RFD HOM Coupler Challenges

Naeem Huque – Jefferson Lab

14th HL-LHC Collaboration Meeting. – Oct. 7th–10th 2024

Outline

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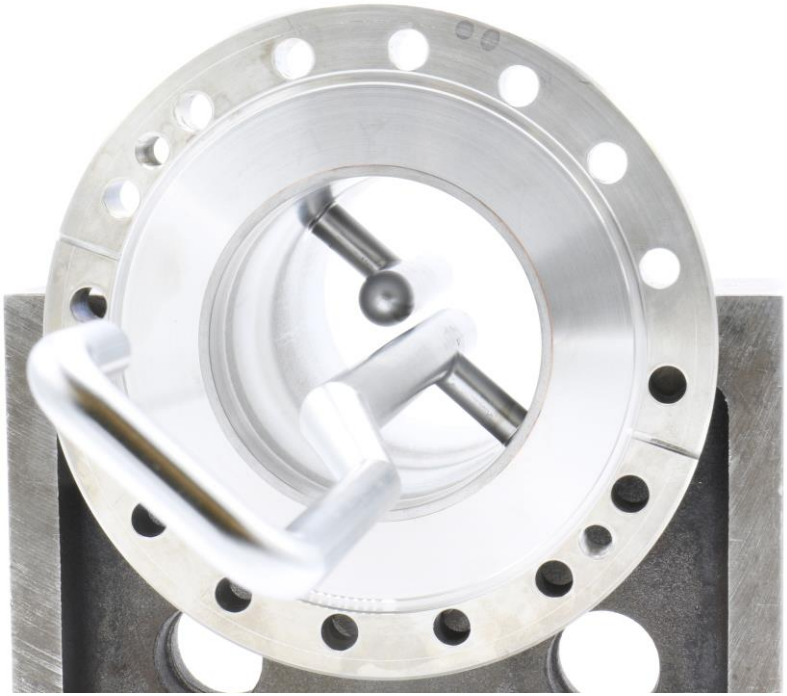
- Interfaces
- Current Challenges
  - Niobium Material Testing
  - Ceramic Brazes
  - Helium Line Configuration
- Series Production Status
- Summary



JLab Scope of Work

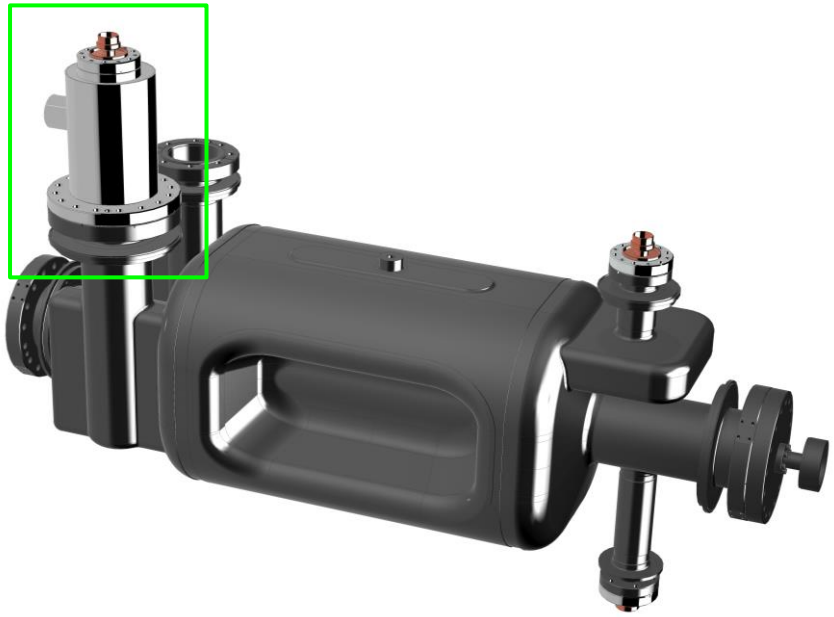
- Fabricate sets of RFD Cavity Ancillaries
  - Prototype: 3 sets (FY21/FY22) **Complete**
  - Pre-Series: 3 sets of HHOM Dampers (FY23/FY24) **Complete**
  - Series: 10 sets of HHOM Dampers (FY24/FY25)
- RF design is provided by AUP; mechanical design proposed by JLab with CERN as the design authority
- All activities are in full compliance with CERN Engineering Specification Document (EDMS 1389669 v2.6)
- Develop manufacturing drawings and strategy
- Develop brazing and welding processes and formal documents
- Share production information with the CERN MTF

