Development and Scale-Up of an HF Free Electropolishing Process in Single-Cell Niobium SRF Cavities

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FERMILAB Project

- Program objective is to progress to industrial scale polishing of single superconducting RF cavities
- Subsequent efforts would transition to industrial scale polishing of full-scale 9-cell superconducting RF cavities
- Project started August 2010; planned end date of March 2012
- Project has requirements that include the following:
  - Total material removal of 150µm; 130µm bulk removal and 20µm +/- 5µm,
  - Maximum material removal ratio from equator to iris of 1.5:1,
  - Surface finish of 0.2µm Ra or better,
  - Internal surfaces free of frosting, shadows, streaks, erosion, stains, water spots, bubble traces, pits and irregular patterns,
  - Internal surfaces with high reflectivity and high gloss, Minimization of hydrogen adsorption during final polish,
  - Avoid embedded foreign material in the final polished surface.
- Design and build of polishing capability in progress; anticipate polishing single cavities early 2011

Need

- Superconducting radio frequency cavities are fabricated from pure niobium
- Processing of the cavities requires polishing of the interior surface to a mirror finish
- State-of-the-art polishing technology for the Nb cavities uses either buffered chemical polishing or conventional electropolishing
- However, these process employ hydrofluoric acid, which is an "environmental insult" and hazardous to workers
- Ideally, a polishing process for superconducting RF Nb cavities will have attributes that include the following:
  - Electrolyte free of hydrofluoric acid
  - Control of surface roughness to a microscale finish, Ra < 0.1 µm
  - Surface free from contamination after polishing
  - Current distribution control that enables uniform polishing across the entire cavity surface
  - Minimization of the absorption of hydrogen into the bulk material
  - Controlled removal of at least 100 µm of Nb during polishing

Development of Chemical-Mechanical Polishing for Superconducting Cavities, S. Mishra, M.J. Oreglia, C. Spiro, ANL-FNAL-UofC Collaboration Meeting

Comparison of chemical polishing, conventional electropolishing and FARADAYIC Electropolishing.

	Chemical Polishing	Conventional Electropolishing	FARADAYIC Electropolishing
Electrolyte	$HF/HNO_3/H_3PO_4$	HF 10% / H_2SO_4 90%	30% wt H_2SO_4
HF-Based Electrolyte	Yes	Yes	No
Control Mechanism	Viscous boundary Layer	Viscous boundary Layer	Pulsed waveform
Etch Rate	1 µm/min	0.5 µm/min	Up to 5 µm/min
Ra	1 µm	<0.1 µm	0.1 µm
Temperature	15 (chilled)	30-35 (chilled)	RT (chilled)

Patents Filed

- Filed a utility patent (U.S. and International) on the Eco-Friendly polishing technology:
  - Title: Electrochemical System and Method for Machining Strongly Passivating Metals
  - U.S. Patent Application No. 10240426
  - Foreign (PCT) Application No. PCT/US11/39354

Electropolishing Facility - Cleanroom

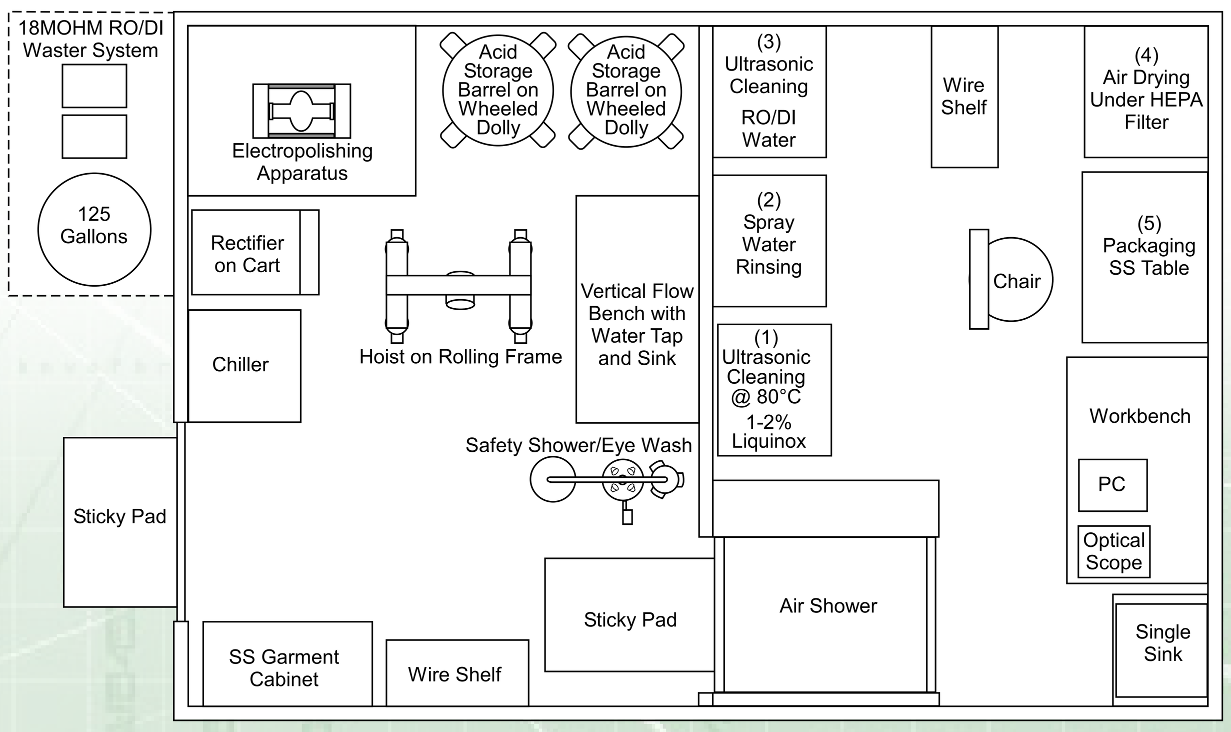
Electrolyte Temperature

- Electrolyte temperature control achieved through insertion of long forward off-times (between anodic and cathodic voltage pulses) Enables chiller to mitigate heat build up from polishing
- Temperature in the bath controlled to as low as 13°C, with chilling of the electrolyte, over several hours – typically on the order of 15-17°C

