Americas Cavity Specification

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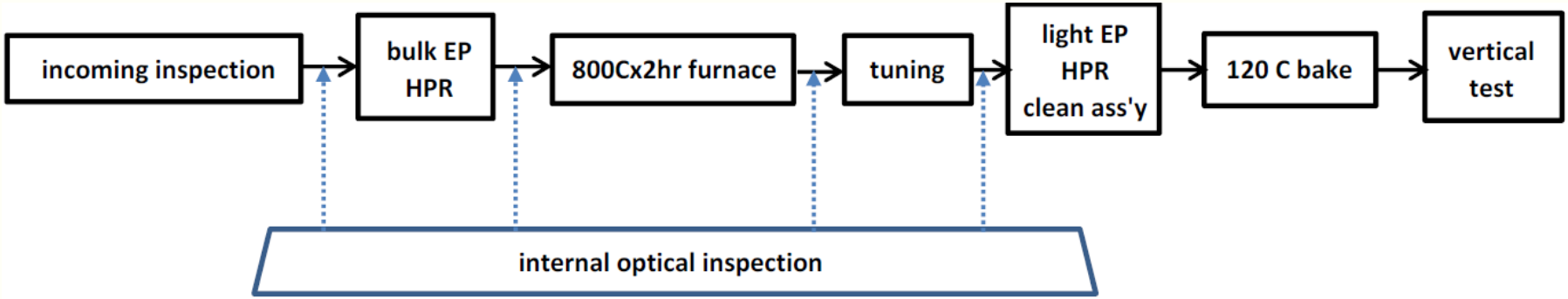
On behalf of the Fermilab cavity crew

October 20, 2010

Overview: Bare Cavity Qualification



- 9-cell 1.3 GHz ILC-style cavities purchased from vendors
- Incoming inspection: (1) visually check external cavity condition including welds and flange sealing surfaces, (2) measure room temperature field flatness, (3) confirm vacuum leak tight at room temperature, (4) check cavity dimensions using coordinate measuring machine
- Additional internal optical inspection sometimes used as intermediate diagnostic tool
- Cavity surface processing follows general scheme of International Linear Collider RDR: (1) Bulk electropolishing (EP) for ~120-150 μm removal, ultrasonic detergent rinse, high-pressure ultrapure water rinse (HPR), (2) 2 hour 800C furnace treatment for hydrogen degassing, (3) room temperature RF tuning, (4) final chemistry of ~10-30 μm removal, ultrasonic detergent rinse, first HPR, first class-10 cleanroom assembly, second HPR, second class-10 cleanroom assembly, cavity evacuation and seal, (5) 120C bake-out under vacuum for 48 hours
- RF qualification test at 2K
- Depending on cavity performance, one or more steps may be repeated