JLab Scope of Work: Interfaces

- Interfaces are defined in LHCACFDC0001 - CERN EDMS 2420659
- Drawings for JLab scope have been approved by CERN

HHOM-FT
DN40 CF

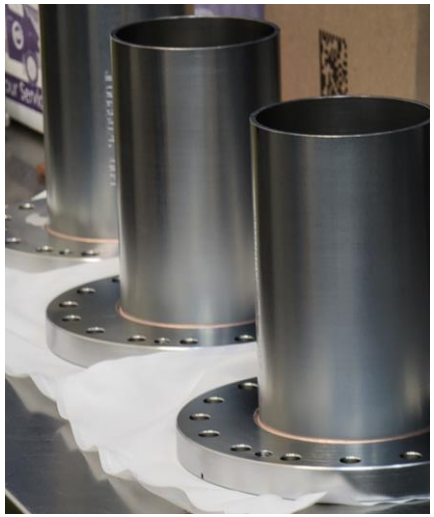
HHOM
DN100 CF



RFD Cavity

Current Challenges: Heat Treatment

- In early 2024, several Nb parts were inadvertently heat treated.
  - Inner can lids went through 950C for two hours (stress relief heat treatment for SS)
  - The material properties would need to be tested to ensure mechanical and RRR compliance
- Additional studies were carried out in reference to the two-step brazing process for the DN100 flange
- The following was to be verified:
  - The accidental heat treatment does not overly reduce the Nb RRR and yield strength
  - The second step of the two-step braze does not overly reduce the Nb RRR and yield strength



Nb can lids (top) and DN100 braze assemblies which use 2-step brazing (bottom)

RRR Tests

Off-Normal 950C Heat Treatment			
Sample	**Temperature**	**Description**	**RRR**
1	None	Baseline	312
2	1X 950 C 1X 1040 C	2 hours dwell (same as SS HT) Same as brazing run	329
3	1040 C	Same as brazing run	332
		RRR Spec	**300**

Effect of Second Brazing Run			
Sample	**Temperature**	**Description**	**RRR**
1	None	Baseline	270
2	1040 C	Same as brazing run	282
3	2X 1040 C	Same as brazing run	286
		RRR Spec	**300**

- RRR values are acceptable to CERN
- Furnace runs do not lower RRR

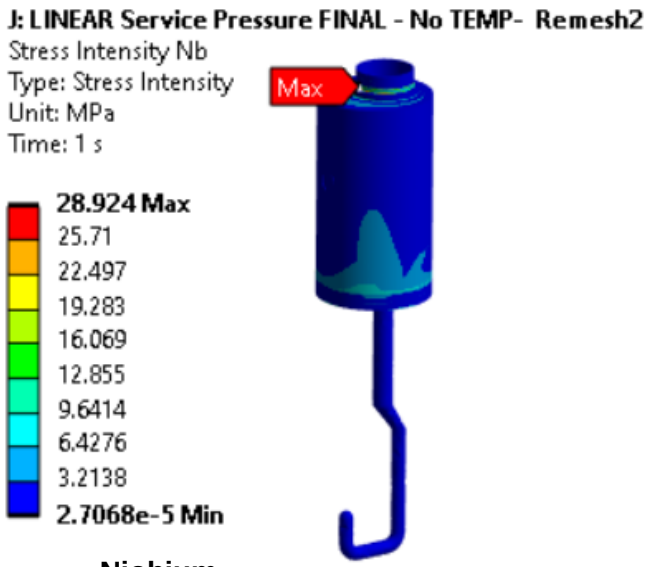
Tensile Testing

Off-Normal 950C Heat Treatment						
#	Temp	Description	$R_{P\ 0.2}$ (MPa)	R_M (MPa)	A_g (%)	A_{BREAK} (%)
1	None	Baseline	79.5	157.5	32.5	63.0
2	1X 950 C 1X 1040 C	2 hours dwell (same as SS HT) Same as brazing run	37.6	130.2	30	44
3	1040 C	Same as brazing run	37.3	128.5	29.3	41.2

Effect of Second Brazing Run						
#	Temp	Description	$R_{P\ 0.2}$ (MPa)	R_M (MPa)	A_g (%)	A_{BREAK} (%)
1	None	Baseline	52.1	158.8	37.2	67.4
2	1X 1040 C	Same as brazing run	48.3	136.0	27.8	35.6
3	2X 1040 C	Same as brazing run	45.9	120.7	22.7	32.9

