SURFACE PROCESSING FACILITIES FOR SUPERCONDUCTING RF CAVITIES AT ANL

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Abstract

New SRF cavity processing systems at ANL, including those for electropolishing (EP), high-pressure water rinsing (HPR), and single-cavity clean room assembly have been developed and operated at ANL for use with cavities for a range of electron and ion linac applications. Jointly with FNAL, systems for 1.3 GHz single- and multi-cell elliptical cavities for the linear collider effort have been developed. New systems for use with low-beta TEM-class cavities have also been built and used to process a set of six quarter-wave resonators as part of an upgrade to the ATLAS heavy-ion accelerator at ANL. All of the new hardware is located in a 200 m^2 joint ANL/FNAL Superconducting Cavity Surface Processing Facility (SCSPF) consisting of two separate chemical processing rooms, a clean anteroom, and a pair of class 10 and 100 clean rooms for HPR and cavity assembly. First cold tests results for elliptical cavities processed in these facilities are discussed.

INTRODUCTION

A facility for processing superconducting (SC) niobium RF cavities has been built at Argonne National Laboratory (ANL) as part of an accelerator physics collaboration between ANL and Fermi National Accelerator Laboratory (FNAL). The facility will house in one location all hardware required to receive fabricated cavities as delivered from industry and, at the end of the process, yield a sealed cavity/coupler assembly ready for installation into a cold test cryostat. Overall costs and effort for construction of the facility are being shared approximately equally by ANL and FNAL. In addition to supporting upgrades for the ATLAS SC linacs at Argonne and linear collider R&D, the facility may also support development for the next-generation light source and proposed hadron linacs.

FACILITY DESCRIPTION

The 200 m^2 surface processing facility contains two types of work areas: chemical processing rooms (see *e.g.* Fig. 1), and clean rooms for high pressure rinsing (see *e.g.* Fig. 2) and clean assembly. Details of the facility layout were presented previously [1]. Other major supporting hardware includes a 3000 scfm large air scrubber to remove hazardous airborne fumes from chemistry operations, a deionized water system with 4500 liter storage capacity for supplying up to 40 liter/minute of clean water to any of the work areas, and a high-pressure Teflon diaphragm pump from LEWA supplying 13 liter/minute of water for performing HPR.

Chemical Processing Rooms

Two separate large chemical processing rooms, one administered by each laboratory is located at one end of the facility. The ANL administered chemistry room is presently configured for electropolishing of 1.3 GHz elliptical cell cavities. A nine-cell cavity, as positioned during electropolishing, is shown in Fig. 1. Previously, the same room has been used to perform electropolishing on six new production quarter-wave cavities for the ATLAS energy upgrade.

The FNAL administered chemistry room holds a buffered chemical polishing apparatus and automated

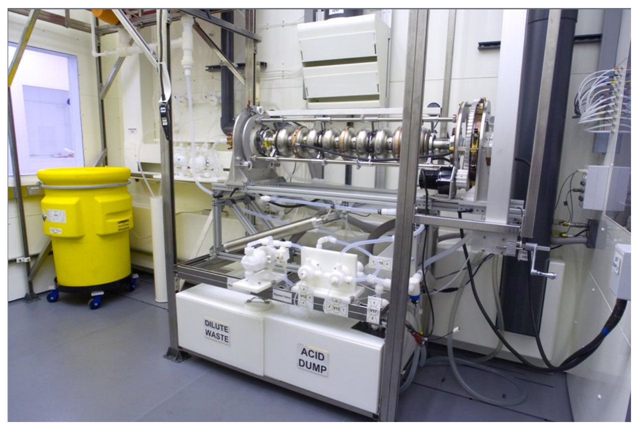

Figure 1: An electropolishing system for single- and multi-cell 1.3 GHz elliptical cavities at ANL

Figure 2: High-pressure rinsing system installed by Fermilab at the joint ANL/FNAL facility.

Table 1: Range of Operating Parameters for the Elliptical Cell Cavity Electropolishing System at ANL.

Parameter	Unit	Value
Voltage	V	0-20
Current	A	0-750
Temperature	C	20-35
Temperature stability	C	+/- 1
Acid flow rate	l/min	0-25
Cavity rotation speed	rpm	0-5
Air flow	scfm	0-3

control system also for 1.3 GHz elliptical cell cavities. The system has been functional since 2007 but requires scheduling of safety review at ANL prior to operations.

ELLIPTICAL CAVITY EP

Specifications

Specifications (see Table 1) for the new 1.3 GHz single- and nine-cell cavity electropolishing system in the ANL portion of the processing facility are based upon the parameters discussed at the 2005 TTC meeting in Frascati [2]. Many other details were based on an EP design review at ANL in February 2007 attended by many of the world's experts on cavity EP.

