RESULTS ON 9-CELL ILC AND 9-CELL RE-ENTRANT CAVITIES *

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Abstract

We have recently upgraded our chemical treatment facility, high pressure rinsing system and low temperature RF test set-up to prepare and test 9-cell cavities for ILC. After removal of 120 um by BCP we reached 26 MV/m accelerating field limited by the high-field Q-slope. There was no quench and no field emission, showing that our facilities are well qualified. We have also extended our vertical electropolishing system to 9-cell cavities. Previously we successfully used vertical electropolishing for one-cell cavities of the re-entrant shape to reach 47 MV/m accelerating[1]. Test results on 9-cell electropolished cavities will be presented. AES has manufactured the first 9-cell cavity with re-entrant cell shapes. The surface magnetic field is 10% lower than for the standard TESLA-shape cavity. Half-cells were electropolished 100 um before welding. We will report on the first 9-cell re-entrant cavity.

INTRODUCTION

The ILC cavity program is ramping up rapidly so that many cavities will need to be tested especially to address the gradient reproducibility topic in the ILC R&D program as well as to prepare good cavities to populate cryomodules. The best facilities available in the world today are at DESY, but the XFEL program, which is now ready to launch, is likely to occupy most of these capabilities very fast. JLAB has upgraded their infrastructure and started testing 9-cell cavities. KEK and Argonne/Fermilab are in the process of installing new facilities, but these are not likely to be ready till late in 2007 or even early 2008. Cornell's upgraded facilites are ready and poised to play a helping role. Cornell is prepared to continue to assist all through the R&D and construction phase for ILC.

VERTICAL ELECTROPOLISHING

Electropolishing (EP) and baking are the central treatment procedures that yield gradients of 35 MV/m and above for ILC[2,3]. All EP facilities mentioned are using the continuous EP method developed by KEK[4]. We decided to develop a simpler method would be less expensive to install when many EP stations must operate in parallel to treat 10 – 20 cavities per day for the ILC construction. The continuous vertical EP method eliminates rotary acid seals, sliding electrical contacts, many items of plumbing and valves, a large acid storage barrel with heat exchanger (for acid temperature control) where chemical residues tend to accumulate and release to contaminate fresh cavities. With water flow on the outside the temperature can be well controlled and equilibrium established in minutes. The standard horizontal EP method requires an additonal set of fixtures to re-position the cavity in the vertical orientation for draiining and rinsing. The method is amenable to electropolish cavities with helium-vessel attached, but this has yet to be demonstrated. One disadvantage of the vertical method is the higher danger of hydrogen pick-up since hydrogen released at the lower cells has to move up through the rest of the electrolyte filled cavity. However, after 100 – 200 microns of material removal, furnace firing at 600 – 800 C removes the H as in the case of the standard horizontal EP method. For light EP (30 microns) after furnace treatment the vertical method has been tested to show no H related Q-disease.

Material removal at the equator for continuous vertical EP is obtained by stirring the electrolyte with a series of paddles located within the cavity cells (Figure 1). Paddles attached to a concentric rotatable tube are free to pivot about pins. Hence the stir-tube and cathode assembly can be inserted and removed through the small aperture at the cavity irises. The maximum upward movement of the paddles is limited by mechanical stops and is chosen to give preferentially more stirring at the cavity equator and bottom half-cell.

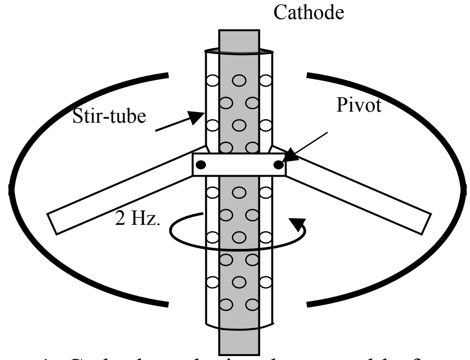

Figure 1. Cathode and stir-tube assembly for one cell. All other cells are identical.

