Cooling Connections Testing and Development: Progress Report

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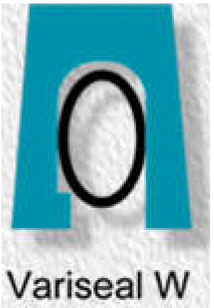
Current Cooling Connections - Permanent Options

- **Adhesive Bonding**
  - 6061 Aluminum fittings at demountable breaks and sector terminations
  - 3003 Aluminum sector tubing and exhaust tubing
  - Capillary material unknown
  - Hysol 9396 adhesive has been used - 9394 may also be desireable
  - Electrical breaks created by PEEK inserts
- **Brazing**
  - 6063 Aluminum fittings at demountable breaks and sector terminations
    - higher melting point than 6061
  - 3003 Aluminum sector tubing and exhaust tubing
  - Capillary material unknown
  - Two braze techniques have been tried
    - vacuum furnace brazing
    - hand torch brazing
  - Metallized alumina pieces used to create electrical breaks

Current Cooling Connections - Demountable Options

- **Custom Aluminum Fittings**
  - 6061 or 6063 machined fittings
    - low mass
    - shaped for either braze or adhesive joint geometry (see subsequent slide)
  - Standard O-ring type groove
  - Custom split clamp
    - low profile and low mass
    - prevents unwanted torque
- **Standard Seals**
  - UHMWPE face seal with SS internal spring - Variseal Brand (www.variseal.com)
  - O-ring compatible groove
  - Also consistent with all-metal Wills C-ring type gasket

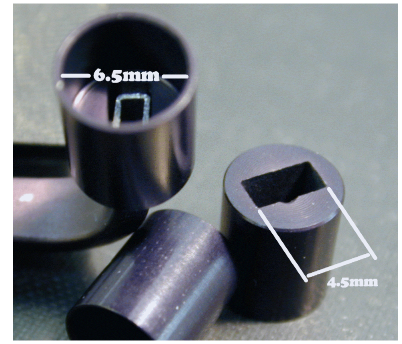


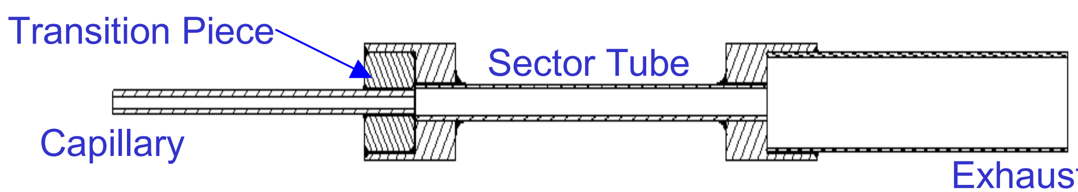
Permanent Connections - Adhesive Bonding

- **Types of Joints**
  - Rectangular (sector) to round (fitting) tube terminations
    - sector tubing is 4.67 x 2.30 mm outer dimension (hydraulic diameter is 2.39 mm)
    - fitting is 4.43 mm ID x 5.50 mm OD (round)
    - requires an intermediate rectangular to round transition piece
  - Capillary to fitting junctions
    - small capillary bonded into larger round fitting
    - exhaust tubing is 5.50 mm OD (hydraulic diameter is 4.43 mm)
    - requires an intermediate adaptor piece (in order to use the same fittings)
  - Exhaust tube to fitting junctions
    - exhaust tube is 5.50 mm OD (hydraulic diameter is 4.43 mm)
    - requires no adaptor - bonds directly into fitting
- **Adhesives**
  - Hysol 9396 (baseline used for all tests so far)
  - Hysol 9394 (aluminum filled version of 9396 - may be more rad hard)

