RFD – RF Dipole
Report on Cavity Progress at JLAB

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Jefferson Lab, Newport News VA , USA
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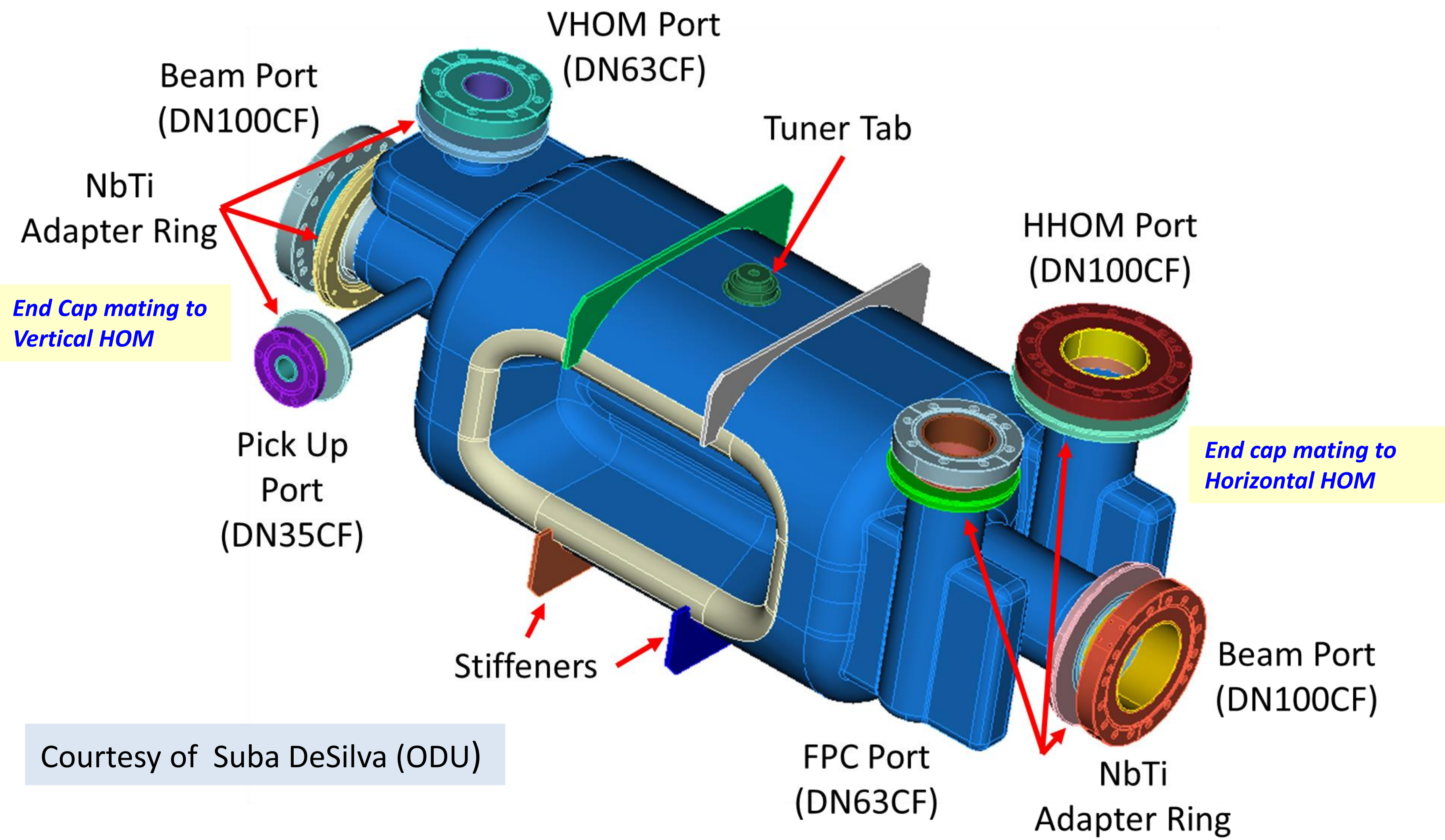
USLARP Status 18May2016 R12

Overview – JLAB Status

- Many collaborators on this project
  - Design - ODU, Niowave, CERN, US LARP & many others
  - Niowave: Fabrication of sub assemblies under an SBIR , completed manufacturing drawings
  - JLAB : Fab & Test, as well as special tasks
    - Example of special tasks analysis of Tuner Attachment
- Current Status at JLAB
  - Steps completed
  - Next steps at JLAB
- For future – HOMs and Helium Vessel

RFD-RF Dipole Cavity Design



Courtesy of Suba DeSilva (ODU)

Plan-LHC Crab R&D RFD & DQW

Plan overview recommended by Niowave April 4, 2016
(revised April 8th in conf call with ODU/JLAB)

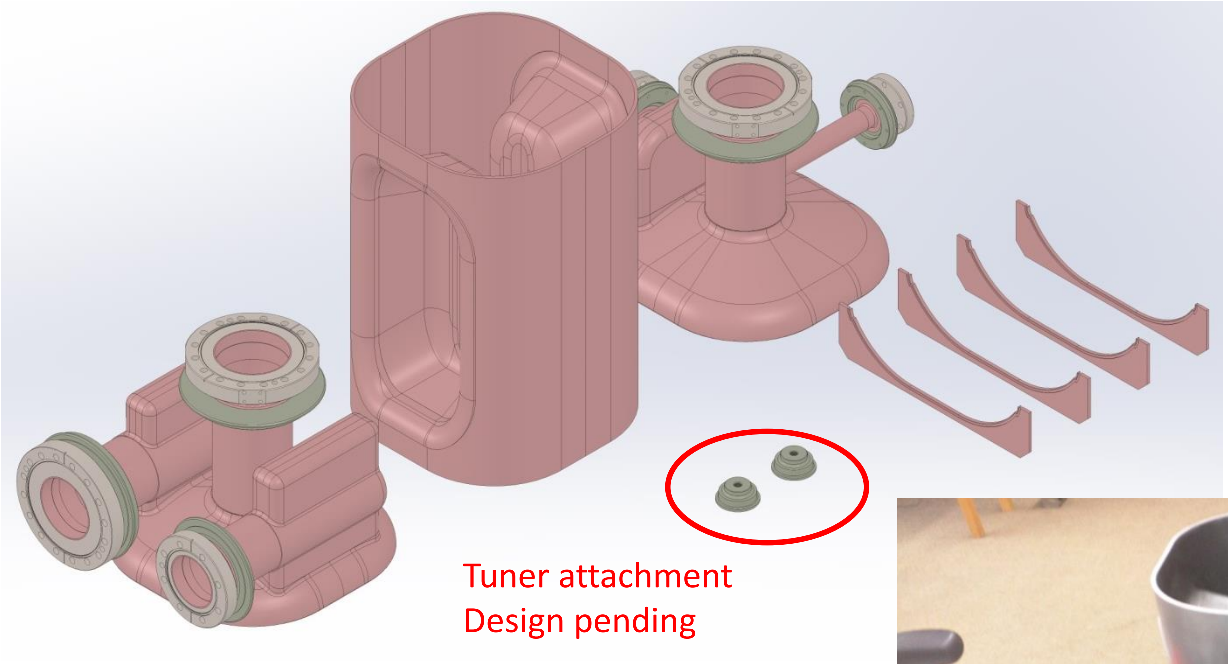
Below is a proposal for completing the two RFD cavities and HOM couplers. Vertical testing of the RFD cavities without HOM couplers

- Ship two RFD cavities to JLab (3 subassemblies with stiffener and tuner assembly not welded)
- Inspect RF surfaces
- Dimensional checks / QA
- Radiography
- Grind/polish surfaces as needed
- Bulk etch 3 subassemblies
- Machine weld prep for 3 mm full penetration welds (if approved by LARP/CERN)
- Trim tune
- Test fit and fixture the stiffeners and tuner
- Weld subassemblies, stiffeners and tuners
- Light BCP and HPR
- Test cavity without HOM couplers

