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Aluminum Reservoir Experiments

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Drivers for aluminum GTS

- **Primary driver:**
  - Improved manufacturability by eliminating stainless steel forgings
    - Long lead-time item, difficult to manufacture, sunset technology
- **Secondary drivers:**
  - Improved confidence in long-term structural integrity
    - Decreased uncertainty in material properties at EOL, BOL
    - Absence of long-term tritium / helium embrittlement
  - Decreased weight
    - Modest reductions are obtainable
    - Benefit for RB/RV applications

GAS TRANSFER SYSTEMS

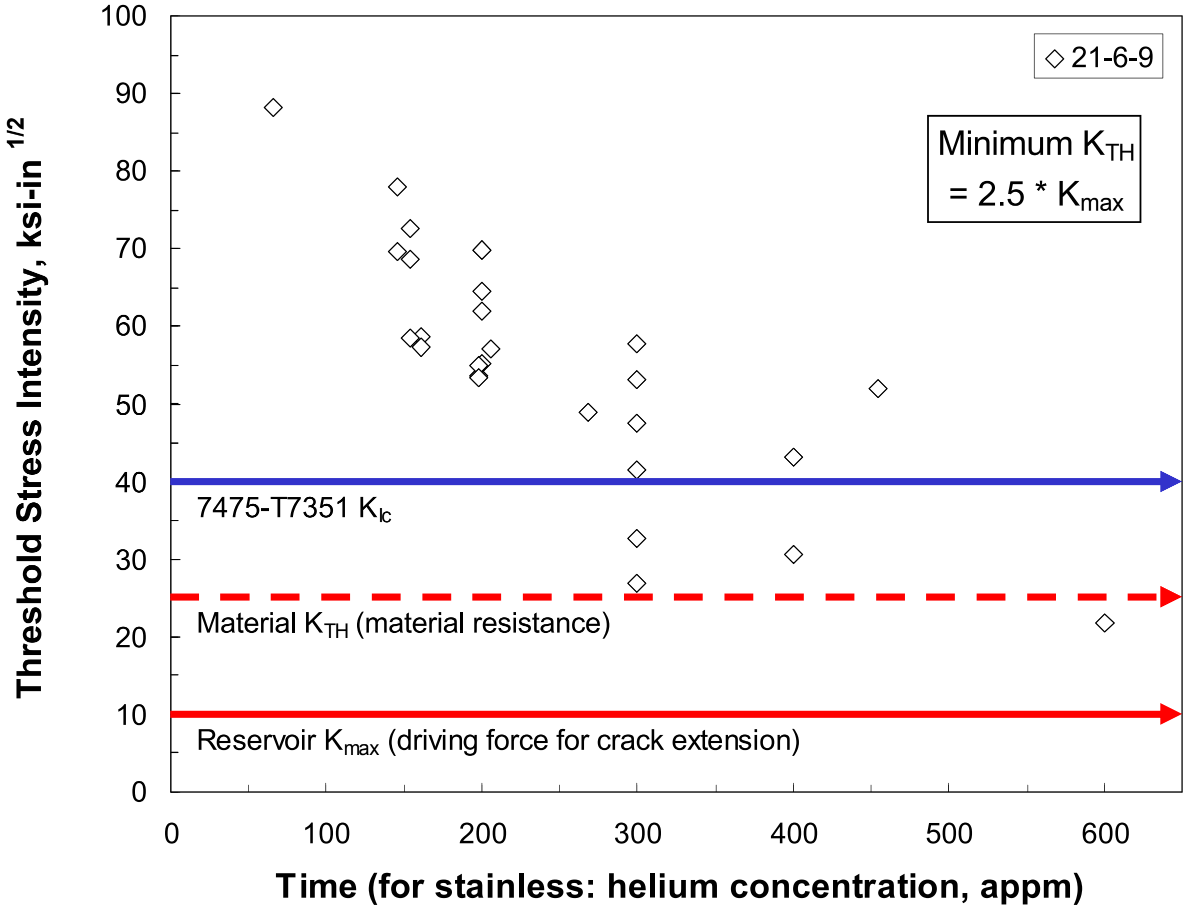
Why forging steels is required

- **Forging of stainless steels accomplishes 3 things:**
  - Increasing strength from annealed properties
    - 304L example: annealed at 30-35 ksi σ_y, forged at 55-75 ksi σ_y
  - Aligns grain flow around circumference of reservoir
    - Minimizes possibility of inclusions or ferrite stringers providing a short-circuit path for tritium permeation
  - Increases dislocation (defects in crystal lattice) density
    - Dislocations trap tritium that diffuses into reservoir walls, as well as the resulting decay helium
    - ***Dislocation density and morphology have a strong effect on fracture toughness after exposure to H_2 isotopes***