Duration of cavity process

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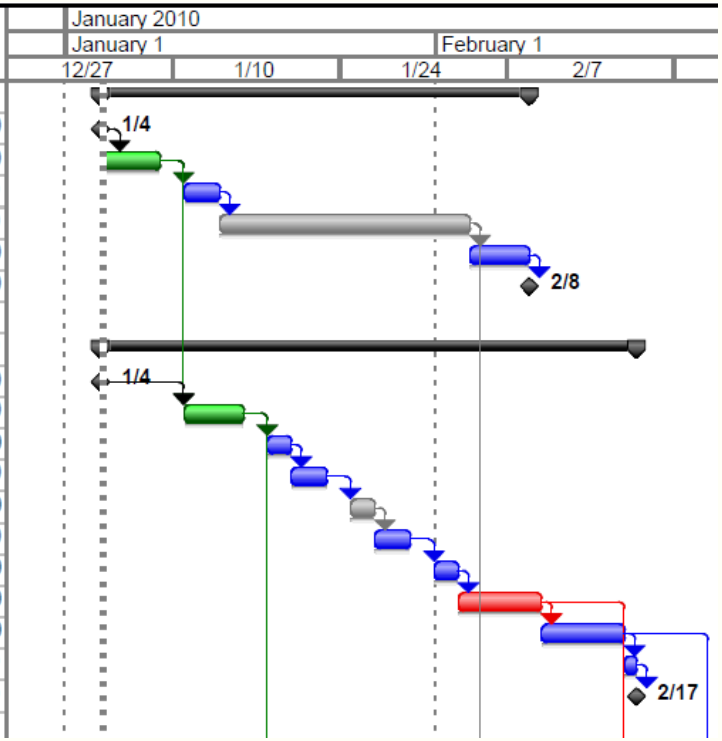
ID		Task Name	Duration	Start	Finish
1		**Prepare RI(no-EP)#1 (via Jlab) for CM (TB9RI026)**	**26 days**	**Mon 1/4/10**	**Mon 2/8/10**
2		Arrival at FNAL	0 days	Mon 1/4/10	Mon 1/4/10
3		IB4 inspection	5 days	Mon 1/4/10	Fri 1/8/10
4		Ship to Jab	3 days	Mon 1/11/10	Wed 1/13/10
5		JLab: bulk-EP,800C,proc/assy/test,replace HW	15 days	Thu 1/14/10	Wed 2/3/10
6		Ship to Fermilab	3 days	Thu 2/4/10	Mon 2/8/10
7		At MP9 ready for dressing	0 days	Mon 2/8/10	Mon 2/8/10
8					
9		**Prepare RI(EP)#1 for CM**	**33 days**	**Mon 1/4/10**	**Wed 2/17/10**
10		Arrival at FNAL	0 days	Mon 1/4/10	Mon 1/4/10
11		IB4 inspection	5 days	Mon 1/11/10	Fri 1/15/10
12		Optical inspection	2 days	Mon 1/18/10	Tue 1/19/10
13		Ship to JLab	3 days	Wed 1/20/10	Fri 1/22/10
14		JLab: 800C	2 days	Mon 1/25/10	Tue 1/26/10
15		Ship to Fermilab	3 days	Wed 1/27/10	Fri 1/29/10
16		Tuning	2 days	Mon 2/1/10	Tue 2/2/10
17		ANL/FNAL light-EP+process/assemble	5 days	Wed 2/3/10	Tue 2/9/10
18		VTS 120C bake,test	5 days	Wed 2/10/10	Tue 2/16/10
19		MP9 re-install cavity HW for dressing	1 day	Wed 2/17/10	Wed 2/17/10
20		At MP9 ready for dressing	0 days	Wed 2/17/10	Wed 2/17/10
21					



Duration of cavity qualification (ideal case- never happened this quickly):
26 days at JLab
33 days at FNAL

Overview: Cavity Path after Qualification

- Dress
  - Weld into helium vessel
  - Attach magnetic shielding
  - Attach high power coupler
  - Attach fast and slow tuners
- Horizontal test qualification
- Install in cryomodule
- [Test in cryomodule]
- [Build accelerator]
- [Accelerate beam of charged particles]
- […]

Cavity Purchase

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- Request for information
- Request for quotes
- Purchase order includes cavity specification - modified DESY/Tesla spec
  - Introduction
  - Scope of Work
    - Fabrication plan
    - Schedule
    - Quality Assurance Plan
  - DESY fabrication specification
    - And list of exceptions particular to FNAL case

FABRICATION OF 1.3 GHZ NINE-CELL SUPERCONDUCTING RF CAVITIES

Prepared by: M. H. Foley
Date: May 1, 2006
First Revision: April 4, 2007
Second Revision: August 7, 2008
Third Revision: November 12, 2009

1. INTRODUCTION

This document describes the required specifications and conditions for the fabrication of nine-cell SCRF cavities. The cavities described herein are designed to operate in the TM010 accelerating mode at a frequency of 1.3 GHz.

SCRF cavities are formed by electron beam welding multiple, deep drawn (or hydroformed), niobium half-cells and end assemblies. The shape of the inner surface of these half-cells is designed so that the welded cells will electrically resonate at a precise frequency. Mechanical tolerances are strict. Adherence to established procedures is essential to avoid contamination during fabrication.