Courtesy of Niowave

Final details of timing and steps in discussion

RFD Sub Assy Fabricated by Niowave

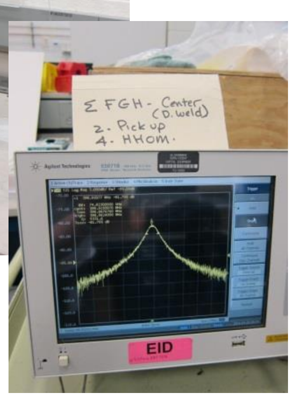


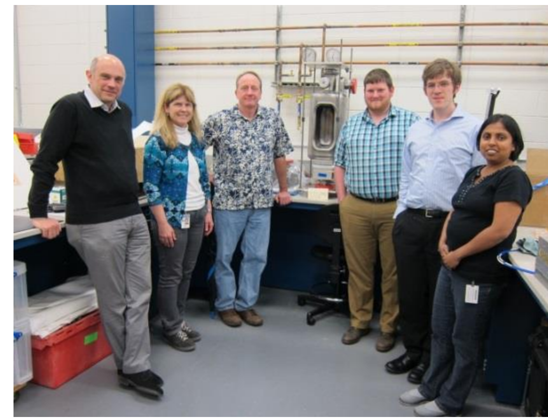
Tuner attachment
Design pending

Courtesy of Niowave

Niowave Cavities at JLAB 28Apr2016

- Two cavity sub assemblies arrive at JLAB
- QC- Frequency re- checked



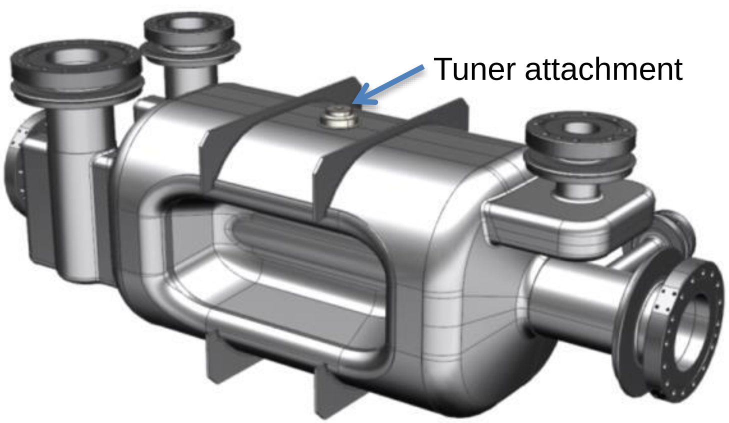


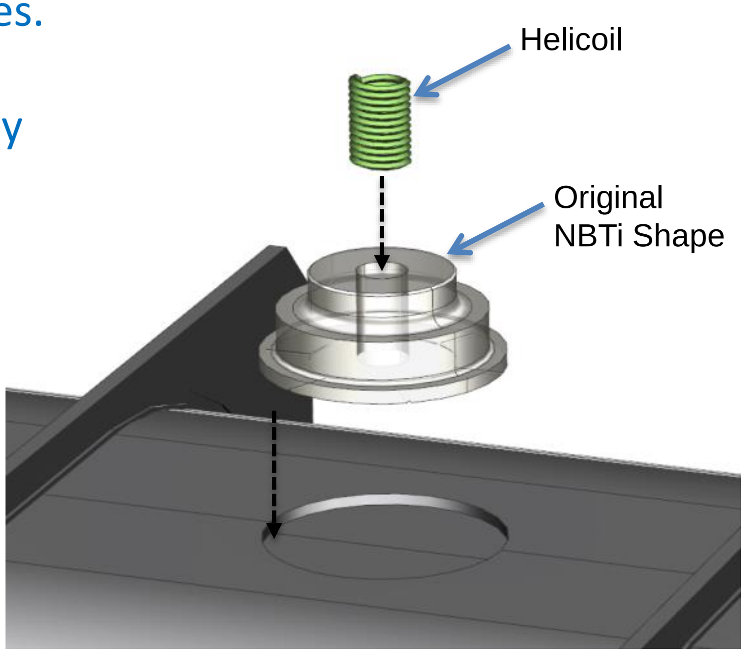
RFD Tuner Attachment Analysis

Background : The original design called for a NbTi to RRR weld, where Titanium was found to migrate on the RRR, ending up on the RF surface. As a result, the decision was made to investigate a simpler solution using welding a RRR tuner connection with helicoil inserts

Proposed New Design :

Tuner attachment is fitted into a recess on the 4mm cavity wall and then EB welded around the edges. Tuner attached by M10 titanium Helicoil thread insert. Several alternatives were analyzed, finally converging on a more conical design

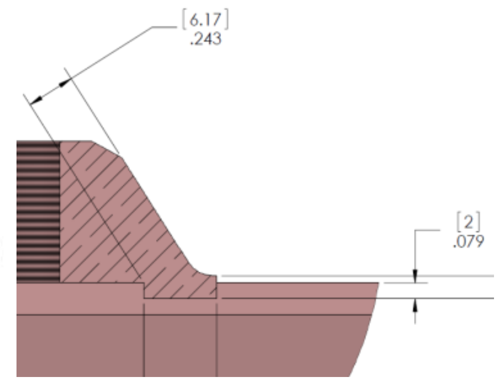




Recommendation RFD Tuner Attachment

Analysis of various design options – presented 22 Apr2016 by F. Fors to CERN & Partners

- Alternative 1 (JLAB) to reduce the stresses in the lower fillet of the original design
- Alternative 2 (Niowave) redesigned Alt. 1 , to minimize the machining of cavity wall . Tuner attachment is fitted in 2 mm deep circular groove rather than a full recessed surface.



Alternative 1: Lower fillet retained but increased in size
Stepped design replaced by conical

Alternative 2: (Niowave)
Similar to Alt. 1 but with redesigned fitting to cavity

Result of stress analysis : Design from Niowave (Alt. 2) had lowest stress

Next steps :

- Need approved drawings from CERN
- From final drawing make weld samples to further validate design

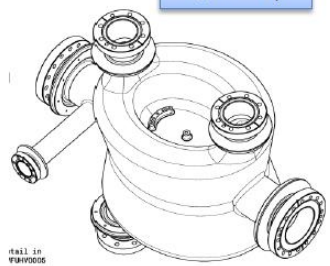
Courtesy F. Fors (JLAB) & H. Park (ODU/JLAB)

Status Weld Certification at JLAB

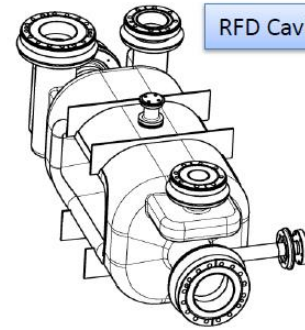
Analysed welds

A: 3mm for 1 side
A1: 3mm for both sides

DQW Cavity



RFD Cavity



Courtesy of
Paula Freijedo
CERN

B: 4mm for 1 side
B1: 4mm for both sides

- Documentation received according to ASME:
  VERY GOOD
- PQR EBW Nb 001-A_WPS EBW Nb 001-A
- PQR EBW Nb 002-A1_WPS EBW Nb 002-A1
- PQR EBW Nb 003-B_WPS EBW Nb 003-B
- PQR EBW Nb 006-B1_WPS EBW Nb 006-B1
- WPQ EBW Nb 001-A & EBW Nb 002-A1
- WPQ EBW Nb 003-B & EBW Nb 006-B1

Acceptance criteria:
- Stringent (level B) of ISO 13919-2
- Additional Restrictions (range 0.1-0.2mm) of Table 7 from Engineering Specification

Status : JLAB Weld Qualification to CERN requirements complete Dec.2015
Final documentation found in CERN EDMS 1612289 V.1

LARP

Weld Inspection Plan Radiography

HiLumi HL-LHC PROJECT

CERN HiLumi HL-LHC PROJECT

EDMS NO.	REV.	VALIDITY
1389669	2.1	DRAFT

REFERENCE : LHC-ACFDC-ES-0001

3.8.7 Electron-beam welding

Prior to the electron beam welding sequence, all parts shall undergo an ultrasonic degreasing and chemical polishing as specified in Section 3.8.5.

Before welding, the chamber shall be cleaned. A mass spectrum shall be taken to demonstrate that there are no residues of hydrocarbon.

All Niobium-Niobium welds shall be performed with 100% penetration, and all welds shall retain a smooth inner surface. Whenever it is possible welding from inside is recommended.

Pressure of the electron-beam welding chamber shall be maintained below 5×10^{-5} mbar, and Niobium vapour from welding shall be evacuated. The welding chamber shall be vented with nitrogen only after the temperature of the niobium part has dropped to 100°C at the hottest spot.