Table 1 lists the parameters for vertical EP on an ILC 9-cell cavity. 5.8 KWatts are generated within the cavity-

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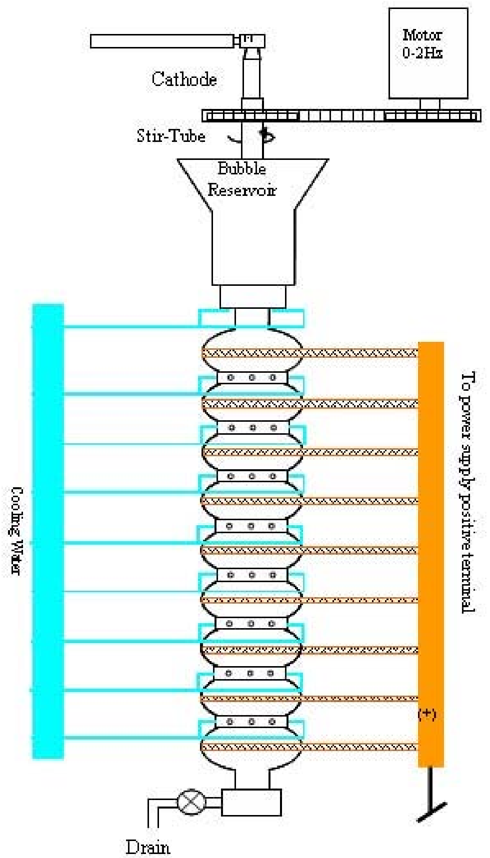

Figure 2: Laout of the vertical EP system

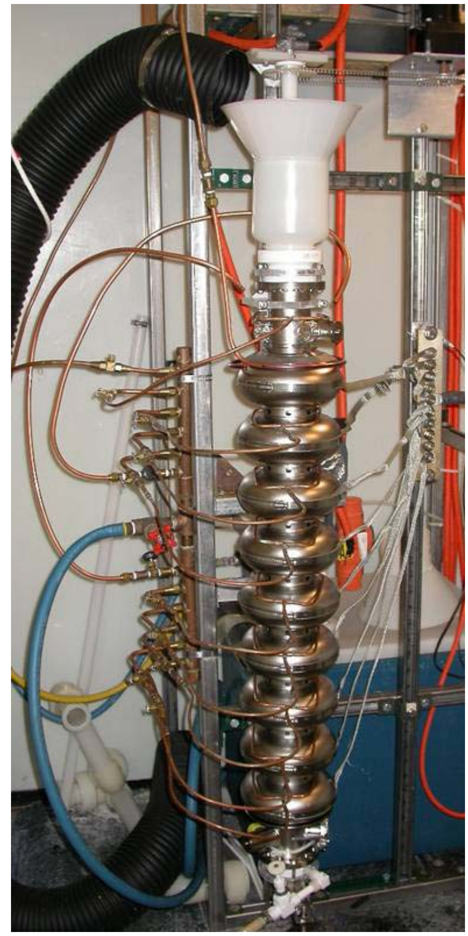

Figure 3: Vertical EP apparatus in operation

electrolyte system. Cooling is accomplished by flowing a thin sheet of water over the exterior surface of the cavity. The entire cavity surface is covered with flowing water including High Mode couplers and Fundamental Mode Coupler ports. Water flow is independently controlled for each cell and water is injected at each iris. Each cell receives a flow of "fresh" coolant that has not been heated by any other parts of the cavity to minimize preferential material removal at the irises.

While filling the cavity with electrolyte prior to electropolishing, 36 degree Celsius water pre-heats both the cavity and electrolyte. This minimizes the time (typically 8 minutes) to reach stable operation at 50 milliamps per square centimeter. As the Hydrofluoric Acid (HF) concentration diminishes during the EP cycle, a constant current of 400 amperes at 14.5 volts is maintained by increasing the temperature of the coolant, allowing the temperature of the cavity wall to increase from 36 to 40 degrees. Periodic current oscillations are seen after thermal equilibrium has been reached. Electropolishing takes place continuiously over 50 minutes. After this the electrolyte is discarded since it corresponds to a calculated value of 7.2 grams/liter of dissolved Niobium. When the electrolyte is used for

Table 1. Parameters for EP

Cathode	Aluminum >99.5%
Stir-Tube	PVDF
Paddles	PVDF
Seals	Viton
End Groups	PTFE, HDPE
Electrolyte	24 Liters
Maximum Use	9 g/L dissolved Nb
Current	400 Amperes
Voltage	14.5 Volts
Temperature	36 to 40 degrees C
Stir -Tube Transparency	>50%
Stir Frequency	2 Hz.
EP rate at Equator	0.5 micrometer/min
EP rate iris/equator	<1.5