- **Meeting all these objectives can be very difficult**

Driver: Improved confidence

- Strength obtained through heat treatment, rather than forging
- Uniform properties with position, unlike stainless steel forgings
- T_2 compatibility even after long-term exposure



Driver: decreased weight

- **Example of weight savings for a generic bottle**
  - Geometry: spherical
  - 304L stainless: 60 ksi (414 MPa) yield strength, 95 ksi (655 MPa) UTS
  - 2219 – T62 Al: 35 ksi (241 MPa) yield strength, 52 ksi (359 MPa) UTS
  - MAWP: 3000 psig
  - Inside diameter: 101.6 mm (4 inches)

- **For yielding during proof testing (4500 psig) through no more than 20% of wall thickness:**
  - Stainless steel reservoir: wall thickness of 2.1 mm, mass of 561 grams
  - Aluminum reservoir: wall thickness of 3.7 mm, mass of 338 grams

  - ***Weight savings: ~ 40% (for this set of geometries and pressures!)***

Qualifying a new material

- **How do we qualify aluminum for long-term service, without long-term storage?**
  - Understanding of baseline (year 0) properties
    - Heat treatment optimization, fracture mechanics & tensile testing
  - Understanding of properties changes: $(\delta K / \delta t)_{P,T,YS}$ and $(\delta YS / \delta t)_{P,T}$
    - Oxide and microstructural stability as affected by gas, temp, and time, hydrogen isotope uptake kinetics, surface interactions
  - Development of manufacturing processes
    - Material specifications, machining and cleaning processes, structural welds (GTA, e-beam), closure welds (pinch, other?), material heat treatment schedules, NDE technique development
  - Long term shelf storage
    - Because we're not as smart as we think we are

Accomplishments

- **Completed upgrades to GTA welder**
  - Improved power supply, automated voltage controller
  - Plasma Arc Welding capability
- **Established baseline weld geometries, schedules, and procedures for 6061 plate and girth GTA welds**
  - Investigated effects of filler metal choice, heat chemistry effects
- **Established baseline E-beam welds for non-GTS applications, supports future GTS e-beam welding**
- **Funded outside resources (WeldComputer) to pursue resistance welding**

Accomplishments (2)

- **Mechanical testing of aluminum alloys**
  - Fracture toughness measurements
  - Tensile testing at room and elevated temperature
  - Tensile testing after long-term elevated temperature exposure
  - Long-term slow crack growth tests in high pressure hydrogen gas

- **Baseline reservoir design**
  - Began evaluation of reservoir geometries, weld joint designs
  - Began draft of revision to DG10215 (WR Reservoir Design Standard) to include aluminum alloys