Throughout this document FNAL will refer to Fermi National Accelerator Laboratory, DESY will refer to the German National Electron Acceleration Facility, and potential vendors will be referred to as "the contractor".

2. SCOPE OF WORK

The contractor will: (1) Develop their own fabrication drawings from the attached FNAL cavity drawings, (2) Design and fabricate all required tooling and welding fixtures, (3) Develop the required e-beam welding parameters, and (4) Fabricate 20 SCRF cavities in accordance with the attached DESY fabrication specification [1] as amended in Section 3 below. The contractor will provide all supervision, engineering, necessary materials, labor, QC inspections, and other services required to fabricate the cavities. All necessary facilities (e.g., buildings, machine shop, clean room, ultra pure water system, ultrasonic cleaning, chemical etching, devices for mechanical inspection, and leak detection equipment) will be the responsibility of the contractor, unless otherwise specified. All drawings, tooling and welding fixtures will become the property of FNAL upon completion of the contract.

Records of all fabrication measurements and inspections for each cavity, as specified in the attached QC document [2], will be submitted to FNAL with the completed cavities.

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Communication with cavity vendors after order

- Specification delivered to vendor, but practically speaking the engineer in charge makes many visits to the manufacturer at critical steps to ensure compliance with requirements, even with experienced vendors
- Vendor delivers fabrication plan, including schedule, QA
- Vendor may receive Nb from Fermilab or purchase sheets independently
  - All sheets are eddy current scanned at FNAL
- Cavity acceptance occurs after incoming inspection, and does not include a performance specification
  - Despite a great deal of careful study, we are normally unable to point at particular manufacturing errors which cause poor performance and do not hold manufacturers responsible for, e.g., heat-affected zone features which cause quenches
  - However, manufacturers are very sensitive to cavity performance, and are very responsive to suggestions for improvement


Advanced Energy Systems, Inc.

Manufacturing Plan

Symmetric 9-Cell II C Superconducting Cavities

1240-ENG-0008

Specifications on Drawing

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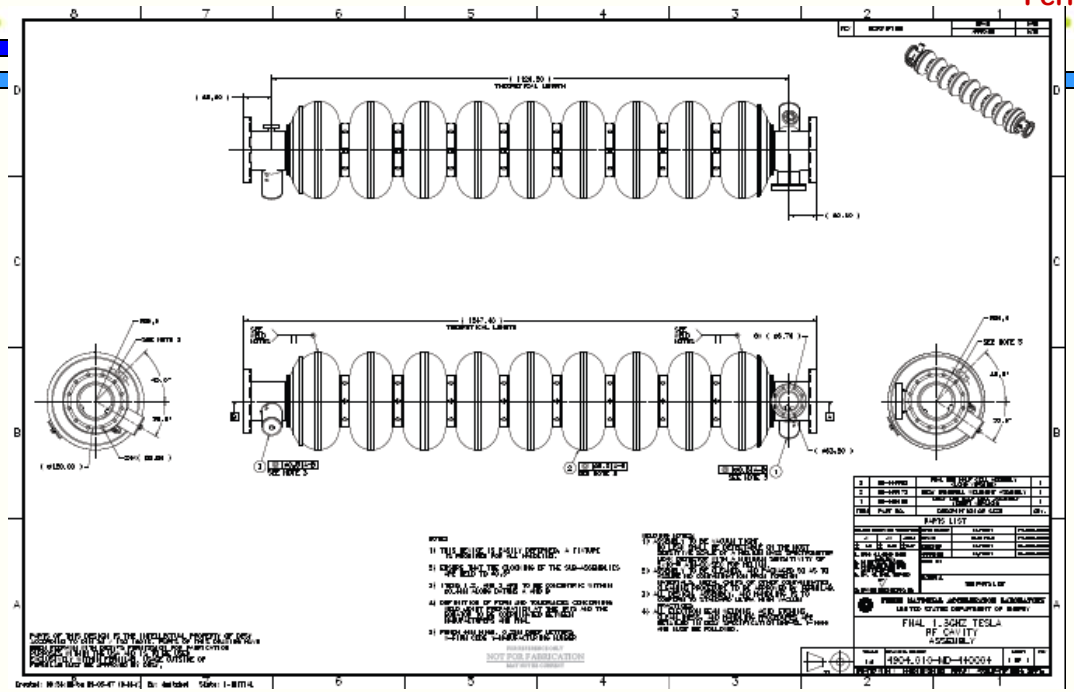