Electrolyte formula by Volume

H_2SO_4(96%) / HF(48%) = 10/1 + additional 2.5cc HNO_3 (70%) per liter

longer periods of time, we see significant sulfur deposits in the system. Hydrogen bubbles evolving at the cathode exit the stir-tube through the same series of holes

(Figure 1) intended for the electrolyte to reach the cathode. Because stirring is weakest near the central stir-tube, bubbles tend to flow upward near the tube. There is no polytetrafluoroethylene (PTFE) barrier mesh to prevent Hydrogen bubbles from reaching the Niobium surface. No signs of grooves or bubble tracking have been seen in a finished cavity. There is a higher removal rate for the top half cell which necessitates flipping the cavity and electropolishing an equal amount in the opposite orientation. Bubbles exiting the cavity through the top beam tube collect in a reservoir at the top. The KEK formula for electrolyte [5] generates approximately half the volume of hydrogen bubbles as for the standard electrolyte without Nitric Acid.

After EP the cavity is ultrasonically degreased in soap and water, then high pressure rinsed for 18 hours, assembled to the variable input coupler in the clean room, to the test stand, evacuated, leak checked and baked at 110 C for 48 hours.

CAVITY TEST RESULTS

Two 9-cell 1.3 GHz cavities have been vertically electropolished and tested. Both cavities were built by ACCEL corporation. A8 received 25 microns EP after 140 microns BCP and reached 30 MV/m. A5 received 140 microns EP furnace treatment, 25 microns EP. A5 reached 24 MV/m and A8 reached 30 MV/m (Fiture 4). Both tests were limited by quench. Absence of X-rays shows indicatesd no field emission. In order to verify that the 30 micrometer VEP treatment was not introducing enough Hydrogen to cause Q-disease, A8 was held at 90 to 100 degrees Kelvin for 24 hours and re-tested. No Q-disease was indicated. All data was measured at 2 degrees K.

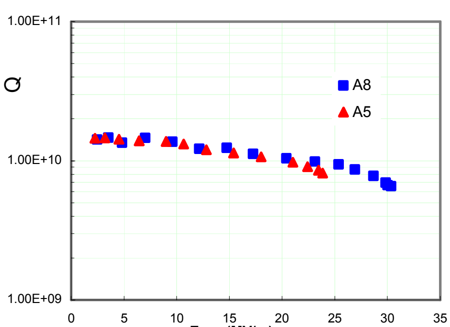

Figure 4. Cavity test results

MULTI-CELL RE-ENTRANT CAVITY

The maximum gradient in TESLA-shape cavities is 42 MV/m corresponding to a surface magnetic field of more than 1760 Oe. The push for higher gradients is based on new cell shapes which lower the surface magnetic field and a combination of the best surface and material treatments available. Both 70 mm and 60 mm aperture single cell re-entrant cavities have been built and tested in a Cornell-KEK collaborative effort. Cornell built the cavities and post-purified the material to provide 700 RRR. KEK carried out tumbling to smooth the equator weld region. The record accelerating fields are 53 and 58 MV/m corresponding to surface magnetic fields of more than 2010 and 2030 Oe.

AES built a 9-cell, 70 mm aperture re-entrant cavity (figure). The half-cells were electropolished in the open configuration for 100 µm material removal. The mating surfaces were then machined for the weld geometry. Figure 5 shows a finished 9-cell cavity without HOM and fundamental power coupler ports. AES tuned the cavity for a flat field profile and target frequency. The cavity has been electropolished 35 microns and is under HPR for the first test. Future treatments will involve post purification and tumbling to duplicate the record single cell results.

Figure 5: 9-cell re-entrant cavity

CONCLUSIONS

The vertical EP method has been used successfully for single cell cavities for some time. The best results are Eacc = 47 MV/m. The vertical EP method is now extended to 9-cell cavities. Gradients of 24 and 30 MV/m have been reached in two 9-cell cavities, both limited by quench. Facilities at Cornell have been successfully upgraded to treat and test 9-cell ILC cavities.

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