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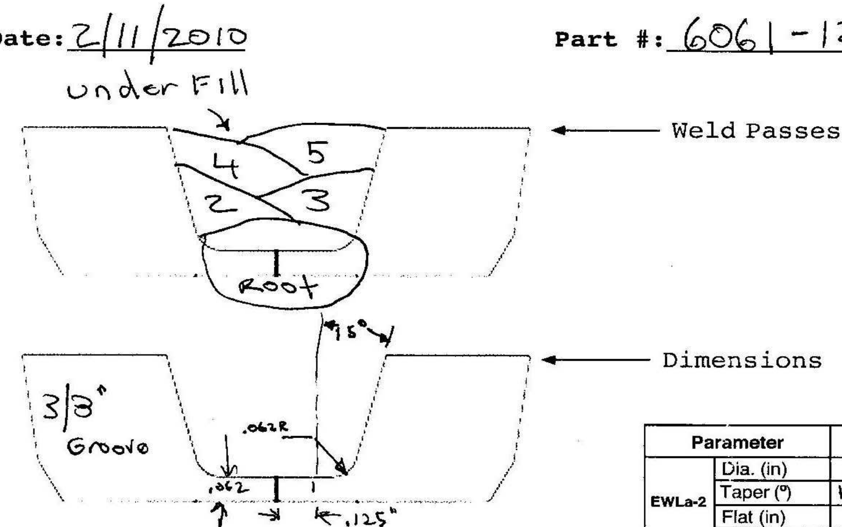
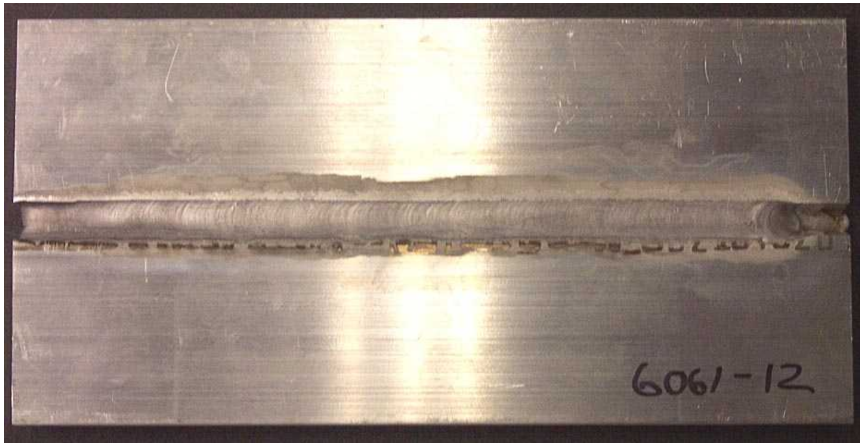
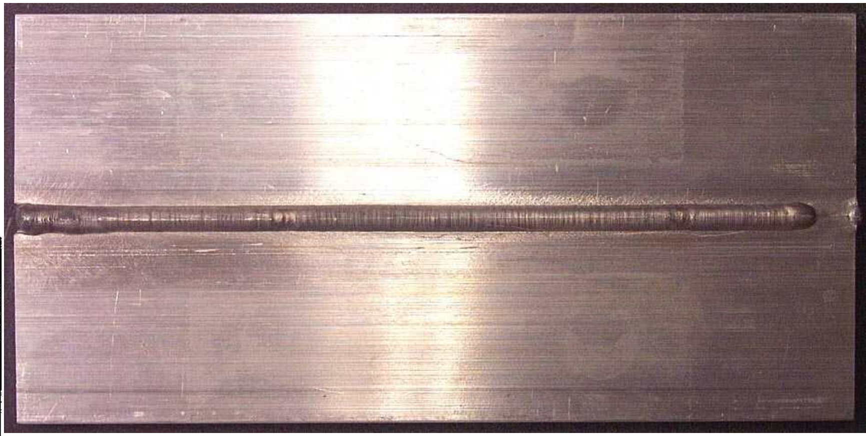
6061 GTA plate welds