The welds shall be smooth and uniform. No repair of defective welds is allowed without prior approval from CERN.

CERN requests 100% visual inspection, radiographic inspection of 25% of the total circumferential seams and 100% of the total longitudinal seams. For corner joints and areas of high bending stress treat the circumferential seam as a longitudinal seam.

The electron-beam welding, and operator, qualifications shall be in agreement with the standards specified in Table 6.

Refer to proposal by S. DeSilva (ODU) presented 22April 2016

Status at JLAB : Estimate in process from ATS our Radiography supplier .
3 sub assemblies will be checked once dimensional work is complete

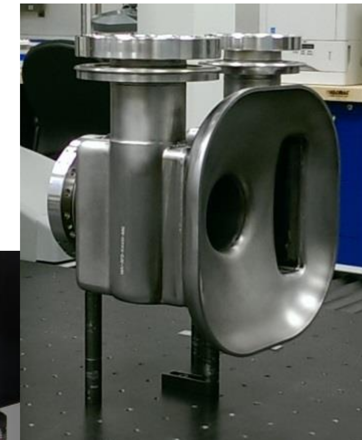
Jefferson Lab

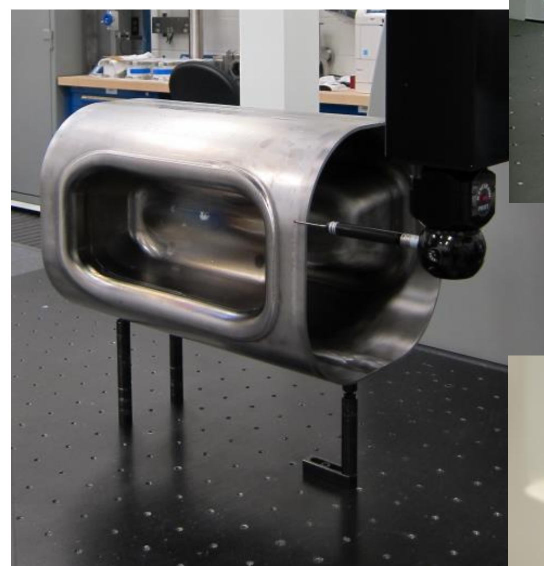
Dimensional check started May 9, 2016

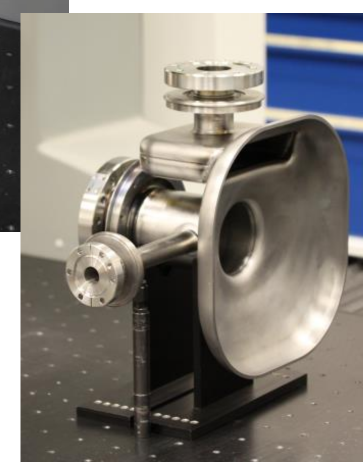
- Based on Requirements & Inputs
  - Plan from ODU (DeSilva)
  - Niowave sub assembly drawings
  - Weld Prep Tool design feedback from JLAB designers

- Using 3D CAD Model from CERN compared to data from CMM at JLAB

- Results to be recorded in JLAB Inspection Traveler







Plans for Weld & Pre-Weld Machining

From the Niowave Plan (slide 4) : Propose Machine weld prep for 3 mm full penetration welds (if approved by LARP/CERN)

- JLAB Machine shop is proposing a way to do the weld prep machining based upon a similar ODU cavity done recently
  - May use similar fixture concept for weld prep chemistry
- With the parts from Niowave we are starting to finalize the plan.
- Meet again with JLAB Machine Shop & JLAB designers once dimensional measurement data/report available (~ wk of May 23)

Overview of Chemistry

Chemistry Process presented 22Apr2016 to CERN

To summarize :

- Both BCP& Light BCP to use custom tooling in JLAB Closed Chemistry Cabinet with parts mounted in standard cage
  - Chemical Process Tools use Quill ("snorkel") proposed by JLAB
  - Fixtures concept for sub assembly as proposed by S. DeSilva (ODU)
- HPR to use the same Cage & Brackets as BCP
- Weld Prep Chemistry with custom tooling under Fume Hood

Details in the slides that follow

JLAB Closed Chemistry (BCP) Cabinet

Closed Chemistry Cabinet Cavity loaded from the Clean Room side of Tool

Example of a cavity inside the cabinet showing manifold customized for flow distribution for specific cavity*

BCP Cabinet Capabilities

Basic Process Steps (in order):

- Water Leak Check
- Nitrogen Leak Check
  - <5psi N2
- Acid Filtering
  - 0.2um filters
- Acid Polishing/Processing
  - 11-30 LPM, 8-10 deg. C
- Ambient Rinse
  - ~22 deg. C, ~40 LPM
- Hot Rinse
  - up to 80 deg C, ~40 LPM

Courtesy of Phil Denny & Jim Folkie (JLAB)

* Example shown is a Half Wave Co-Ax Cavity

JLAB HPR High Pressure Rinse Cabinet

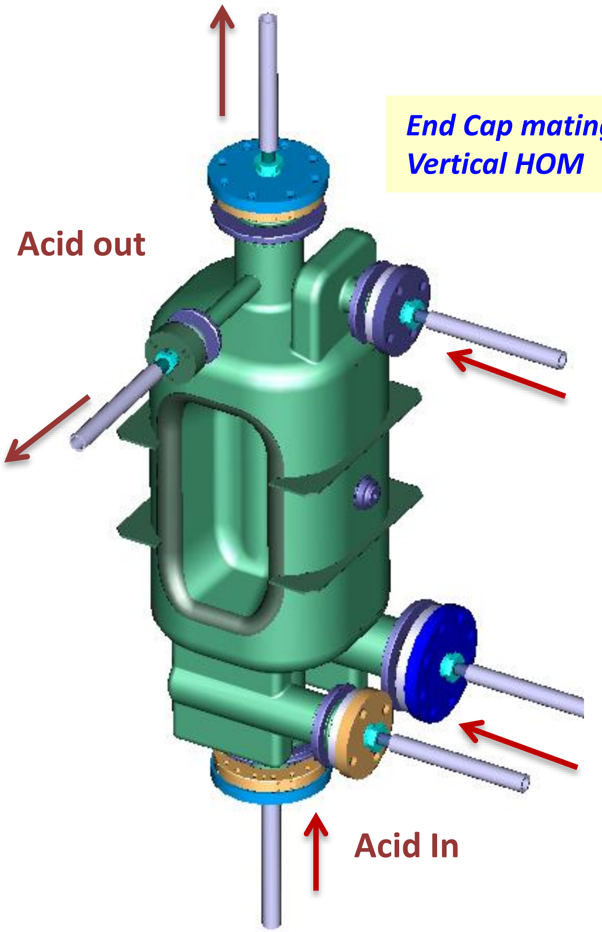
New JLAB HPR was installed & commissioned in 2015

Similar Machines at AES (2009), ORNL (2012), CERN (2013), & JLab (2015)

- Size
  - Rotational Diameter = 41” (104cm)
  - Chamber Opening = 48” W x 75” H (122 x 190cm)
  - Rinse Stroke Height = 72” (183cm)
  - Max Weight = 1000 LBS (450 kgs)
  - Wand O.D. = 1” (25.4mm)
- Rotation Speed
  - Rotation .5 – 5 RPM (CW or CCW)
  - Wand Speed 0.1 – 300 IPM (762 cm/min)
- Rinse Capacity
  - Ambient UPW = 70F (21 C)
  - Hot UPW = ~176F (80 C)
  - Pressure to Nozzles* = 200-1500 PSI (14- 103 Bar)
  - Flow* ≤ 10 GPM (38 LPM) @ max pressure
  - *Note: Flow is nozzle dependent.
  - *Note: HPR controlled by pressure, not flow!