Mechanical Properties

- The accidental heat treatment of the Nb did not affect the final yield stress (beyond the effect of the regular brazing run)
- The second furnace run of the DN100 two-step brazing process did not deteriorate the mechanical properties of the Nb
- The strength analysis was carried out using the lowest yield strength (EDMS 3086558) and was acceptable



Niobium

- P_m < 150 MPa
- P_{m+b} < 225 MPa

No stress above 29 MPa

Eduardo Cano-Pleite, CERN

Current Challenges: Ceramic Brazes

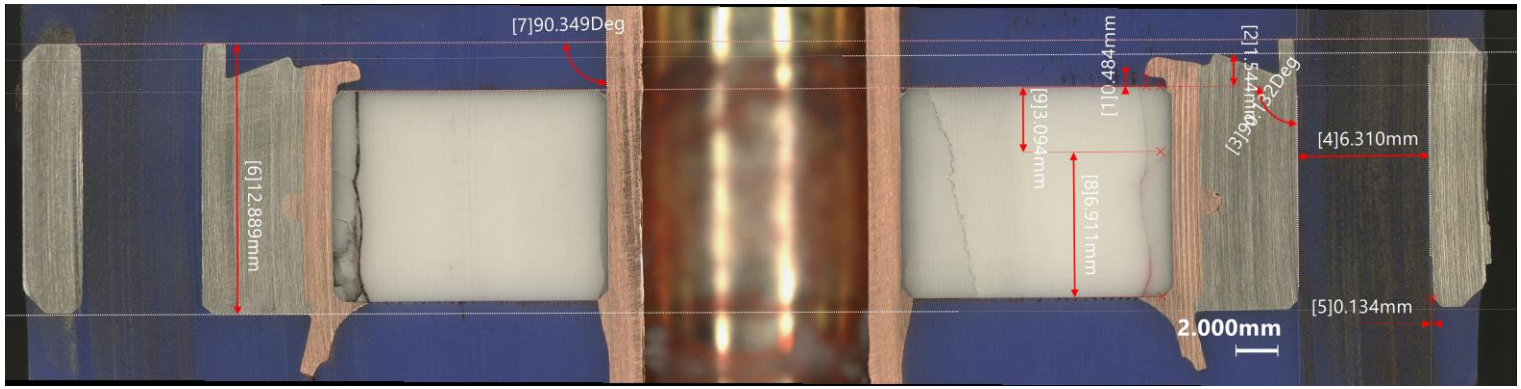
- CERN uses a rotatable titanium flange on the ceramic feedthroughs (below right)
- JLab uses a copper interface ring between the ceramic and a 316LN non-rotatable flange (below left)
- In particular, the concern is that the brazing/installation process will form cracks within the ceramic which will propagate over time
  - Destructive section is the only way to identify cracks
- The JLab design has been implemented on prototypes and has been included in a number of VTA cycles without failure

JLab Design

CERN Design

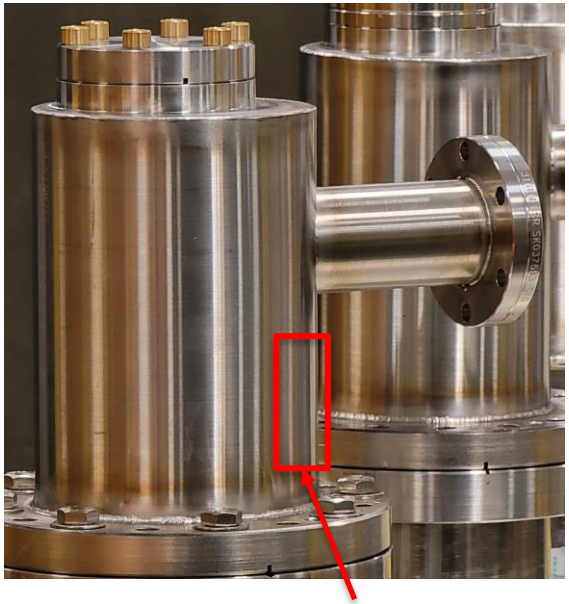
Ceramic Testing Conclusion

- Ceramic braze qualifications and testing have been ongoing for three years
- The presence of internal micro-cracks in the ceramic after brazing/mounting could not be measured with confidence.
- A setback was a batch of ceramics, bought from the same vendor and the same specifications as others, which had unknown inherent defects and failed upon mounting
- A final qualification run was held in January 2024
- The JLab design met the qualification goals, but was found to crack if the torque was raised from the spec of 10 Nm to 12 Nm
- Due to the risk of over-torquing occurring during the installation process, the CERN design was down-selected



