Cooling Services Joining Techniques: Progress Report

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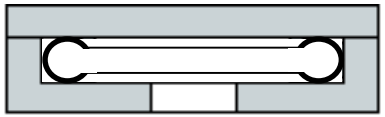
Current Cooling Connections - Permanent Options

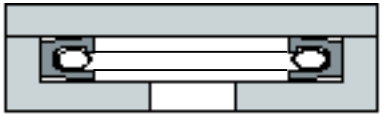
- **Adhesive Bonding**
  - 6063 Aluminum fittings at demountable breaks and sector terminations
  - 3003 Aluminum sector tubing and exhaust tubing
  - Capillary material unknown
  - Hysol 9396 adhesive
  - Electrical breaks created by PEEK or alumina inserts
- **Brazing**
  - 6063 Aluminum fittings at demountable breaks and sector terminations
  - 3003 Aluminum sector tubing and exhaust tubing
  - Capillary material unknown
  - Torch brazed (by hand)
  - Metallized alumina pieces used to create electrical breaks

Current Cooling Connections - Demountable Options

- **Custom Aluminum Fittings**
  - 6063 machined fittings
    - low mass
    - Same fitting used for both brazing and gluing
  - Standard O-ring type groove
  - Custom split clamp
    - low profile and low mass
    - prevents torque in joint
- **Standard Seals**
  - O-ring compatible groove
  - Sized for use with standard wills c-ring
    - Busak & Shamban brand (The TI Group)
    - Hastelloy C-276, coated with Au/Ag
  - Also fits polymer face seal ("variseal")
    - Also Busak & Shamban brand (The TI Group)
    - UHMWPE seal with internal 302 ss coil spring



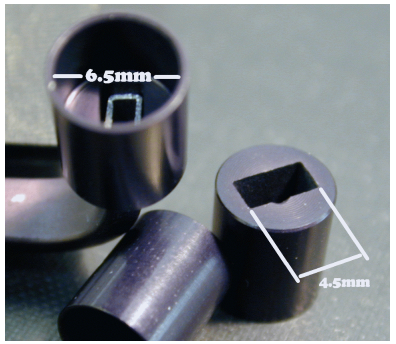
Wills C-Ring schematic
(in gland)

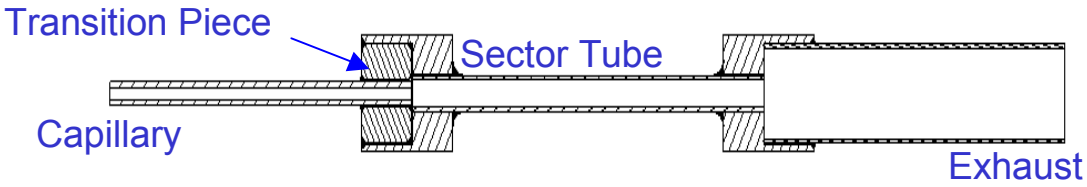


"Variseal" Face Seal Schematic
(in gland)

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



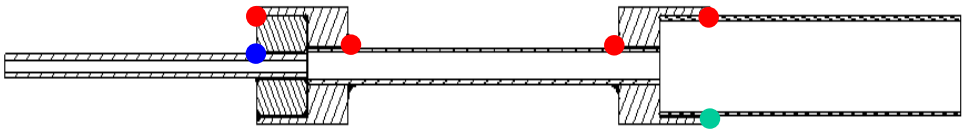


Samples black anodized to simulate worst possible bond

- **Samples prepared for Thermal Cycling tests**
  - Un-irradiated samples only
  - Immersed in –40 C fluid to cause thermal “shock”
  - Leak rate checked before and after cycling, at internal pressure of >6 bar
  - Thermal cycles repeated to failure, with measurements after each cycle

Bonded Joints – Thermal Cycling Results

- **Tests showed large leaks after small number of thermal cycles**
  - Leaks occurred different places in different samples (there was no one culprit)
  - De-lamination was visible between epoxy and aluminum– indicating bad adhesion
  - Of 8 samples, 6 developed large leaks, and only 1 survived 10 cycles
  - 4 samples that had previously checked OK did not pass the initial pressure test – implying that some damage was done during previous pressure cycles or during handling