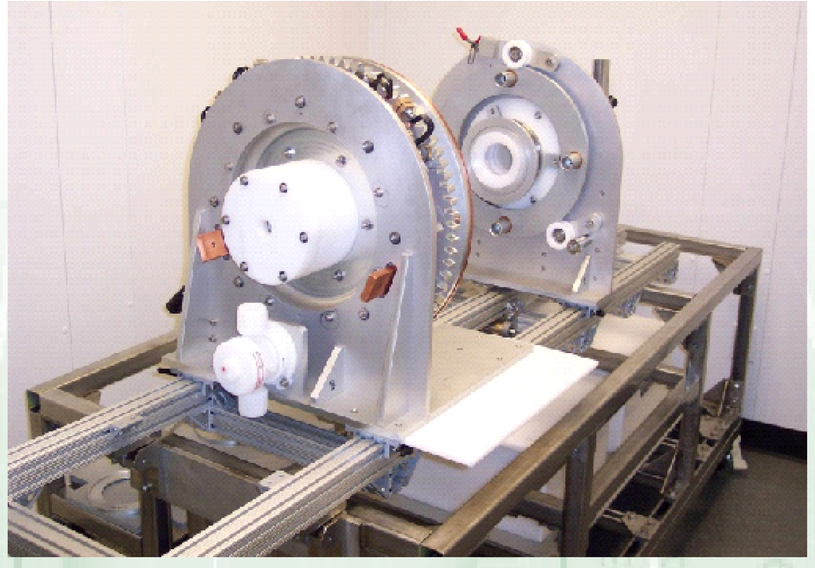
Surface Finish/Polishing Rates

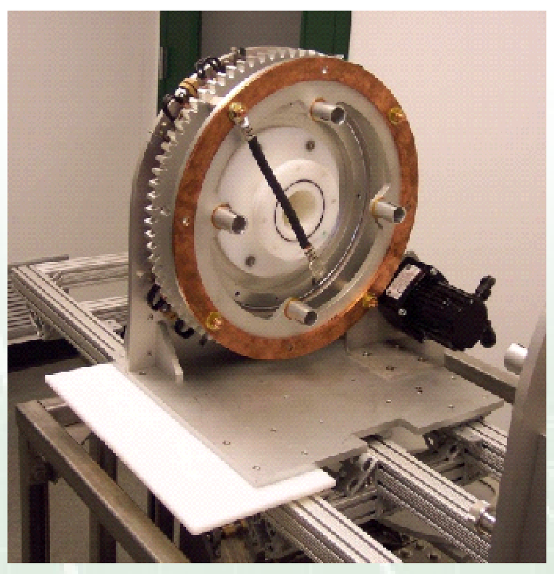
- Achieved Ra as low as 0.18 µm
  - Measured using a profilometer over a 4 mm distance
- Achieved wide range of polishing rates:
  - Polishing rates of up to 5 µm/min have been achieved to replace BCP (10 µm/min)
  - Polishing rates < 0.5 µm/min have been achieved to replace EP (0.5 µm/min)

Cleanroom Layout

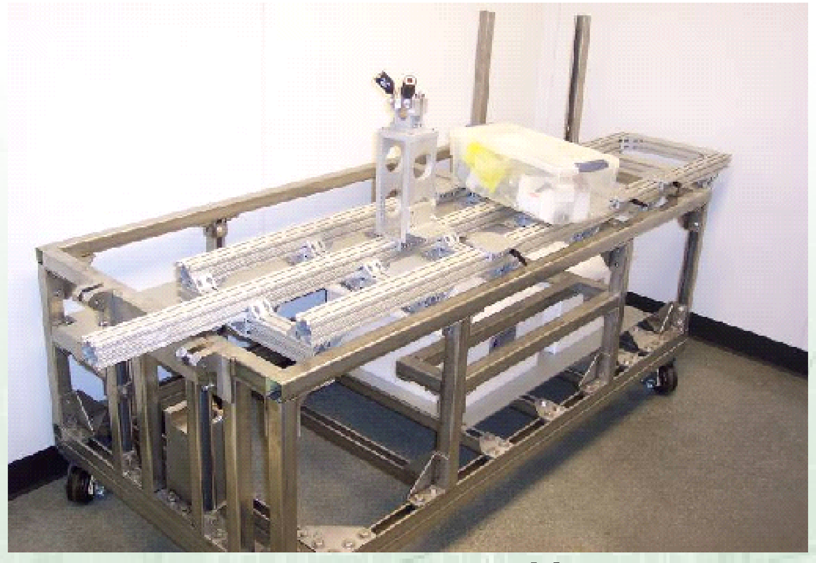


Single-Cell Cavity Electropolishing Tool





Duplicate Fermilab Cavity Electropolishing Tool to Date: full assembly (Left) and view of the Drive Conduction Assembly (Right)



Base Frame Assembly

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