm for the "A" region, 111.01 μm for the "B" region, 119.53 μm for the "C" region, and 229.94 μm for the "D" region (see Figure 3.). The total average current density for all of the cavities was 29.5 mA/cm^2. There was a substantial variation in the average current in the early procedures due to inadequate mixing of the HF into the drums of sulfuric acids. The solution to this problem was to circulate the acid in the drum by pumping the mixed acids from the top of the drum to the bottom of the drum for a minimum of 45 minutes at a pumping speed of 4 GPM.

Future improvements to the EP system

The material removal from the "A", "B", and "C" region of each cavity is fairly consistent, indicating that the temperature gradients were indeed small. However, in further procedures, more marks should be added along the housing axis to get a more accurate picture of the EP rates. Also, the "D" region has shown a removal rated roughly twice that of the other three regions. This is believed to be caused by the fact that roughly two inches of the housing was not submersed in the cooling water (see Figure 4.), increasing the heating of that area, therefore increasing the removal rate. A simple fix for this is to redesign the top HDPE flange to ensure the cavity is fully submersed in the cooling water over its entire length.

REFERENCES

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