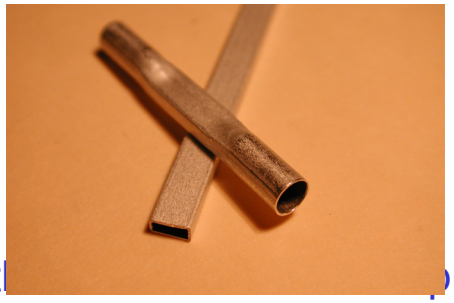
Leak Locations =

Test Results Summary

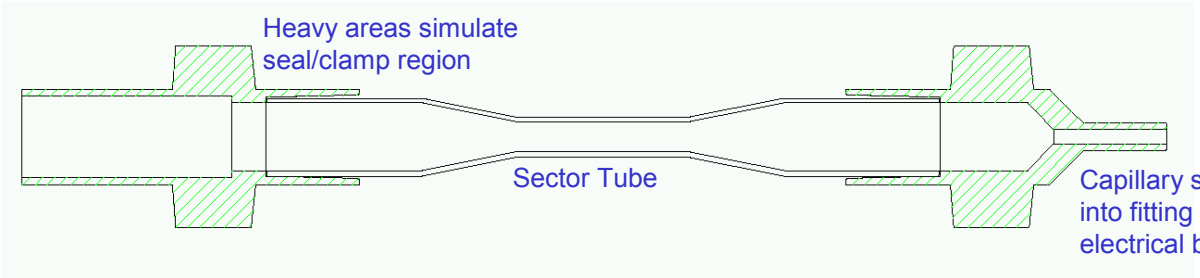
# SAMPLES	# COLD CYCLES	PASSED?
4	0	N
1	1	N
1	10	N
1	1	Y
1	10	Y

Changes Being Made to Joint Design

- **simple changes could eliminate many problems**
  - Use chromic acid etch for surface prep – eliminate black anodization
  - Eliminate rectangular to round junction at sector (possible stress riser) – using swage



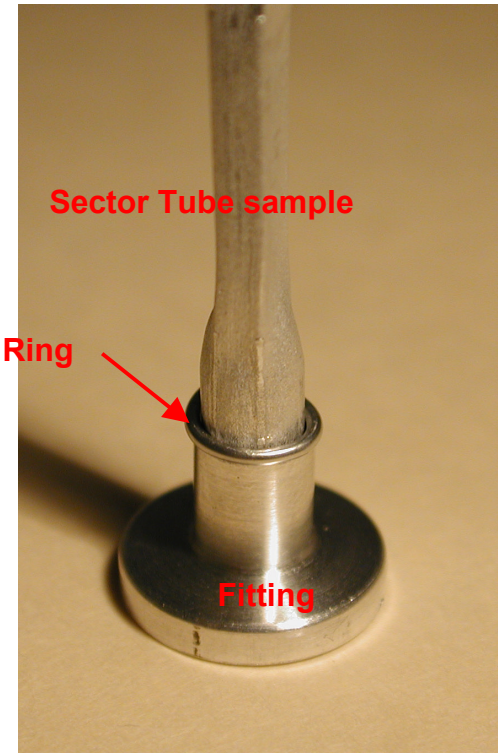
  - Remove heavy sectional changes t[illegible]roblems during thermal shocking



Pixel Detector

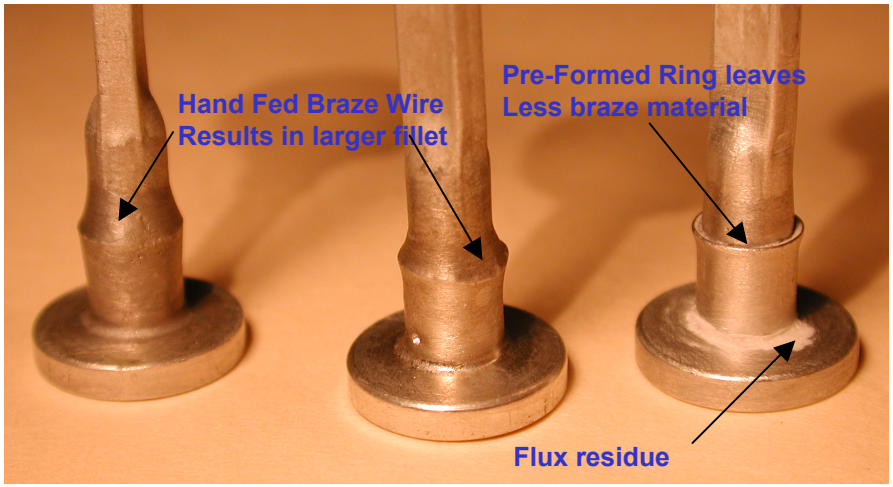
Brazing Samples

- **In Response to previous successes, torch brazing was pursued instead of furnace brazing**
  - Approach is to fillet joint, rather than relying on capillary
  - Same pieces used for bonding and brazing
  - Al-Si filler rod used under propane torch
  - In some cases ring was applied before heating, in others rod was hand-fed, as in traditional fillet technique
  - Standard and non-corrosive fluxes tried
  - First samples consisted of sector termination junctions only
  - Future samples will mirror bond testing type