NOTES

1) THIS DEVICE IS EASILY DEFORMED. A FIXTURE IS REQUIRED FOR ALL HANDLING.

2) ENSURE THAT THE CLOCKING OF THE SUB-ASSEMBLIES ARE HELD TO ±0.5°

3) ITEMS 1,2, AND 3 ARE TO BE CONCENTRIC WITHIN Ø0.4MM ALONG DATUMS A AND B

4) DEFINITION OF FORM AND TOLERANCES CONCERNING WELD JOINT PREPARATION AT THE IRIS AND THE EQUATOR TO BE COORDINATED BETWEEN MANUFACTURERS AND FNAL

5) PUNCH 4MM HIGH, 0.2MM DEEP LETTERS X=FIRM CODE Y=MANUFACTURING NUMBER

WELDING NOTES:

1) ASSEMBLY TO BE VACUUM TIGHT. NO LEAK SHALL BE DETECTABLE ON THE MOST SENSITIVE SCALE OF A HELIUM MASS SPECTROMETER LEAK DETECTOR WITH A MINIMUM SENSITIVITY OF 2×10^{-10} ATM-CC/SEC FOR HELIUM.

2) ASSEMBLY TO BE CLEANED, AND PACKAGED SO AS TO ASSURE NO CONTAMINATION FROM FOREIGN MATERIALS, METAL CHIPS OR OTHER CONTAMINATES. CLEANING PROCEDURE TO BE APPROVED BY FERMILAB.

3) ALL DESIGN, ASSEMBLY, AND HANDLING IS TO CONFORM TO STANDARD ULTRA HIGH VACUUM PRACTICES

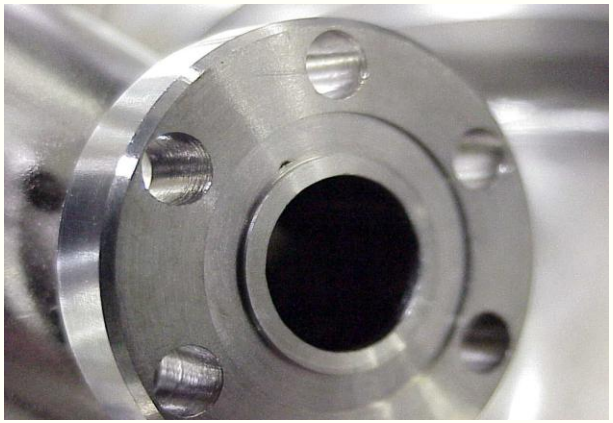
4) ALL ELECTRON BEAM WELDING, ACID ETCHING, CLEANLINESS, AND HANDLING PROCEDURES ARE DETAILED IN DESY SPECIFICATION MHF-SL 1-1999 AND MUST BE FOLLOWED.