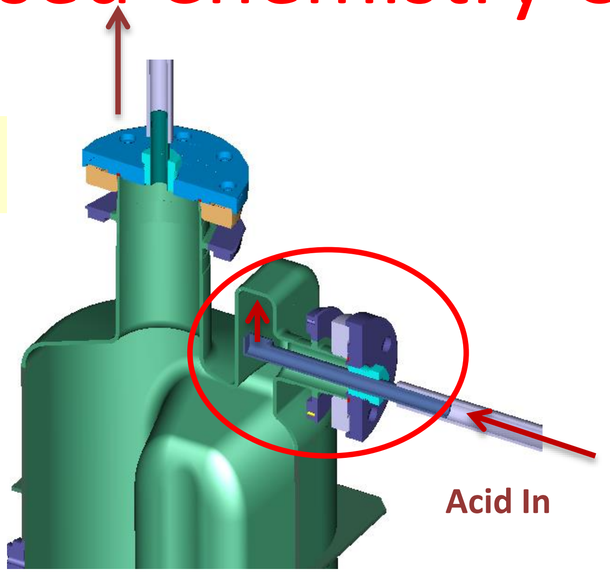
Courtesy of Phil Denny (JLAB)

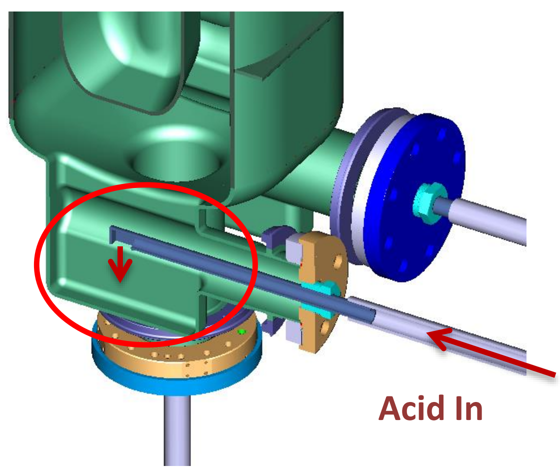
Final BCP Closed Chemistry Cabinet

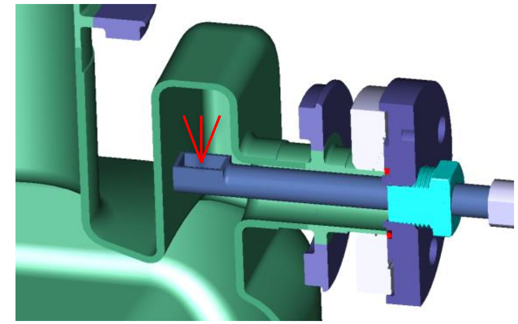


End Cap mating to Vertical HOM

End cap mating to Horizontal HOM





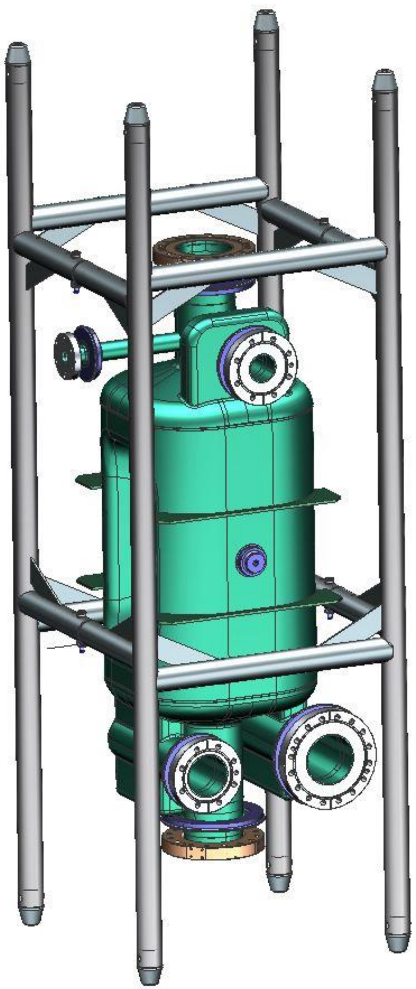


Chemical Injection Quill "*Snorkel*" directs the flow of Acid & Water

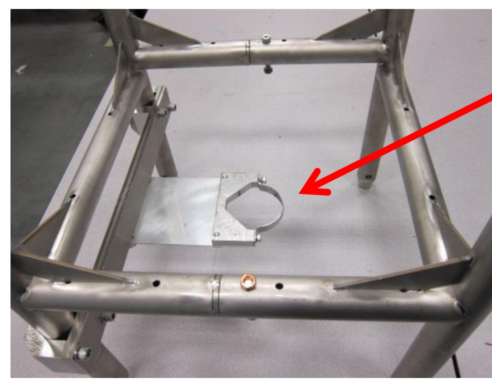
Status :

- Tooling Design in process
- Tooling Fabrication, Procedure & Traveler to follow

Cavity Chemistry & Test Fixtures



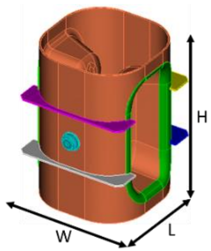
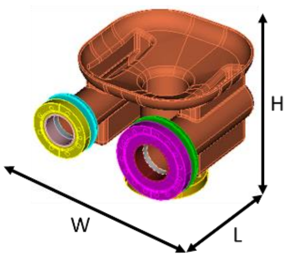
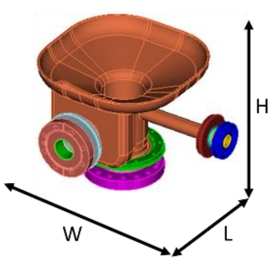
- 16"x16" Titanium Cage
  - Chemistry & VTA
  - Standard Design at JLAB
- Custom "V" Blocks for specific cavity



Status of Tool Design & Fab for full assembly

JLAB May2016 : Tool Design in process

Sub-Assemblies of RFD Cavity

Sub-Assembly	Parameter	Value	Unit
	**Center Body CTR (ODU SA-1 or NWV Center Section)**		
	Height (H)	16.6	in
	Length (L)	12.3	in
	Width (W)	11.9	in
	Volume	7.24 + 0.35	gallons
	Weight	43.3	lb
	Weight with acid	139.7	lb
	**End Cap Horizontal HOM EHHOM (ODU SA-2 or NWV End cap 2)**		
	Height (H)	11.0	in
	Length (L)	13.5	in
	Width (W)	13.46	in
	Volume	1.73 + 0.17	gallons
	Weight	35.4	lb
	Weight with acid	59.6	Lb
	**End cap Vertical HOM EVHOM - (ODU SA-3 or NWV End Cap 1)**		
	Height (H)	8.5	in
	Length (L)	13.5	cm^3
	Width (W)	18.077	m^2
	Volume	1.15 + 0.17	gallons
	Weight	24.0	lb
	Weight with acid	40.8	lb

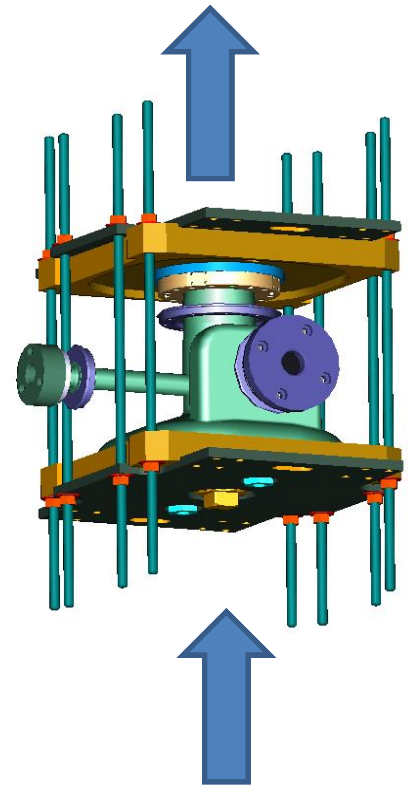
Courtesy of Suba DeSilva (ODU)

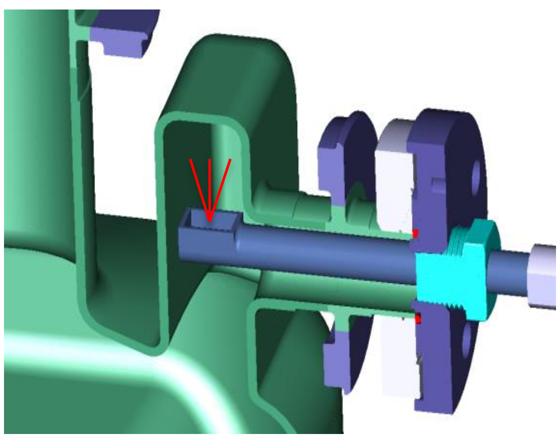
Additional volume and weight with acid is included in the estimate, considering the pre-trimmed parts.