Adhesive Bond Samples

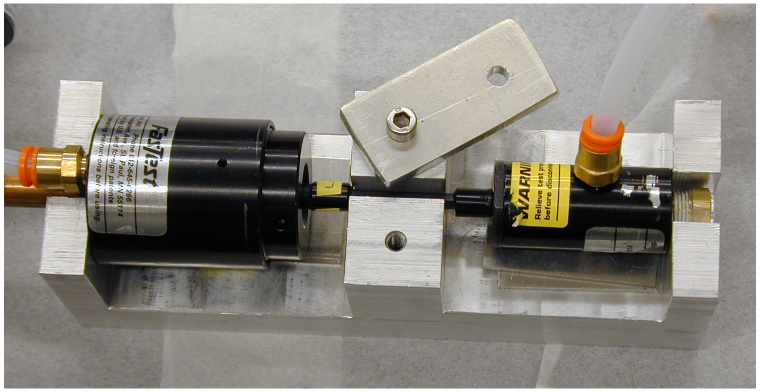
- **Test piece models all three connections (but no electrical breaks)**
  - Sector termination
    - rectangular to round transition
  - Capillary Termination
    - small to large diameter transition
  - Exhaust Termination





- **Samples prepared for several tests**
  - Pressure testing
  - Irradiation
  - Thermal cycling
  - Black anodized to simulate worst possible bond

Adhesive Bond Test Setups



Fas-Test Fitting Setup

- **Pressure Testing**
  - Tested at 100 psi (6.5 bar) using Fas-Test fittings
  - Pressurized with N2 gas - pressure decay measured
  - Tested before and after irradiation

- **Irradiation**
  - Samples exposed to 3 Mrad in liquid C3F8
  - Leak rates measured before and after irradiation
  - Thermal cycling will also be tested

C3F8 Pressure Vessel

Acceptable Leak Rates

- **Meaningful leak rate specification must be defined in order to conduct any sort of testing**
- **Decision must be made as to how much C3F8 contamination is acceptable in detector volume**
- **Rough estimate of leak rate spec was made for comparison purposes only:**
  - Assume allowable mass leak is 1 kg per 100 days = 125 L @ STP, and that system pressure is 1 bar gauge = 760 Torr
  - Estimate 100 sectors and 100 staves (each circuit is equivalent to 1 test piece) = 200 circuits total; assume that there are 2x200 circuits in pixel thermal volume (including demountable fittings) + 100 fittings = 500 total
  - These assumptions arrive at an approximate leak rate of 2×10^{-5} Torr-Liters/sec for each circuit (test piece)

Adhesive Bond Pressure Test Results

- **10 Samples made for irradiation - 10 samples made for thermal cycling**
  - Irradiation samples tested before and after
  - Thermal cycling samples tested before (cycling is not yet complete)

Test Condition	Avg. Leak Rate Before Torr-L/sec	Avg. Leak Rate After Torr-L/sec	Passing Samples (Before) (Out of 10)	Passing Samples (After)
Irradiation	8.51E-06	2.79E-06	10	2
Thermal Cycling	1.22E-04	NA	4	NA

- **Test Implications**
  - Only positive leak rates were averaged into above table
  - Many test pieces showed pressure *gain* with time - this means that either the test equipment is too susceptible to noise, or that the test fixture was leaking high pressure gas into the fittings
  - Of the 14 tests that “failed” only 3 actually registered leak rates above the nominal leak rate spec (the remaining samples showed pressure “gain”)
  - Samples that passed (16 of 30 tests) showed high factors of safety (above 10 on average)

Permanent Connections - Brazing

- **Types of Joints**
  - Joint geometries are identical to those examined for adhesive bonding, except that clearances must be changed for brazing
- **Braze types**
  - Furnace Braze
    - Foil situated in the joint, between concentric tubes
      - foil made in house at LBNL, rolled to 25-100 microns thick
      - Al-Si eutectic created, with 1% Mg added to aid wetting
    - Braze paste placed in and around joint area
      - Commercially available paste with no Mg
      - Mg must be supplied through atmosphere to aid wetting
      - Furnace cycle run in dry N2 or Argon
  - Hand Torch Braze
    - Paste in and around joint (pre-mixed with flux)
    - Wire around edge of joint (with flux) - contains Mg for wetting
    - Use oxy-acetylene or propane torch

Permanent Connections - Brazing cont.