Examples of items noted to vendors after acceptance

- Scratches on sealing flanges frequent

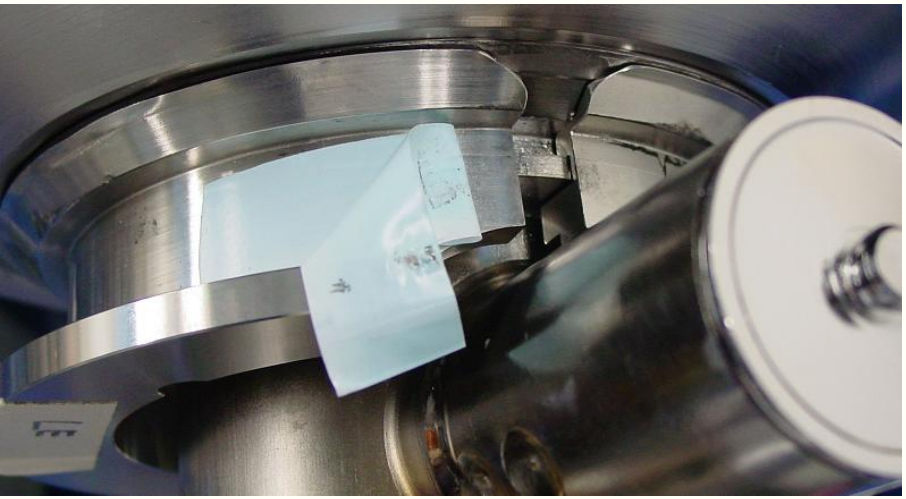
42 MV/m cavity (quench/FE)

- Ugly welds seldom

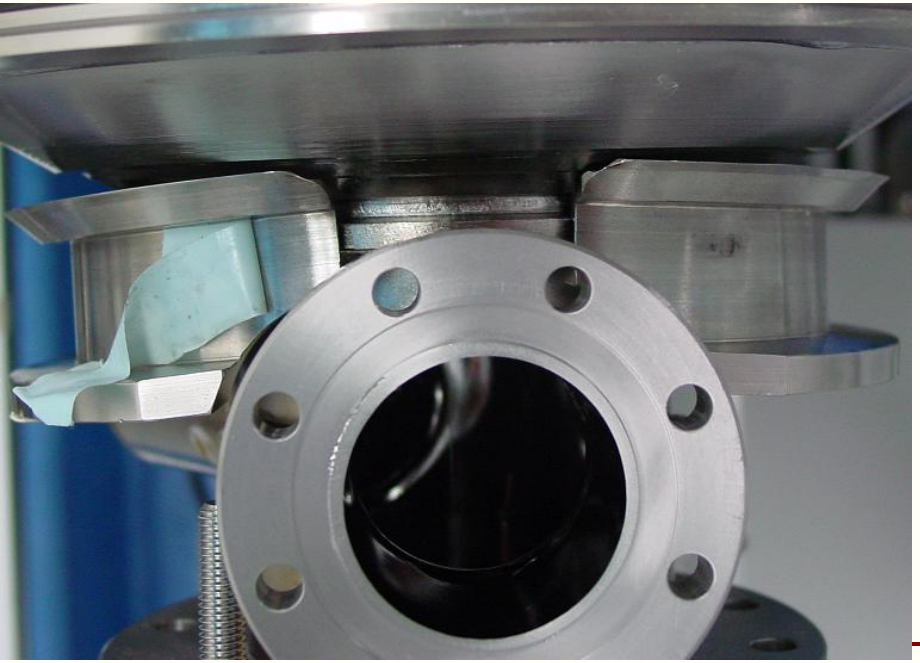


- Features not to specification which we can work around, e.g., small variations in cavity dimensions may be compensated with tuning
- One cavity from a new vendor has a dent on the end cell
- No cavities have been rejected so far for features inconsistent with spec