A horizontal orientation for the cavity during EP was chosen based on the large experience with such systems at DESY, KEK and JLab. During EP the cavity is rotated slowly about the beam axis. After EP the system is rotated vertically in order to remove the acid and then rinse with water.

Materials

Wetted materials used in the EP system have proven compatibility with the EP electrolyte and include: Teflon (PTFE), PFA, HDPE, and high-purity aluminum. Cathodes for single- and nine-cell cavities were fabricated from high-purity aluminum tubing provided by Jefferson Lab.

Non-acid-wetted structural materials located inside the chemistry room are constructed from chemical- and deionized-water-resistant materials including stainless steel, aluminum, HDPE and Type II PVC. Electrical leads and contacts are fabricated from copper, copper-graphite, aluminum and bronze. To the extent practicable electrical leads are coated or covered in order to prevent corrosion.

Acid Seals

The horizontal EP system requires an acid tight seal between the rotating cavity assembly and the fixed cathode and EP end groups. ANL chose to use a double-Teflon lip seal available from industry and developed previously for automotive and petroleum industries. A section view of the EP system end group showing the location of the lip seal is shown in Fig. 3. After dozens of hours of operation using both water and EP acid solution no leaks have occurred. Additional acid seals for non-rotating connections include four flat Viton gaskets and a pair of Teflon-encapsulated Viton o-rings.

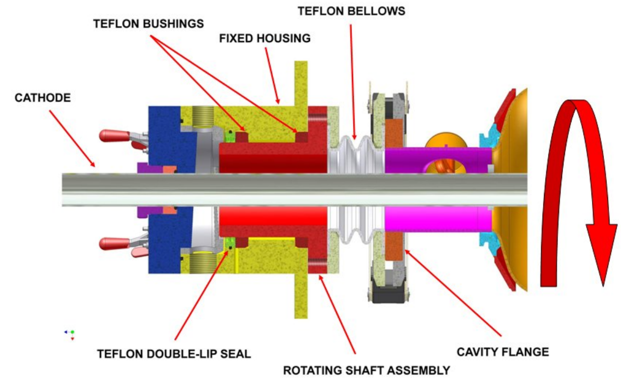

Figure 3: Section view of the electropolishing end group assembly.

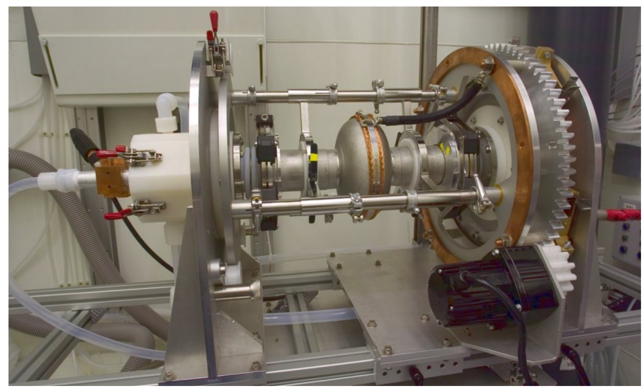

Figure 4: The electropolishing system re-configured for a 1.3 GHz single-cell elliptical cavity.

Heat Exchanger

In order to maintain the acid temperature to within $^{+}/{-1}$ ^{o}C of the nominal operating temperature during EP, a heat exchanger made of 30 meters of 1 cm diameter high-purity (3003) aluminum tubing is located inside an external acid cooling tank labeled "Acid Dump" in Fig. 1. The heat exchanger is similar to those used in the electropolishing of TEM cavities at ANL for more than three decades. A water chiller with a capacity of 10 kW at 5^{o}C is used to circulate cold water through the heat exchanger. Possible external (direct) water cooling to minimize temperature gradients across the cavity during EP was considered and may be added in the future.

First Cold Test Results

Two 1.3 GHz cavities, a 1-cell and one 9-cell, have received a 20 µm EP at ANL. Cavities were tested at FNAL and JLab respectively with E_{ACC}~23 MV/m in each case. For the 1-cell cavity, performance was limited by field emission. More recently, a single-cell cavity received a 65 µm EP at ANL after having received heavy BCP at Cornell. Preliminary field tests at FNAL show E_{ACC}=33 MV/m after EP.