BCP/HPR of 3 sub assemblies- RFD

The same principles apply to the 3 sub assemblies before final weld

- JLab Closed Chemistry Cabinet
- fitted with custom tooling
- Use Chemical Injection Quills or "*Snorkel*" to direct the flow

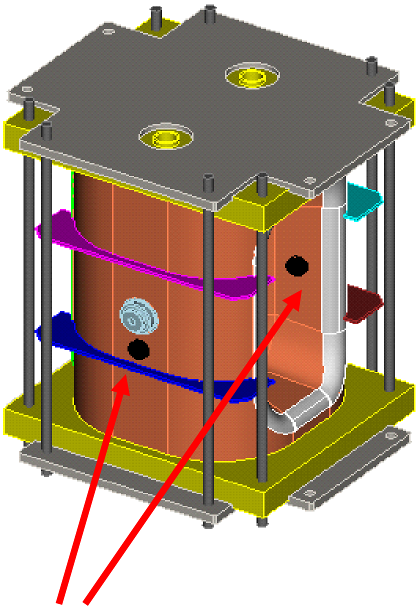




Detailed slides to follow

Proposed BCP Processing Sequence

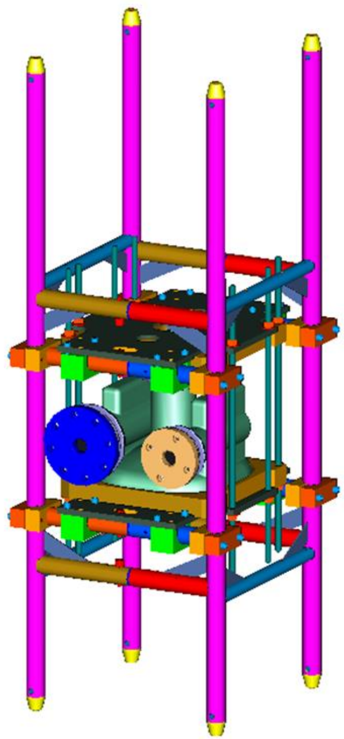
- Total removal <u>140 microns</u>
  - 1:1:2 BCP
    - one part Nitric, one part HF, 2 parts Phosphoric Acid
  - Achieve as much uniformity as possible
  - Specifically at High Magnetic Field Surface Areas
- Bulk BCP of sub assemblies (SA-1, SA-2 & SA-3)
  - Will be performed in JLAB closed chemistry cabinet
  - ODU propose 4 iterations of 35 microns and flipped after each iteration
  - Thickness measurement during BCP at two locations
    - SA-1 : at the two locations of High Magnetic Field and High Electric Field
    - SA -2 : at the two wave guide stubs
    - SA- 3 : location TBD



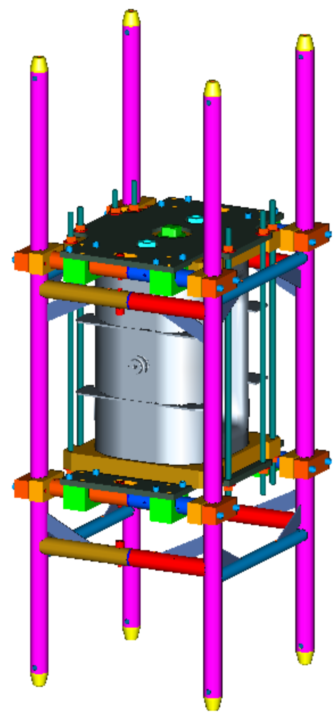
Thickness measurement at two locations

Courtesy of Suba DeSilva (ODU)

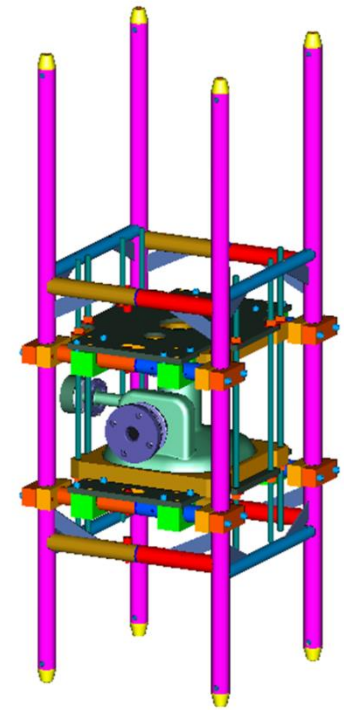
Same 16"x 16" Standard Cage used for Chemistry



