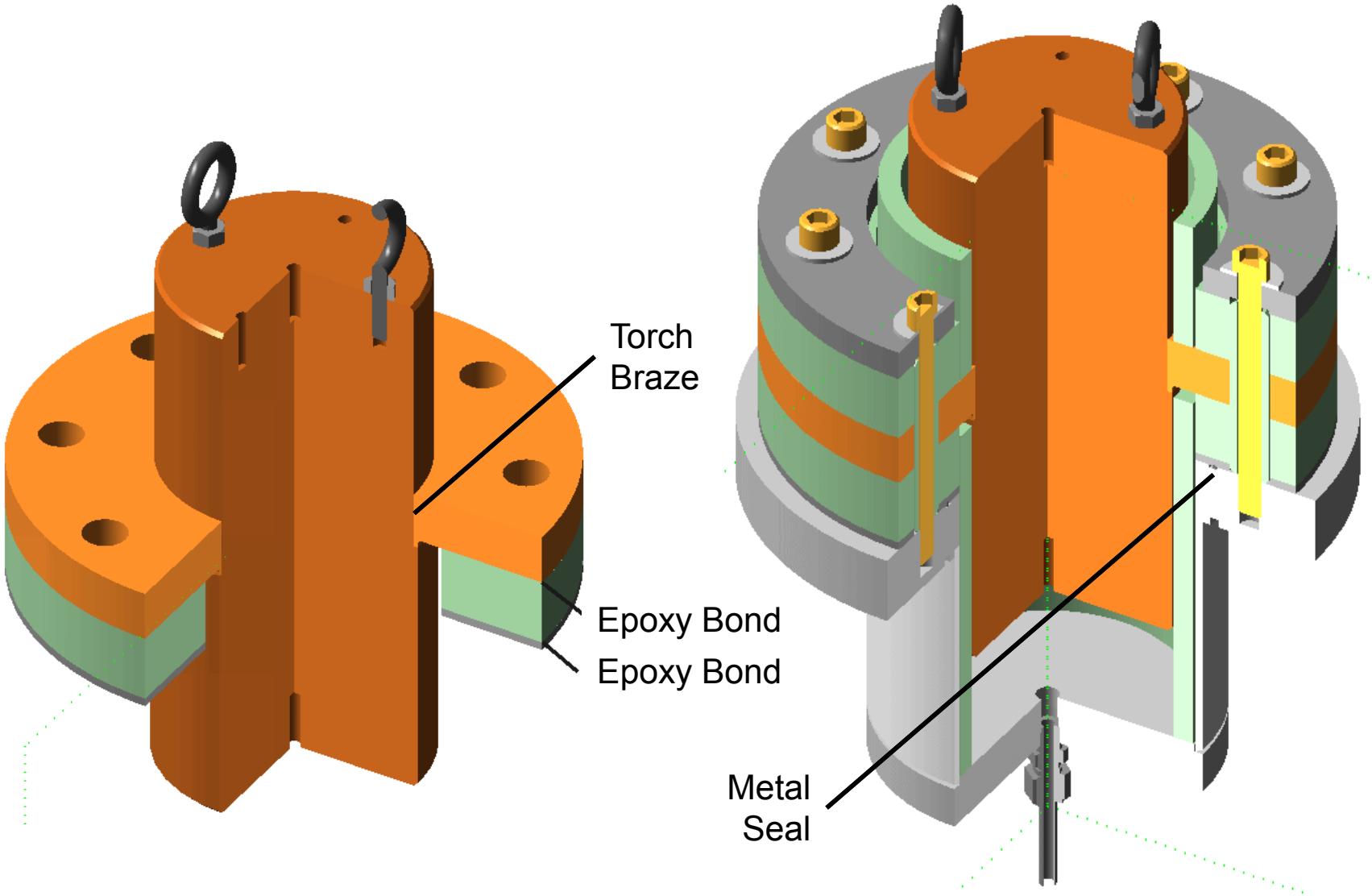
APUL – Current Lead Upper Section Test Report

Hi-Pot, Leak Check, and Pressure Tests

Test Plan

- A test fixture was designed to simulate the upper section of the APUL 13 kA Current Lead and the DFX Box mounting plate
- The fixture will test the ability of the design to withstand the system pressure, vacuum, and electrical standoff requirements
- The fixture will test the ability of the current lead to be reliably removed and resealed

Test Fixture 3-D Model



Torch Brazing – Braze Test

- Components
  - 4” Tellurium Copper Round, UNS C14500, Central Steel
  - Flange from copper plate, UNS C11000, McMaster 8995K17
- Oxygen content prevents welding or vacuum brazing

Torch Brazing

- Excel Silvaloy 15 brazing rod, .05” x .12”
- Harris Stay-Silv Black Hi-Temp paste flux
- Ram’s horn torch under flange in constant motion
- Wide flame torch on top of round to heat mass