- **Braze fittings**
  - Since braze success was uncertain, simple mock fittings were made for testing
  - Two types of fitting were made, each with two different clearances
    - close fit - 50 micron radial gap - for wire and paste brazing
    - loose fit - 100 micron radial gap - for paste, wire, and foil brazing
- **Tests**
  - Samples were cleaned with NaOH prior to brazing
  - All brazes were Helium leak checked after brazing and cleaning
  - The following braze test combinations were attempted (# brazes)

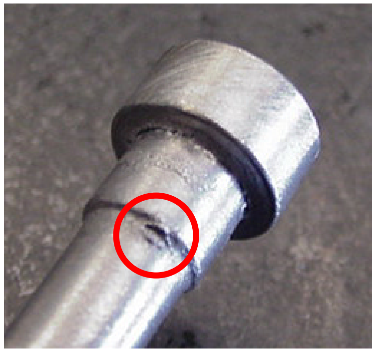
TORCH	Foil	Wire	Paste
Close Fit	0	4	2
Loose Fit	0	0	2
FURNACE	Foil	Wire	Paste
Close Fit	0	0	0
Loose Fit	2	0	2

Brazing Results - Furnace

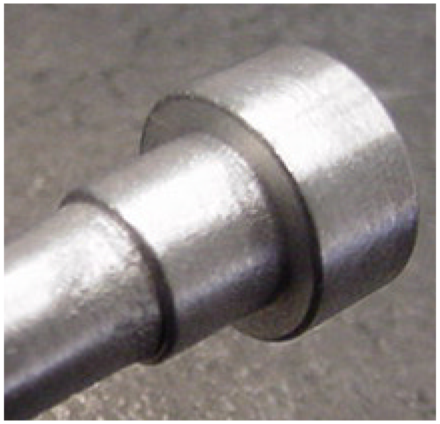
- **Furnace brazing turned out difficult to control**
  - Temperatures could not be kept even along the part as well as desired (about 10 degrees variation)
  - Wetting was not very substantial
  - Surface quality on components cycled in furnace were variable (perhaps due to overheating)

He Leak Tight Brazes

	Foil	Wire	Paste
Close Fit	0	0	0
Loose Fit	0/2	0	1/2



Failed Paste Braze



Successful Paste Braze

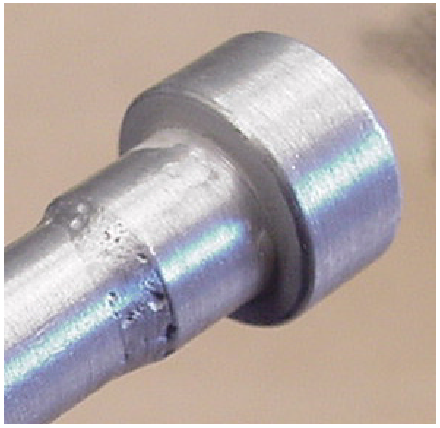
Brazing Results - Torch

- **Torch results are good for certain geometries**
  - Melting of the parts was not a problem
  - Wetting was not very substantial - but filleting could be easily achieved
  - Surface quality at overheated areas was poor - need to simply use care in application of torch

Successful wire fillet braze

He Leak Tight Brazes

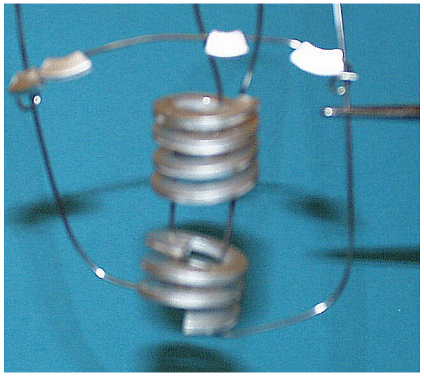
	Foil	Wire	Paste
Close Fit	0	4/4	0/2
Loose Fit	0	0	1/2



Porous but leak tight paste braze

Corrosion Tests on Al in C3F8

- **Sector Tubing (3003) was placed in liquid C3F8 and irradiated to 3 Mrad**
  - Two sample sizes
    - Large coil - approximately 1.5 grams
    - Small section - approximately 0.05 grams
  - Samples were held off of the bottom of containment vessel with SS wire, in order to insure complete contact with C3F8
  - Masses were measured with high precision balance numerous times on different days and averaged



