Fermilab EP Facility Improvement

TUP022

F. Furuta, D. Bice, A. C. Crawford, T. Ring
Fermi National Accelerator Laboratory, Batavia, USA

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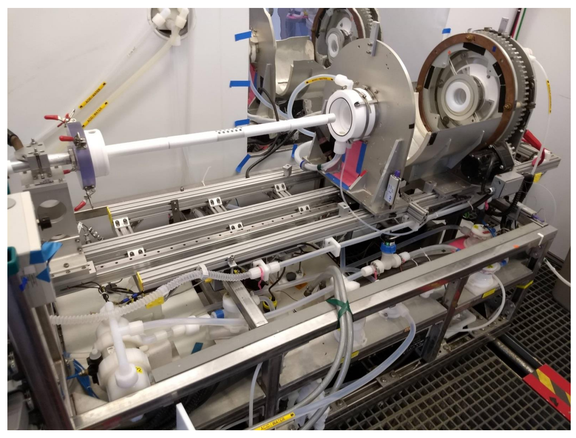
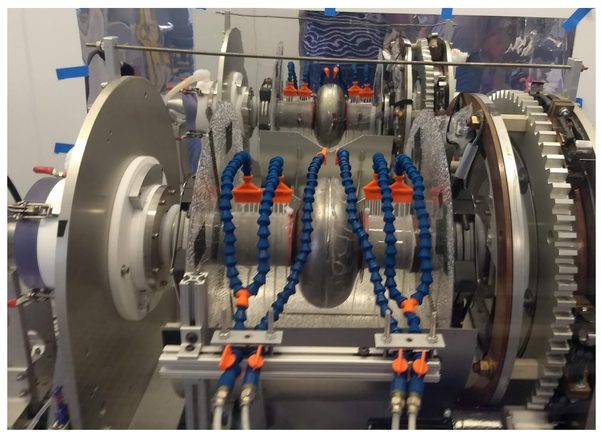
Abstract

Electro-chemical Polishing (EP) is one of the key technologies of surface treatments for niobium superconducting cavities. FNAL has established ***Cold EP method*** and applied on all single cell cavities (1.3GHz~3.9GHz) processed at FNAL EP facility since 2016. Cold EP method allows to achieve continuous large current oscillations during EP process and provide the uniform removal over the cell with the variation of ±15%. The details of Fermilab EP facility and Cold EP method are presented in this poster.



FNAL EP tool



1.3GHz single cell on FNAL EP tool

EP electrolyte drum (left) and Waste drum (middle) at chem storage room behind EP tool cabinet

Electrolyte

Fermilab uses EP electrolyte with the ratio of H_2SO_4 : HF = 13.5 : 1 by volume. Concentration of each acid are H_2SO_4 > 96% by weight, and HF ~70% by weight. The ratio of HF to H_2SO_4 is similar to traditional mixtures, but this high concentration of HF provides low concentration of water and minimizes HF evaporation during acid mixing. EP electrolyte was pre-mixed by the company and delivered to Fermilab (~110L/drum). The fresh electrolyte of 10L was transferred from the EP electrolyte drum to the acid tank of EP tool for one EP of single cell and dumped to the waste drum after the process (max removal = 80µm/10L (1.3GHz single cell) ↔ Nb concentration ~11g/L).

Cold EP method, 15C@cavity equator outside

EP reaction can be described in two parts, 1)an electrochemical reaction develops niobium pentoxide (Nb_2O_5), 2)HF acid removes those niobium oxide layer, and these reactions happen simultaneously. The keys of Cold EP method are low concentration of water in the electrolyte, low electrolyte flow, and low temperature at the cell surface. These key factors control EP reactions to maintain continuous large current oscillations.

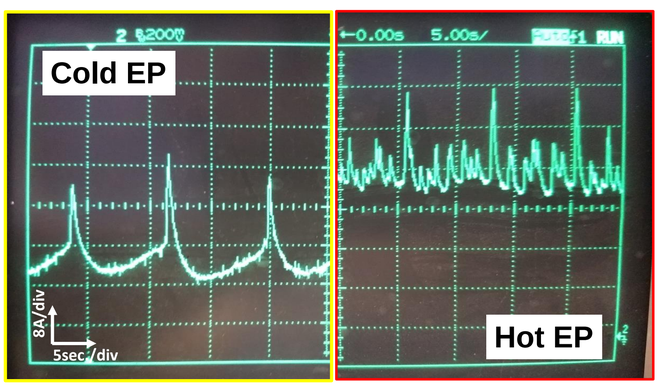
Zone separators (flexible plastic disks on iris) that divide a single cell cavity in three zones (cell and beam tubes) had important role during the temperature control. Zone separators prevent outside cooling water (30% Propylene Glycol) moves from one zone to another which helps to maintain cell and beam tubes in different temperatures.

The removal rate during Cold EP was small. So if the target removal was larger than 10µm, Hot EP conditions were applied first, then Cold EP was applied during the final 10µm removal. **Table 1** summarizes the optimized parameters of Fermilab Cold and Hot EP conditions.