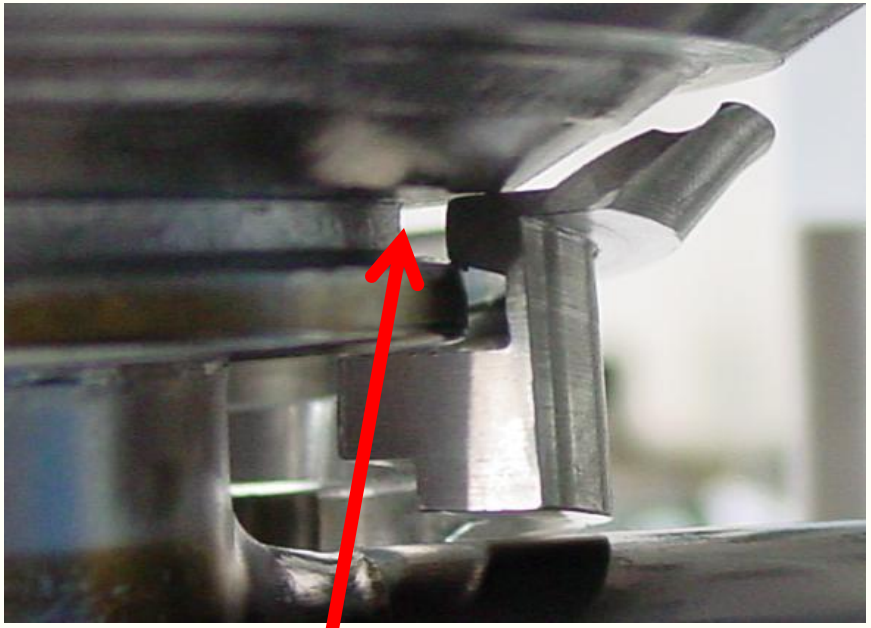
Cavity TB9x reference flange dimensional problem for tuning



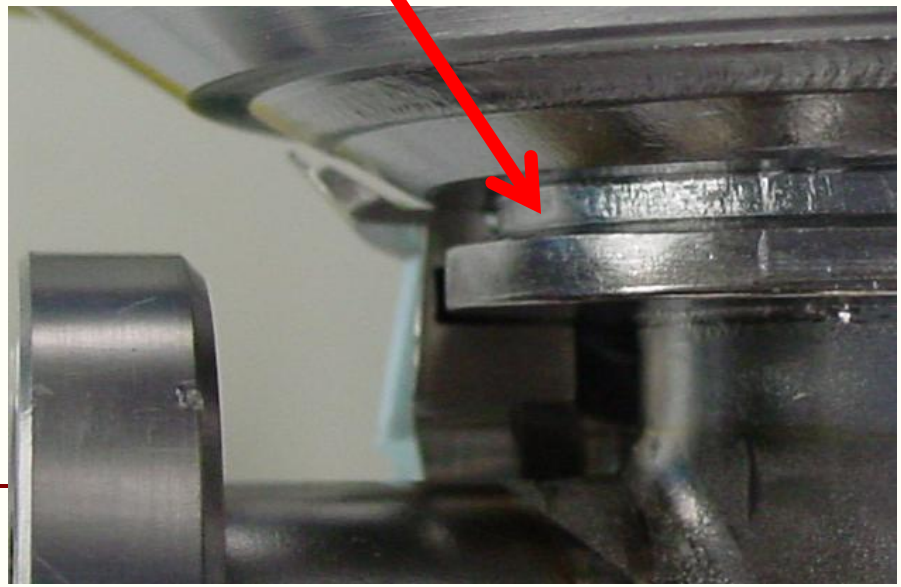
end flange protection rings for Cell #9 do not fit properly. Gap ~10 mm while normally 2mm.



end flange protection rings do not fit on Cell #1 either. Gap ~30 mm.



Cell #1 reference flange groove too narrow.



Effort to optimize 1st pass cavity performance

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- To improve 1st pass cavity performance and reduce cost, want to catch defects present after manufacturing, and before surface processing and vertical test
  - Inspection is key
  - Developing reliable methods for knowing which defects important to repair
- Repair these manufacturing errors by tumbling, spot polishing or laser remelting, etc.
  - 1-cell proof of principle: Good cavity before tumbling 36 MV/m. After laser remelting, EP 20μm+HPR+120C, achieved 39MV/m, quenched at molten region
  - 9-cell fixture being manufacturered
  - New FNAL tumbling machine; two 9-cells tumbled

Summary

- 90 Americas 9-cell cavities in the system: 46 in process, 4 almost done at manufacturer, 40 newly ordered through ARRA
- Make incoming inspection as systematic and documented as possible, understanding that the inspection procedure may change as we realize new things should be checked
- No performance specification in cavity specification
- Cavities so far never rejected; occasionally sent back for repair
- Developing tools to repair features noted after manufacturing