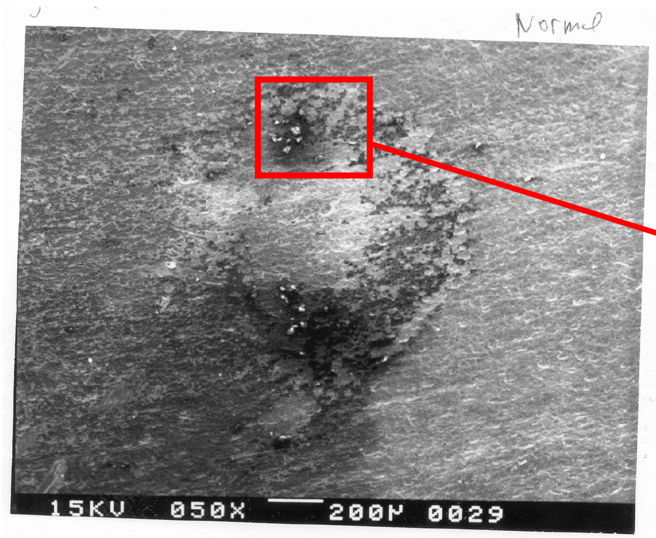
Large coil suspended by SS wire

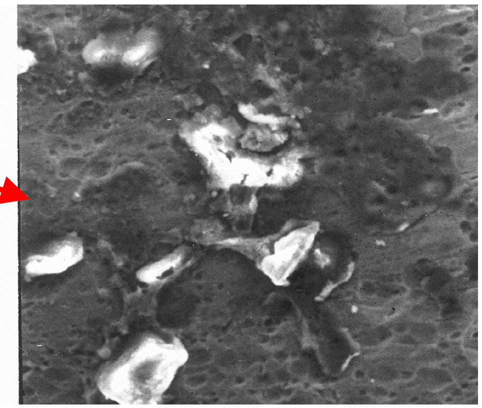
Corrosion Tests Results

- **After 3 Mrad exposure some small changes were observed**
  - Most samples appeared to *gain* mass
    - small samples - about 1 part in 100,000 - on par with the standard deviation of our measurements
    - large samples - about 1 part in 10,000 - approximately 10 times our resolution
  - Samples were examined with SEM in order to check this mass increase, and to look for corrosion
    - evidence of F and C was found by mass spectrometer - indicates some sort of polymerization
    - no sign of corrosion or attack on the aluminum was observed
- **Since results are sensitive but significant, more testing will be conducted**
  - Continue to irradiate current aluminum samples to 6 Mrad total
  - Use same C3F8 as before, which was captured after first irradiation cycle