Current Challenges – Helium Line Issue

- Helium line on HHOM damper's SS jacket (left image) in the wrong position
- Using this new position would result in changes to the cryomodule design
- Issue was not discovered during CAD model and drawing approval process at CERN
- Different design is possibly an artifact from an old LARP prototype (right image)
- Modifying existing dampers is not practical
  - The helium jacket is a pressure boundary and weld repairs would be subject to additional rules
  - The proximity of the Nb can inside the SS jacket makes any cuts risky
  - Additional welds on the part would cause distortion, bringing the dimensions out of tolerance



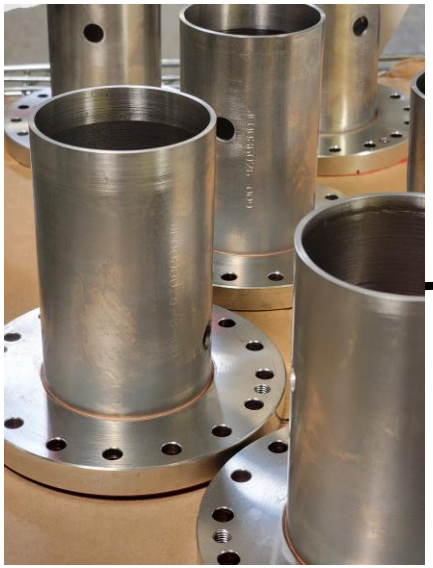
Outlet should be here

Reduced Scope

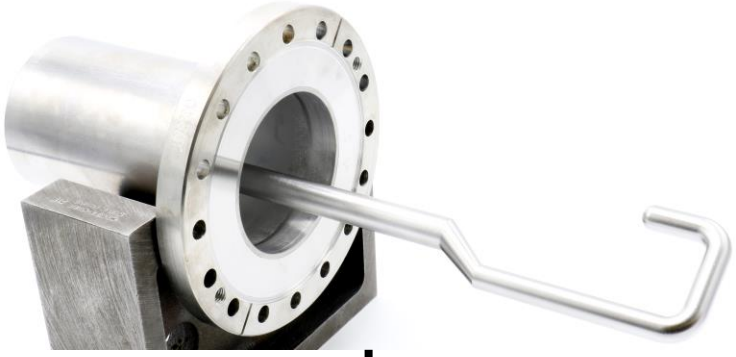
- Feedthroughs will be delivered to JLab for installation on jacketed cavities
- HHOM Dampers will be produced in advance of jacketed cavity delivery to JLab

Source	Feedthroughs	HHOM Dampers	Status
CERN	2 sets	2	At JLab
CERN	4 sets	-	Due Q1 FY25
JLab	-	4	Due Q2 FY25
JLab	-	6	Due Q3 FY25
CERN	8 sets	-	Due Q3 FY25

Production Status



Hook and Tee Weldment



Hooks/Tees
7 out of 10 complete

DN100 Brazements
5 out of 10 complete

DN40 Brazements
8 out of 10 complete

Inner Can Assembly

Final Assembly

Production Schedule

		2024			2025					
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
HHOM 01 - 04	Assembly									
	Testing									
	Acceptance									
HHOM 05 - 07	Assembly									
	Testing									
	Acceptance									
HHOM 08 - 010	Raw Material Procurement									
	Part Fabrication									
	Assembly									
	Testing									
	Acceptance									

Summary

- JLab scope now includes only fabrication of HHOM Dampers
  - Three fabricated HHOM dampers are not usable due to interface issue.
- Material tests on Nb have validated JLab furnaces and brazing run effects on properties
- Ceramic brazing qualification was successful but CERN design will be used to reduce risk
  - Ceramic feedthroughs will be provided by CERN
- Procurement and assembly plans are in place at JLab to produce HHOM Dampers in time for installation on jacketed cavities

Thanks to the RFD Ancillary Team

- **Fermilab** – Manuele Narduzzi, Colin Narug, Leonardo Ristori
- **ODU** – Suba De Silva, Jean Delayen
- **SLAC** – Zenghai Li
- **CERN** – Nuria Valverde Alonso, Adria Gallifa Terricabras, Sara Domingo Gomez, Eric Montesinos, Simon Barre