Brazing Results –wire braze

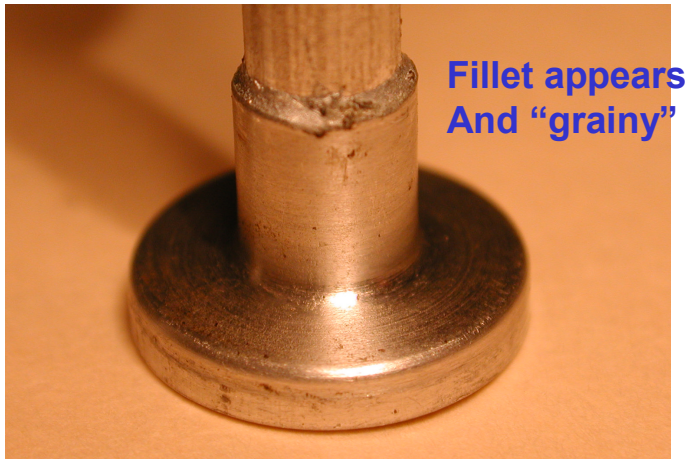
- **Torch brazing turned out to be generally successful**
  - 12 samples were constructed and **all** of them passed He leak testing
  - Non-corrosive flux was difficult to remove, and thus abandoned for more conventional fluxes
  - No samples were melted, however, some tube deformation was seen at temperature (no provisions were made to support the tubes during brazing)
  - Pre-formed braze rings were given up for manually feeding (technicians felt manual feeding was easier to work with)
  - Sealing surfaces have not been tested after brazing



Though no special care was given, excellent braze penetration was seen up to 6 mm away from fillet

Soldering Trials – "Techno-Weld"

- **Commerically available low-temperature joining techniques were attempted in conjunction with sct research**
  - Products from "Techno-weld" and "Castolin-Eutectic" are available which join aluminum at temperatures below 380 C
  - Products contain mostly zinc, with some other elements (Al, Cu, Mg, Mn, Cd….) and need no flux
  - Technicians attempted "soldering" fittings together using same geometry as for brazing and bonding (also attempted SCT fittings)
- **So far, all attempts with low-temperature materials have failed**
  - Joints look clean, but do not pass He leak check
  - Qualitatively, filler material looks porous
  - No special cleaning techniques were used – may be a problem



Fillet appears porous And "grainy"

Summary and Future Plans

- **Bonded Joints**
  - Have not proved to be robust so far, but have known problems
    - Surface prep has been very poor (black anodization)
    - Heavy sectional transitions and stress risers (corners) have been present
  - Plans and solutions
    - Use adhesive manufacturer's recommended surface prep (chromic acid etch)
    - Reduce heavy sectional transitions (already incorporated in design)
    - Remove stress risers at rectangular transitions (already accomplished with tubing swage)
  - Yet to be addressed
    - Electrical breaks (peek or alumina) need to be incorporated in bond samples
    - Irradiated samples need to be thermally cycled and pressure tested
      - Previous radiation testing has shown no reason to believe that there will be problems

Summary and Future Plans, cont.

- **Brazed Joints**
  - So far, torch brazing has been very successful
    - All samples pass leak checking
    - No samples have been lost during the braze process (operators find it very controllable)
  - However, issues need to be addressed
    - Tubes need to be supported so that they don't deform at temperature (this should pose no problems)
    - Sealing surfaces need to be tested after being heated to close to melting point
    - Flux removal needs to be checked (to make sure that there are no lingering corrosion problems, and that seal surfaces are not degraded)
    - Low temperature solders address many of these problems, but have categorically failed (we do not plan on further investigation)
  - In the Future
    - Alumina breaks need to be incorporated in braze samples (torch or furnace?)
    - Braze samples need to be irradiated in C_3F_8 and tested in all manners

Conclusions

- **Neither brazing nor bonding have yet been fully proven – work still needs to be done on both**
- **Final solution may incorporate a combination of techniques**
- **Pixel Disks and Barrel should work towards common solutions (even if not using identical materials and techniques)**