End cap mating to Horizontal HOM



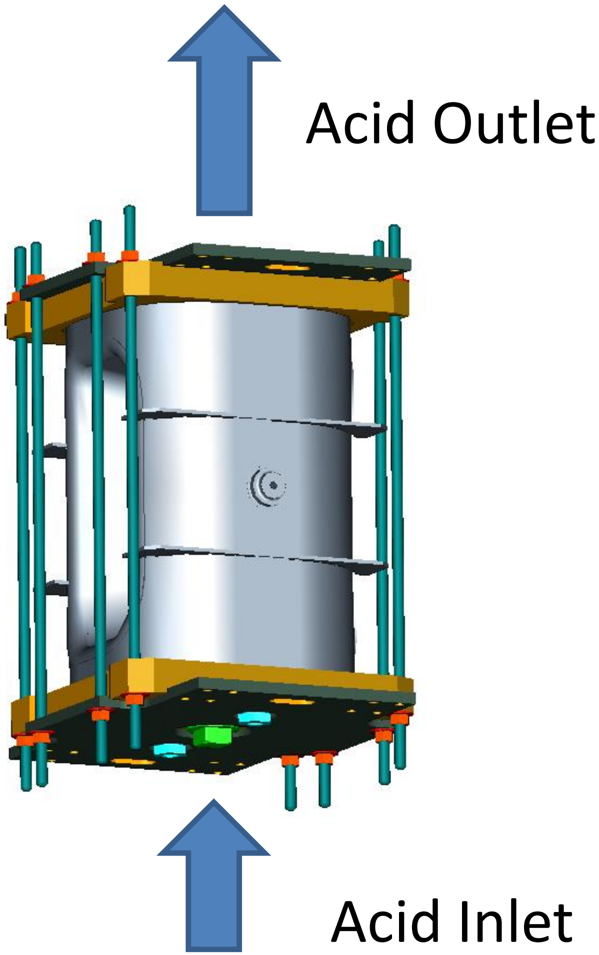
Center Body



End Cap mating to Vertical HOM

The Full assembled cavity would be mounted in the same Cage with V Blocks

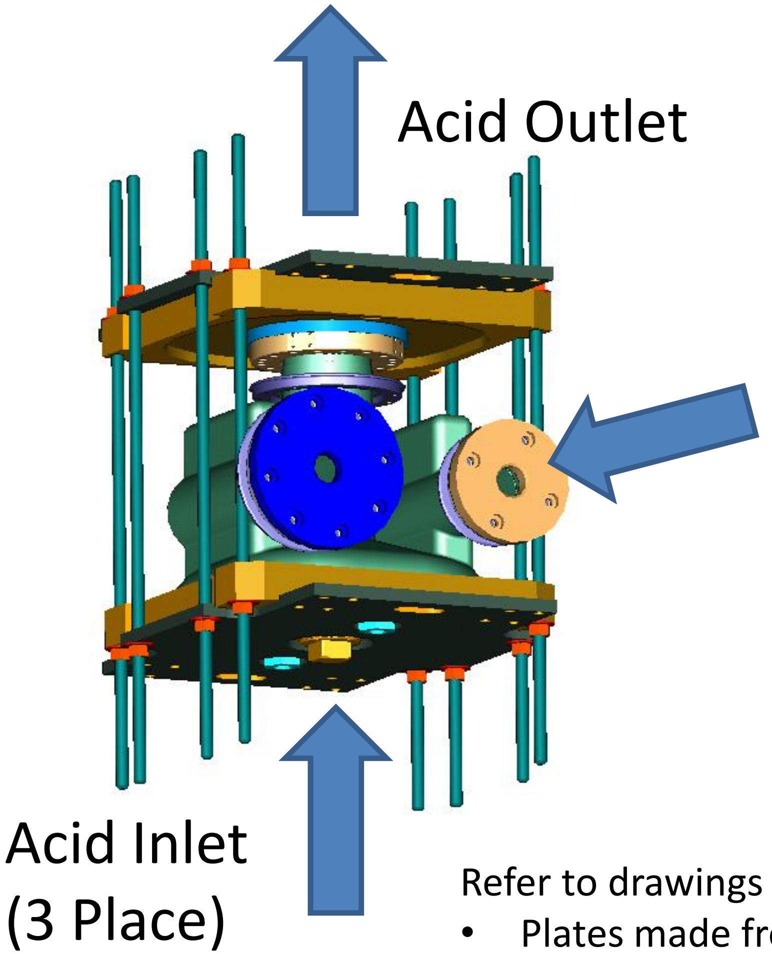
Center Body CTR (SA-1) BCP Fixture

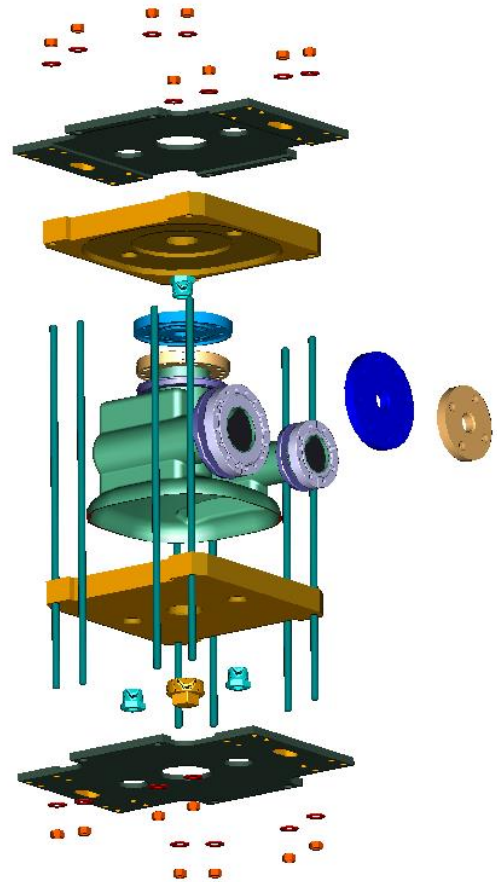


Refer to drawings for details

- Plates made from PVDF
- End Seals from Gortex Sheet

End Cap EVHOM (SA-2) BCP Fixture

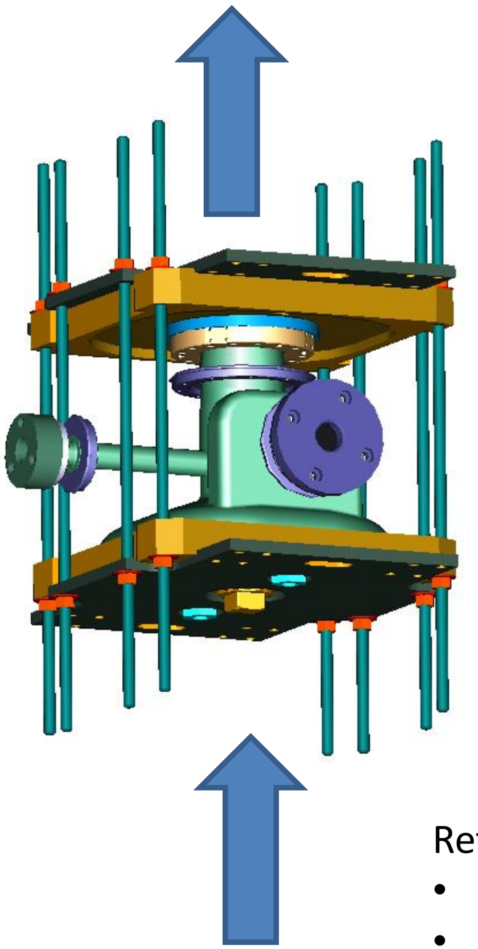


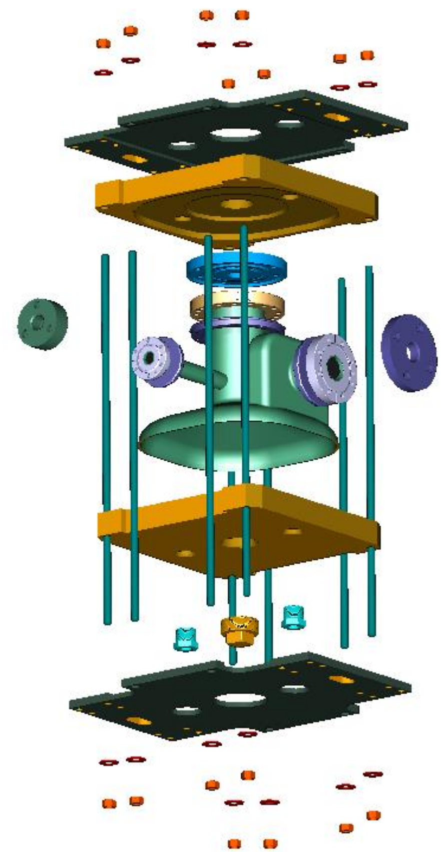


Refer to drawings for detail

- Plates made from PVDF
- End Seals from Gortex Sheet
- O-rings for Conflat Flanges :
  - Teflon Encapsulated Viton

End Cap HHOM (SA-3) BCP Fixture





Refer to drawings for detail

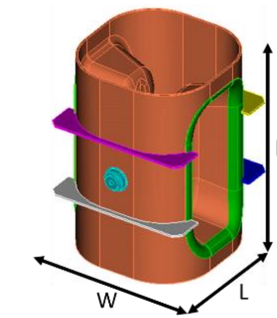
- Plates made from PVDF
- End Seals from Gortex Sheet
- O-rings for Conflat Flanges :
  - Teflon Encapsulated Viton

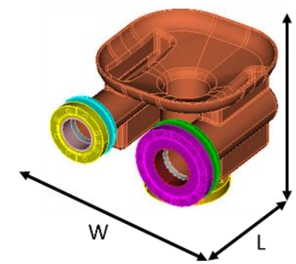
Weld Prep Chemistry - RFD

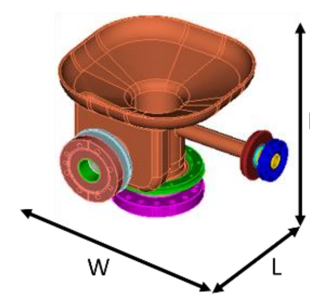
US LARP weld prep will be done in the Fume hood in photo above

Weld Prep for RFD:

- Lower 0.5 inch of cavity will be immersed in Acid for ~ 90-120 seconds







Status :
- Fixture Concept agreed in principle
- Final Fixture Design & Fab to follow

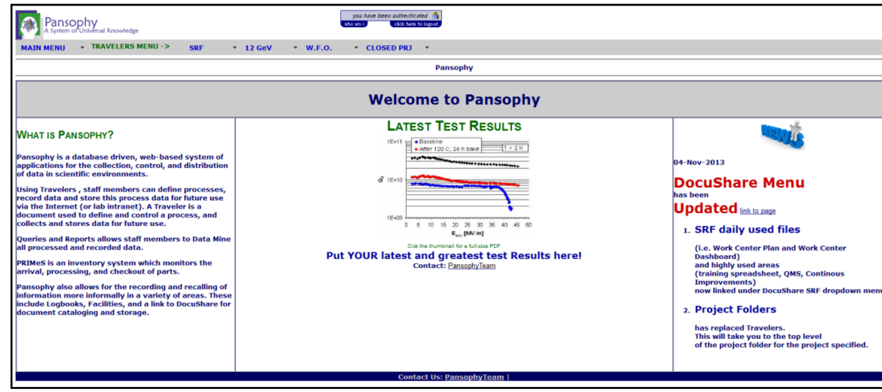
Documentation at JLAB

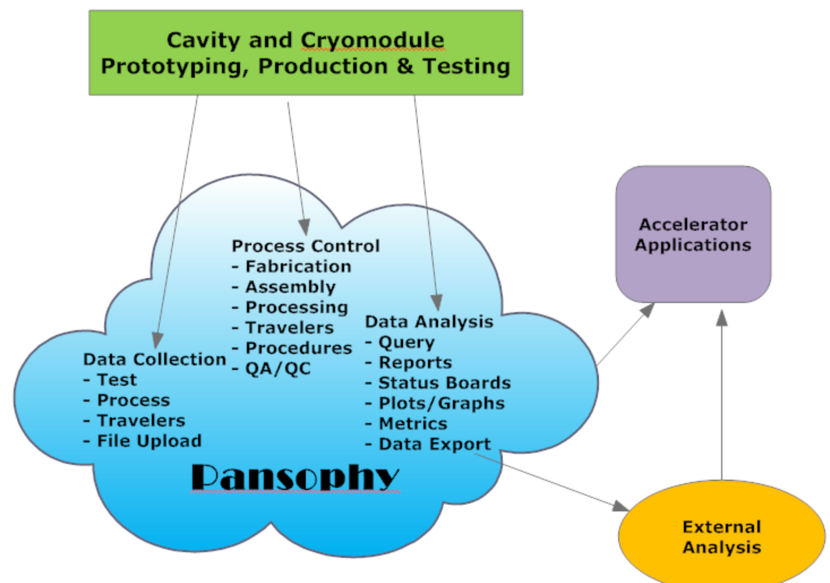
Data, Document & Process Management

PANSOPHY : A Process & Data Management Tool

- **Data Management & Storage**
  - subcomponent test data
  - processing & testing procedures
  - Inventory
  - R&D and Production