Torch Brazing – Braze Test

Before

After

Torch Brazing – Real Components

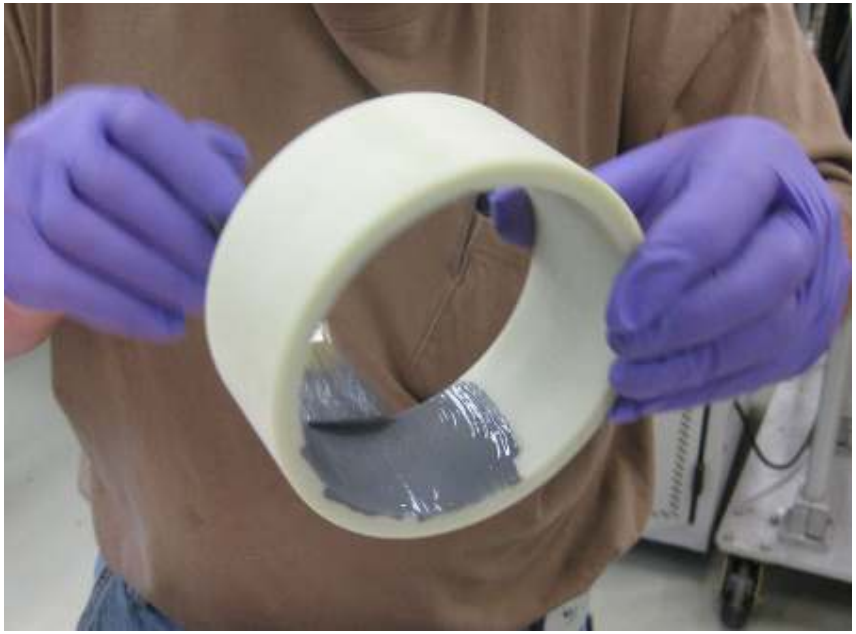
- Same materials and techniques
- Heated to dull red
- Used ~24” length of brazing rod, visible excess material flow
- Grit blasted, cleaned and degreased

Epoxy Bonding Current Lead Section

- G-10 insulator and 304 SS seal plate
- 3-M Scotch-Weld 2216, translucent
- Plastic rod alignment
- 8x C-clamp pressure
- Wipe off excess
- 66 °C cure overnight

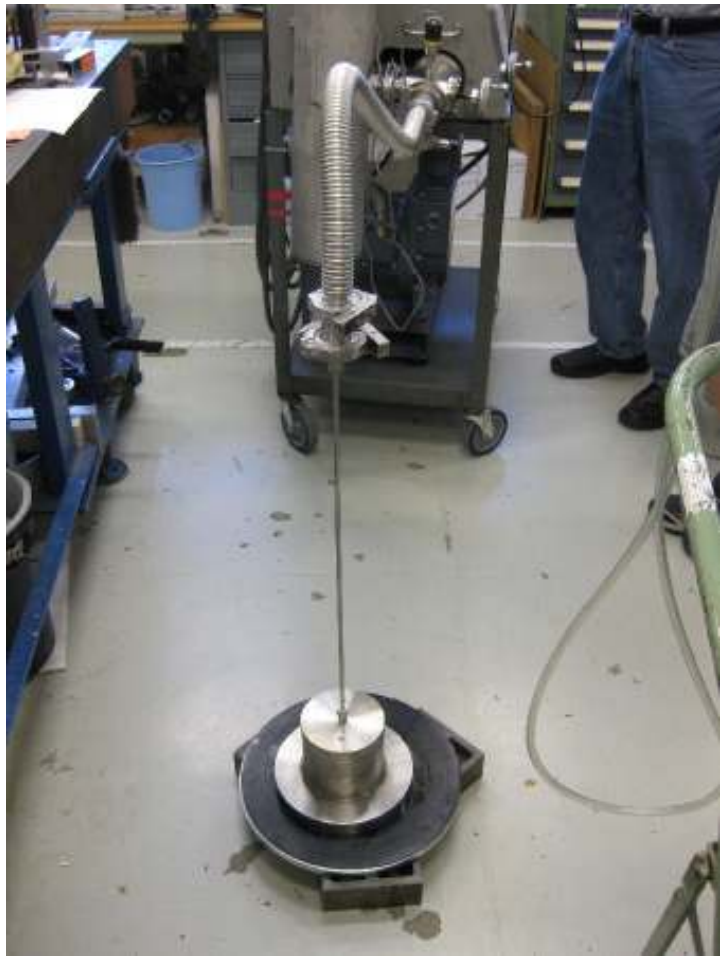
RTV Coating on Insulators

- All exposed G-10 insulator surfaces coated
- Si-Coat 570 RTV grey Silicone High Voltage Insulator Coating
- 7 day full cure cycle



Leak Check Pressure Can / Fittings

- 304 SS pressure can weldment
- Swagelok SS-400-1-2
- Anti-Seize Sealant AST-Seal-PH #22545
- 1/4” 304 SS tube
- No response above 3.0 e^{-9} atm·cc/sec



Fixture Assembly – Seal #1

- Bonded current lead section and pressure can weldment
- Garlock Helicoflex HNV200 Delta Seal
  - 5.509” seal OD
  - .130” Dia. CS
  - Alloy 600 Al jacket
  - 13,500 LB seat load