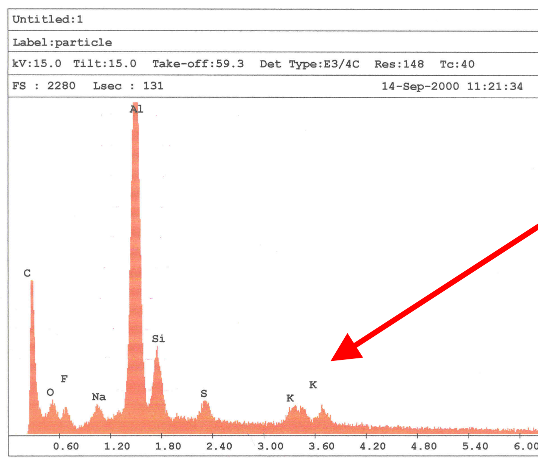
Pixel Detector

Corrosion Tests Results - SEM





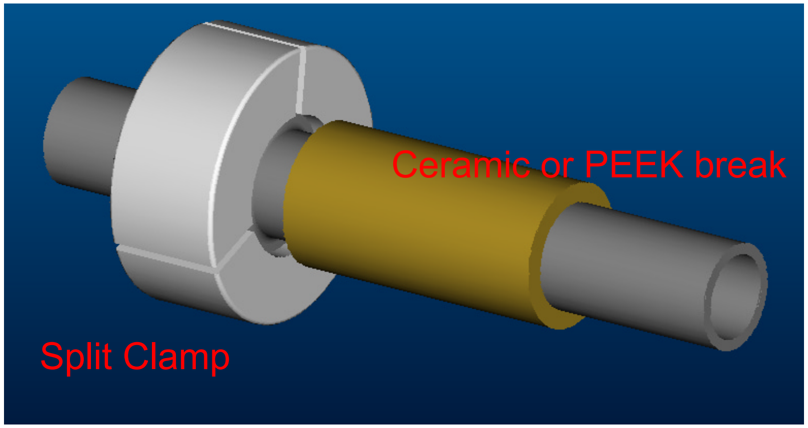
Closeup of deposition area

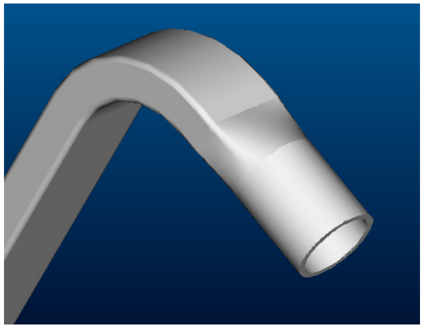


Mass Spec results show evidence of polymerization and cleaning agents

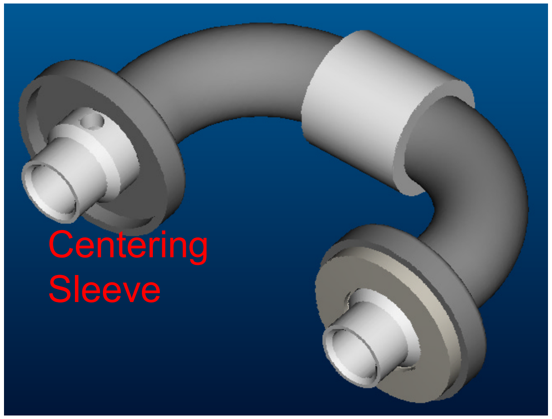
Pixel Detector

Proposed Real Sector Fittings

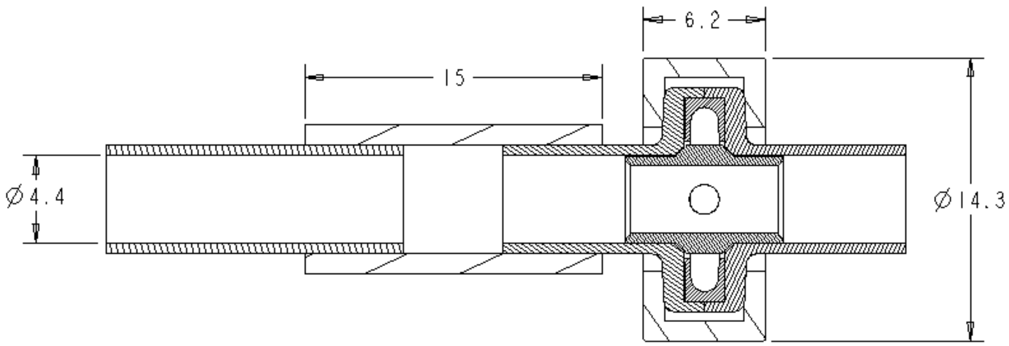




Proposed swage on end of sector tubing



Proposed U-tube design with electrical break



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Summary

- **Adhesive bonded sector terminations work well and pass our initial leak rate spec estimation**
  - Need to fix problems with leak check tests - pressure gain should not be seen, so we may need different appartus (perhaps with more sensitivity)
  - Need to test the split clamp demountable fittings (may eat up leak budget)
  - Need to recheck irradiated samples (many more will most likely pass our spec once we iron out test technique)
  - Helium leak check all terminations for comparison
  - Must complete thermal cycling tests
- **Brazed sector terminations have shown mixed results**
  - Furnace brazing is time consuming and hard to control, and results have not been good
  - Torch brazing is fast and inexpensive, but results with paste and foil are not good
  - Torch brazing with wire (fillet style) is effective - need to make new termination geometries that are conducive to fillet brazing and test

Pixel Detector

Summary Cont.

- **Corrosion of Al in C3F8 was not observed**
  - Mass gain was measured with larger samples
  - SEM shows carbon and fluorine in deposition areas
  - Need to irradiate further to demonstrate clear trend
  - Should test carbon panels in same manner (may see more polymerization)
- **Demountable fittings must still be tested**
  - Leak checking has begun, but few samples have been made
  - Need to prototype all joints in their proposed forms
  - Ceramic or PEEK electrical break must be fabricated and tested
- **General Work Needed**
  - Demountable Fittings
  - Meaningful Leak Spec
  - Capillary terminations in actual material
  - Corrosion/polymerization potential for carbon/plastics