- **Knowledge Management**
  - to Maximize learning from expensive prototyping and low-volume production
  - **Adopted by other DOE Lab**
  - SNS (Spallation Neutron Source)

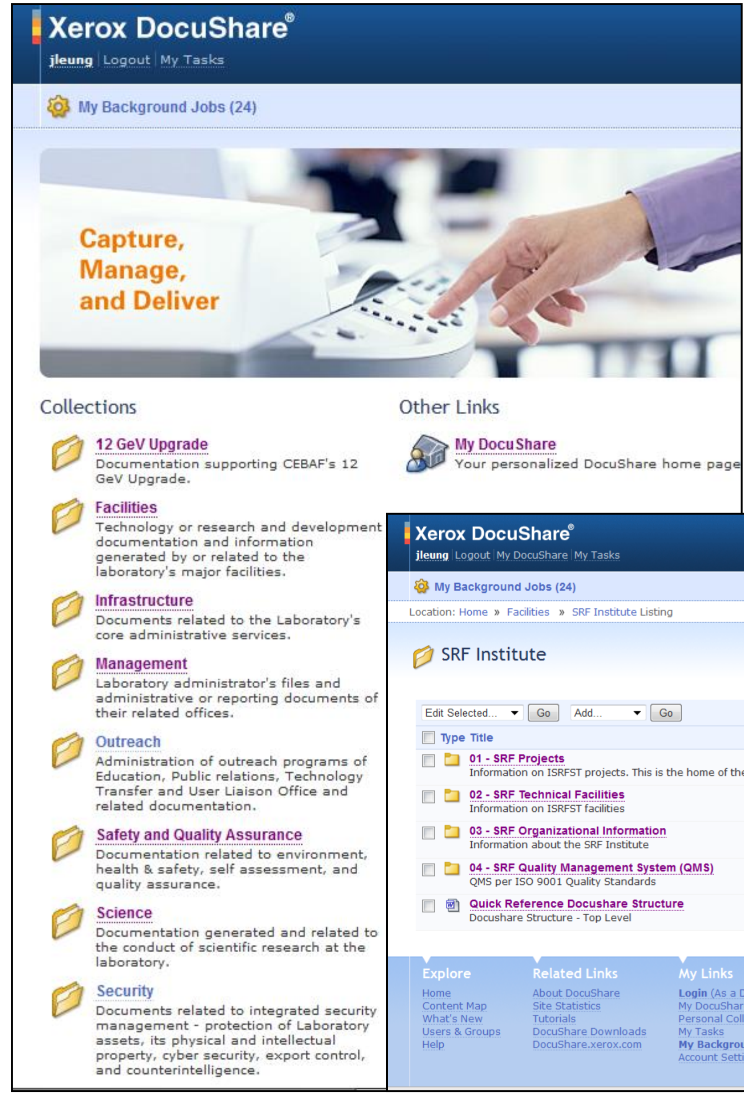




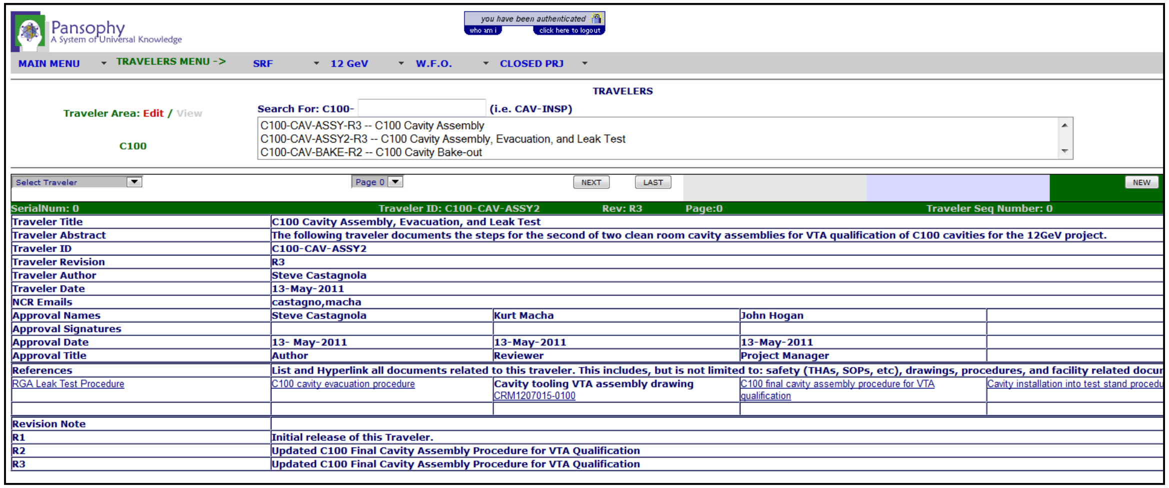
Data, Document & Process Management

DocuShare Tool

- Web-accessible centralized file storage database (Lab-wide & SRF).
- **Controlled-Sharing** access to site content.
- **Collection-Based** filing structure.
- Files for SRF organizational info, Quality Management System, Project Management, procedures, travelers, etc.
- Plus other account and content features.

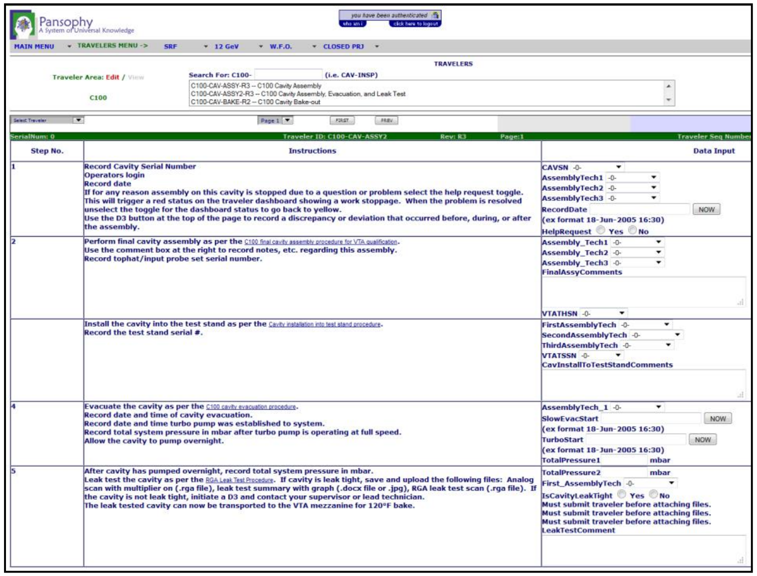


Pansophy Traveler – Example



Traveler Cover Page:

- Descriptions & approvals.
- ***Links to associated procedures.***
- Revision history.



DATA INPUT –

1. Process instructions & steps to guide work flow.
2. Data Input – **data entry and comments** made by user at prescribed process points.
3. 'Hooks' to inventory system – **automatic serial number push** and **I.D.s** for individual components and assemblies.