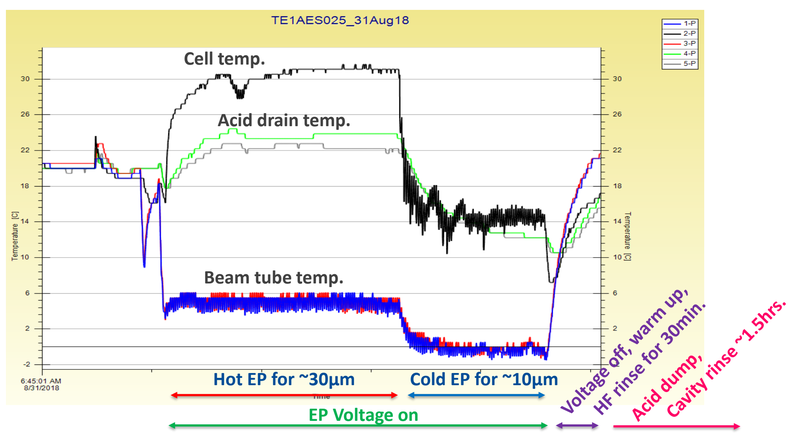
Table 1: Fermi EP conditions for 1.3GHz single cell

Parameters	Cold EP	Hot EP
Target removal	10 [µm] or less	>10 [µm]
EP voltage *1	18 [V]	
EP current *1	15 [A]	40 [A]
Equator temp. *1	15 [C]	32 [C]
Beam tube temp. *1	0 [C]	5 [C]
Acid temp. *1, 2	12 [C] or below	20 [C]
Removal rate *1	5 [µm/hour]	13 [µm/hour]
Acid circulation *1	1.5~2.3 [L/min.]	
Cavity rotation	1 [revolution/min.]	
Nitrogen gas flow *1	1 [L/min.]	

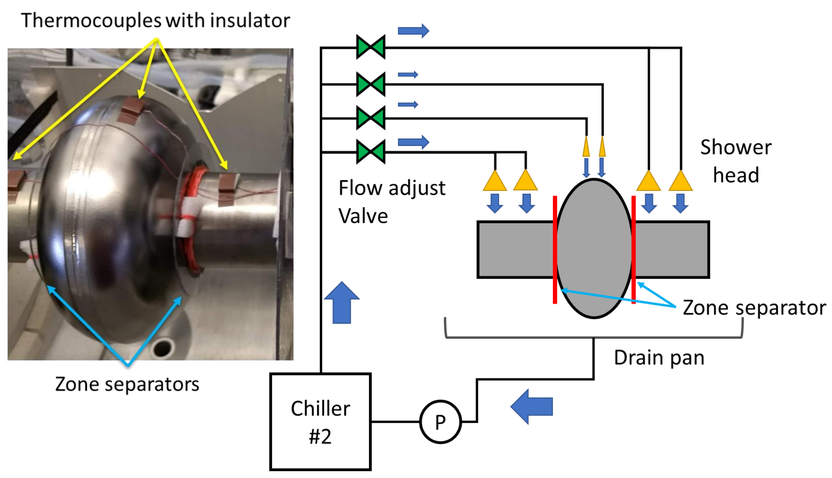
*1: average value, *2: in the acid tank



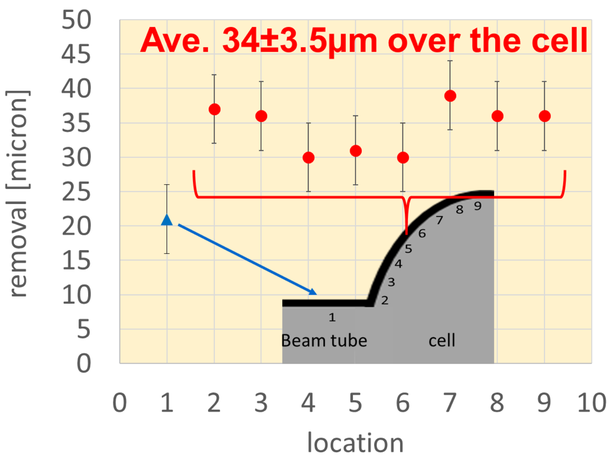
Current oscillation profile during Cold/Hot EP



Typical temperature profile during 40µm EP on 1.3GHz single cell



Schematic of cavity outside cooling



Removal measurement post bulk Cold EP (30 µm in average)

Large EP tool at FNAL CPL (top) a dummy tube was installed on EP bed for water flow test (bottom).

Summary

- **More than 200 EP on over 60 single cell cavities** had been successfully performed using **Cold EP method** at **FNAL** and helped to achieve **high Q, high field, and FE free** performances during cryogenic tests of single cell cavities.
- **Uniform removal over the cell** with the **variation of ±15%** had been achieved by Cold EP method, this is especially **important on final removal for doped-cavities**.
- **Cold EP method on 9-cell** cavities at **ANL EP facility** is in progress.
- **Large EP tool for 1.3GHz 9-cell and 650MHz 5-cell** was transferred from AES to FNAL CPL (Cavity Processing lab.) and the re-built work is under discussions.

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