Fixture Assembly – Seal #1

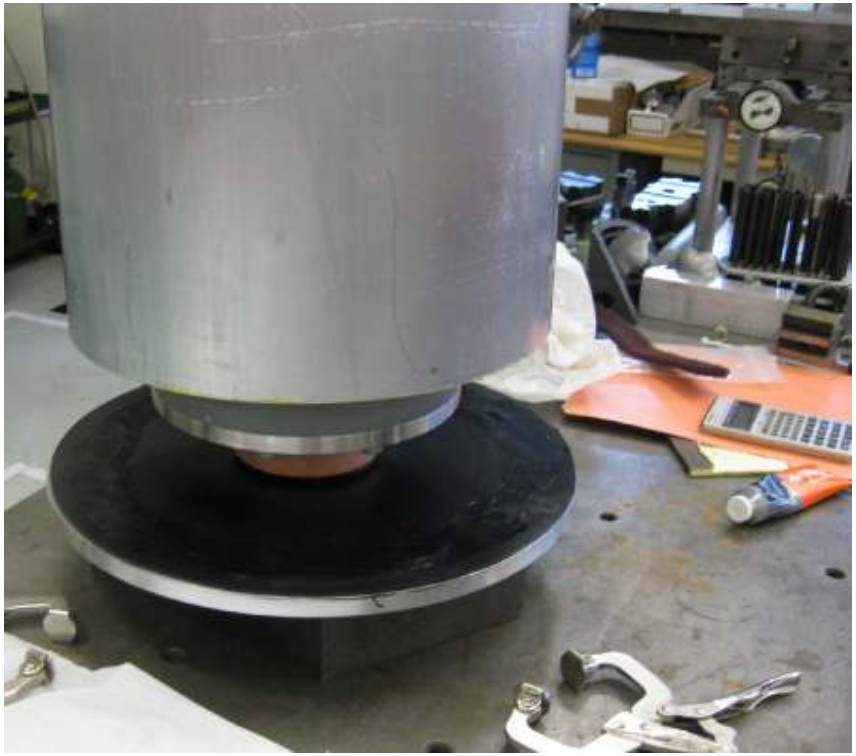
- 3/8-16 SHCS x 4” long McMaster 91274A352
- Belleville Washer McMaster 97125K41
- Torque to 168 Lb-in in alternating pattern for 1,939 Lb clamping force per bolt

Hi-Pot Test #1 – Seal #1

- 1 atm pure He internal pressure (29 psia)
- 2 kV potential
- 10 μA allowed
- .02 μA measured leakage

Assembly Into Vacuum Vessel

- Vacuum vessel acts as a containment chamber for safety during pressure test
- Sealed to perform subsequent leak check



Pressure Test #1 – Seal #1

- Hold-down tooling
- Nitrogen gas to 12 atm fixture internal pressure (190 psia)
- Gauge divisions to 0.5 psia
- No detectable pressure drop after 10 minutes

System Leak Check #1 – Seal #1

- Pump down vacuum vessel
- Pressurize fixture within with Helium gas at 3 atm internal pressure (59 psia)
- No detectable leak on most sensitive scale after 5 minutes

Cold-Shock Tests

- Install fixture into insulated liquid Nitrogen container with floating liquid level gauge
- Fixture positioned so that copper current lead section will be in liquid Nitrogen

Cold-Shock Tests

- Nitrogen gas purge into fixture internal volume through tube
- Liquid Nitrogen to fill vessel 1.25” deep
- Soak for 25 minutes after level stabilized

Cold-Shock Tests

- Fixture removed from liquid Nitrogen bath
- Fan warm-up for 25 minutes

Cold-Shock Tests

- Need to repeat cold-shock test this day
- Hot water warm-up for 15 minutes
- Repeat 25 minute Liquid Nitrogen soak
- Fan warm-up overnight

System Leak Check #2 – Seal #1

- Pump down vacuum vessel
- Pressurize fixture within with Helium gas at 3 atm internal pressure (59 psia)
- No detectable leak on most sensitive scale after 5 minutes

Hi-Pot Test #2

- 1 atm Pure He internal pressure (29 psia)
- 2 kV potential
- 10 μA allowed
- .01 μA measured leakage

Disassemble Fixture – Seal #1

Repeat Pressure Test and Leak Check

- Same procedures as with Seal #1, but with no Hi-Pot or Cold-Shock tests and only one leak check after pressure test
- Seal #2 Pressure Test – Passed
- Seal #2 Leak Check – Passed
- Seal #3 Pressure Test – Passed
- Seal #3 Leak Check – Passed

Testing Complete

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Conclusions

- Tests simulated actual operating conditions
- Design holds 12 atm pressure, 1.5 times the 8 atm maximum system pressure
- Design is vacuum leak tight
- Design survives severe cold-shock
- Design is extremely well electrically isolated
- Design is reliable and able to be sealed and resealed repeatedly