Example : JLAB existing STP Travelers

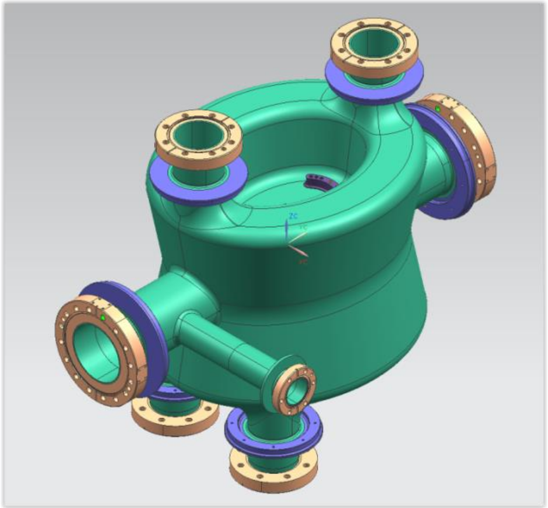
	TRAV_ID	TRAV_TITLE	TRAV_ABSTRACT
Inventory	**NEW**	**Incoming Receiving**	Normally project specific , may want a separate traveler for US LARP
Inspection & QC	STP-INSR	Inspection Summary Report	This is a standard report that is used to document inspections on parts and supplies received into SRF. For US LARP will include incoming Radiography reports
Inspection & QC	USLARP-EBW-CERT1	Weld Qualification Record	Record of weld coupons and qualifications (includes CERN report)
Fabrication & Tuning	STP-CAV-PROC-RFIN	STP Cavity RF Incoming Inspection Traveler	This traveler collects data from incoming RF inspection measurement.
Fabrication & Tuning	STP-CAV-PROC-TUNE	STP Cavity Tuning Traveler	This traveler collects data from several different tuning steps during cavity production.
Fabrication & Tuning	**NEW**	**Leak Check**	Normally leak checks recorded in other travelers , may want a separate traveler for US LARP
Fabrication & Tuning	STP-EBW-WELD	EBW Traveler	Traveler captures Electron-Beam Welding processes
Chemistry & heat treat	STP-CAV-CHEM-BCP	STP BCP	This document captures the data generated from a Buffered Chemical Polish executed in the Closed Chemistry Cabinet.
Chemistry & heat treat	STP-CAV-CHEM-DEGR	STP Cavity Degrease	This Traveler captures information from ultrasonic cleaning of STP cavities.
Chemistry & heat treat	STP-CAV-CHEM-THKN	Cavity wall US thickness measurements	Cavity wall measurements using ultrasonic method
Heat Treat & Furance	STP-CAV-PROC-BAKE	STP Cavity Bake-out	120 deg. C bake of STP cavities before VTA qualification test.
Heat Treat & Furance	STP-CAV-PROC-HEAT	STP Cavity Heat Treatment	This Traveler collects data from cavity heat treatment furnace runs.
VTA Test	STP-CAV-VTA-TSTP	VTA RF Cavity Test Plan	Test Plan / Request for testing of cavities in the Vertical Test Area (VTA)
VTA Test	STP-CAV-VTRF	VTA RF Cavity Test	Standard Data Acquisition for testing of cavities in the Vertical Test Area (VTA)

Next steps :

US-LARP specific set up Procedures have yet to be developed

Plans for DQW Cavity

- DQW process will be very similar to RFD
- Exception: chemistry done on the fully assembled cavity only.



- Since CERN is also building DQWs, the current focus is on the RFD
- DQWs will be following whenever possible the same steps as the RFD once these have gone past each step.
- At JLAB final details of the plan will depend on <u>when</u> the cavity is needed
  - Resources will be assessed at that time

Summary JLAB Status to date

- 2015 to April2016
  - Certification of JLAB EBW to CERN (Dec2015)
  - Special Tasks, Tuner attachment analysis (Feb2016)
    - CERN Final design (Drawing) & confirmation needed
  - Niowave Process Flow agreed ODU/JLAB (08Apr2016)
  - April/May 2016 tool /Process design in process
    - BCP Tool design ready for sign off (April) , quote in process
    - Light EP tool design incl “snorkel” in process
    - Thickness Measurement (2 channel) & wireless- Tests start soon
    - STP Travelers list available - review needed
    - US LARP Project Requirements & Procedures (ODU/LARP/CERN)
- Niowave Sub assemblies at JLAB (28Apr2016)
    - Inspection & Dimensional check in process
    - Quote for Design and Fab of Machining & trimming tools to follow

For Future Consideration -Next Steps

- Confirm (or modify) Process Flow per plan of April 8th
- Finalize Procedures & Tooling Designs , confirm Traveler(s)
- Update Timeline to include :
  - Fabrication & EBW
    - inspections and radiography on sub assemblies
    - RF Tuning , Machining & Welding including required Tooling
  - Chemistry & Processing
    - Process Flow Chart
    - Tooling and process design
    - plans for chemistry, from tooling to processing
  - Testing in the JLAB VTA
- For future – HOMs and Helium Vessel

Thank you for your Attention

Appendix

LARP

JLAB-SRF Dewar Sizes

HiLumi HL-LHC PROJECT

Dewar	Inside Diameter* (cm) / (in)	Inside Height (cm) / (in)	Height to Baffle (cm) / (in)	Volume/cm (Liters)	Useful Volume (liters) design fill	max fill	Heat Losses** (watts)
1	40.6 / 16	183 / 72	102 / 40	1.3	136	140	0.6
2	40.6 / 16	183 / 72	102 / 40	1.3	136	140	0.7
3	71.1 / 28	275 / 108	163 / 64	3.98	648	800	1.2
4	71.1 / 28	275 / 108	163 / 64	3.98	648	800	1.2
5	88.3 / 34	336 / 132	204 / 80.3	5.87	1197	1400	1.2
6	40.6 / 16	275 / 108	163 / 64	1.3	212	250	0.7
7	71.1 / 28	336 / 132	204 / 80.3	3.98	812	960	1.3
8	71.1 / 28	336 / 132	204 / 80.3	3.98	812	960	1.3

* The Instrument and wire protecting channel, and the purge line take up some of this space.

** The measured heat losses are without top plate inserts, and with baffled in the neck region with 1/8 " radial clearance

VTA RF Amplifier Capabilities

"805 System" 500MHz - 1000MHz, 500 Watts (hard routed to dewars 7 & 8)

"1497 System" 1425MHz - 1510MHz, up to 500 Watts (dewars 3 - 8)

Portable 1.3GHz amplifiers, 250 Watt and 500 Watts

Portable 1.5GHz amplifiers, up to 200 Watts

Portable 2 - 4 GHz amplifier, 200 Watts

Note: PSS Amplifier Switch Boxes can handle amplifiers rated up to 500 Watts with frequency ranges of 100MHz to 4GHz.

Courtesy : K. Davis

Jefferson Lab

Please consult with JLab –SRF Specialists to confirm details of application suitability

JLAB Cavity Furnace & Heat Treatment

Other Cavity Process Equipment

- EP Electro Polish Machine for Cavities
- Furnace & Heat Treatment
- Barrel Polishing
- Optical Inspection & Metrology

Niowave/JLab Serialization

Proposed Serialization for Niowave RFD Cavities

Title of Component	JLAB Serial Number	Niowave identifying numbers	ODU Ref.
Final RFD Cavity Assembly for US LARP	NWV-RFD-CAV-001		
	NWV-RFD-CAV-002		
Cavity End Sub Assembly (mates to vertical HOM)	NWV-RFD-EVHOM-001	1	SA 3
	NWV-RFD-EVHOM-002	2	SA 3
Cavity End Sub assembly (mates to Horizontal HOM)	NWV-RFD-EHHOM-001	3	SA2
	NWV-RFD-EHHOM-002	4	SA 2
Cavity Center Sub Assembly	NWV-RFD-CTR-001	A-B-C-D	SA 1
	NWV-RFD-CTR-002	E-F-G-H	SA 1
Stiffeners	NWV-RFD-STF-001A	A (use on sector A Cavity 1)	
	NWV-RFD-STF-002B	B	
	NWV-RFD-STF-003C	C	
	NWV-RFD-STF-004D	D	
	NWV-RFD-STF-005E	E (Use Sector E Cavity 2)	
	NWV-RFD-STF-006F	F	
	NWV-RFD-STF-007G	G	
	NWV-RFD-STF-008H	H	
Tuner Attachment	NWV-RFD-TNR-001		
	NWV-RFD-TNR-002		
	NWV-RFD-TNR-003		
	NWV-RFD-TNR-004		

Agreed with Niowave/Larp/ODU/JLAB – 28Apr2016