ELLIPTICAL CAVITY HPR

A new high pressure rinse (HPR) apparatus and pump has been installed by Fermilab at the joint ANL/FNAL facility. The HPR tool, shown in Fig. 2, is based on a

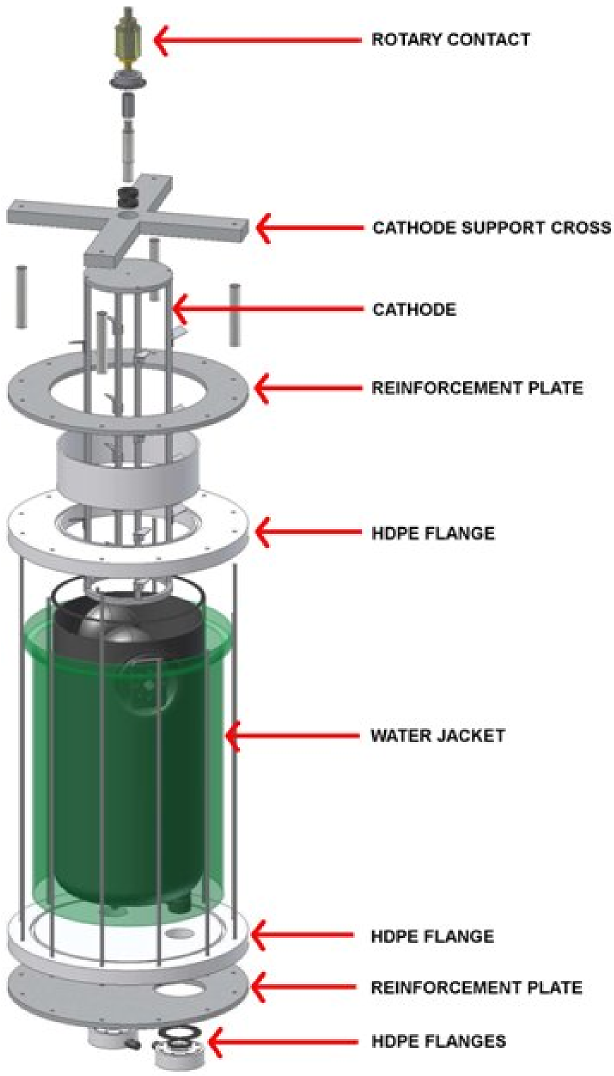

Figure 5: Exploded view of quarter-wave EP system.

system developed and operated at Cornell. During HPR the cavity is raised and lowered while a rinsing wand and nozzle is rotated inside the cavity.

Ultra-pure water will be supplied from a stainless steel body Teflon diaphragm pump manufactured by LEWA. The pump and deionized water plant are located on the service floor next to the processing facility. The HPR design operating pressure is 90 bar with a relief pressure set at 100 bar. A programmable and automated control system may be started from a pendant inside the clean room or from a control panel just outside the clean room.

QUARTER-WAVE CAVITY EP

An EP system in the ANL chemistry area has been used with six quarter-wave resonators (QWR) as part of an upgrade of the ATLAS SC ion linac. EP was used to remove 100-150 µm of niobium from the cavities, the first to be processed in the joint ANL/FNAL facility.

Costs are reduced over previous systems by performing EP on only two major subassemblies prior to the final electron-beam closure weld. A model of the system for the larger subassembly is shown in Fig. 5. Both subassemblies after EP are shown in Fig. 6. To minimize temperature gradients in the electrolyte, which occur naturally in a vertical EP system, a rotating high-purity aluminum cathode with aluminum fins is used to mix the acid. Ref. [3] contains additional details on the system along with measured removal rates. Ref. [4] has first cold test results for these cavities.

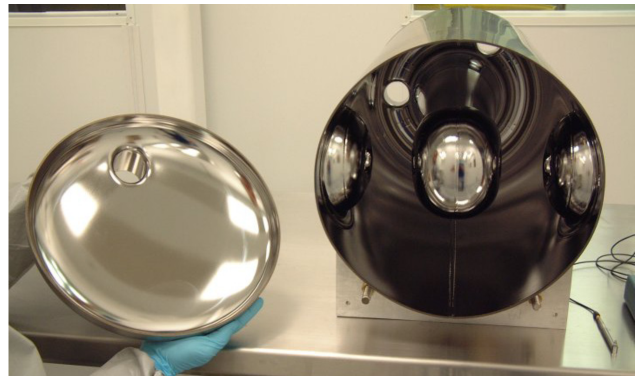

Figure 6: 109 MHz β=0.15 quarter-wave cavity after EP.

CONCLUSION

A facility for processing superconducting niobium RF cavities has been built at Argonne in collaboration with Fermilab. The facility contains all of the systems to process, clean and assemble cavities for cold testing. To date, more than two dozen EP procedures on quarter-wave and elliptical cell cavities have been performed. High-pressure rinsing and clean assembly systems for linear collider elliptical cavities are nearly complete and will be operational before the end of 2008.

ACKNOWLEDGEMENTS

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