Date: 2/11/2010

Part #: 6061-12





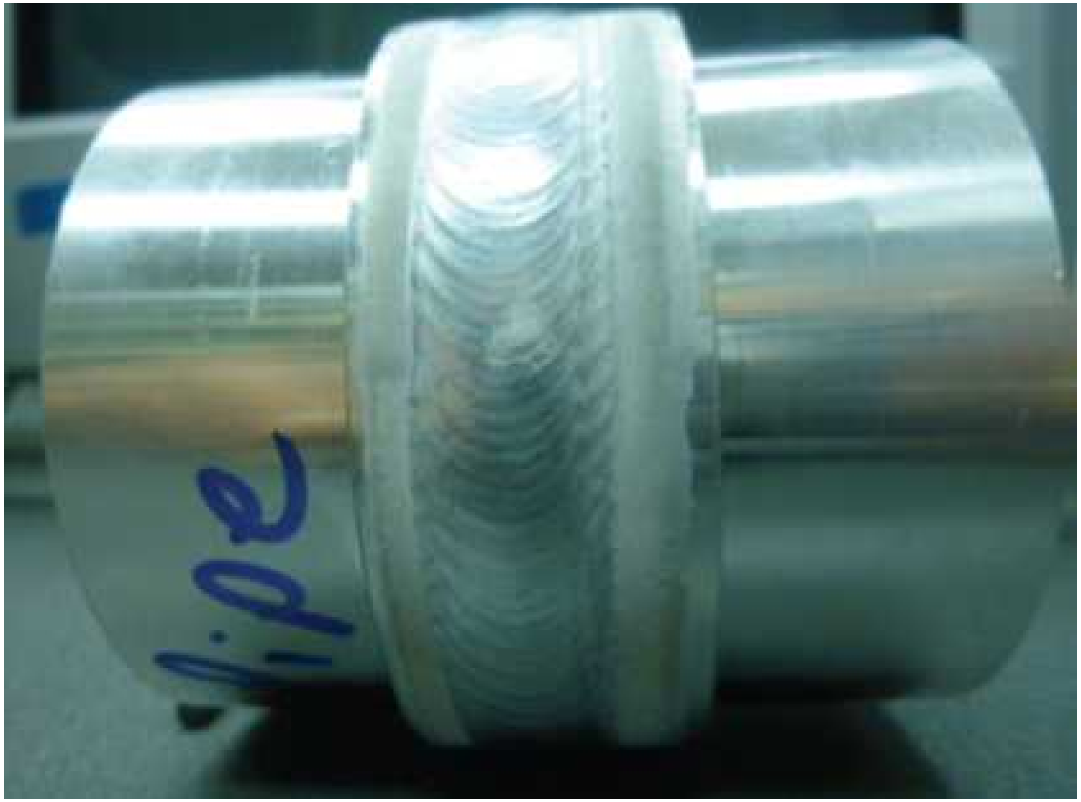


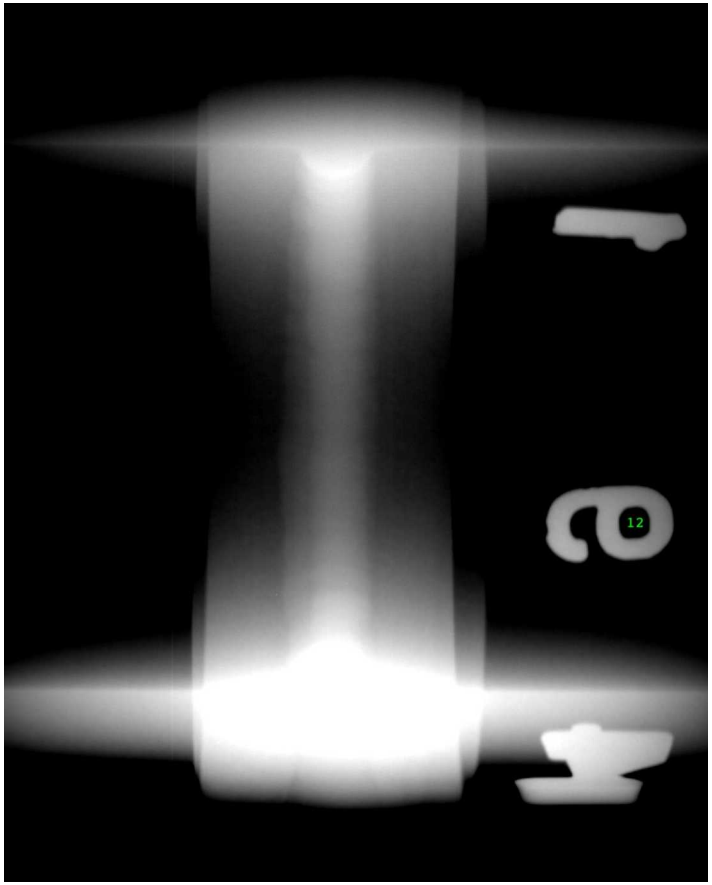
Parameter		Setting
EWLa-2	Dia. (in)	5/32
	Taper (°)	Hand Ground
	Flat (in)	.060
	Stickout (in)	3/4"
Amperage (%)	EN	100%
	EP	100%
Balance (%)	EN	75%
	EP	25%
Oxygen (ppm)		Air

Plate	Filler Wire
Alloy: 6061	Alloy: 4043
Heat #:	Heat #:
Thk: 3/8"	Dia: .045

Weld Passes	Travel (ipm)	Wire Feed (ipm)	Amps (A)	Notes
1st	5	70	220	
2nd	5	70	220	
3rd	5	70	290	
4th	5	70	290	
5th	5	70	290	
6th				
7th				
8th				

6061 GTA girth welds





6061 GTA girth welds

Aluminum primary goals

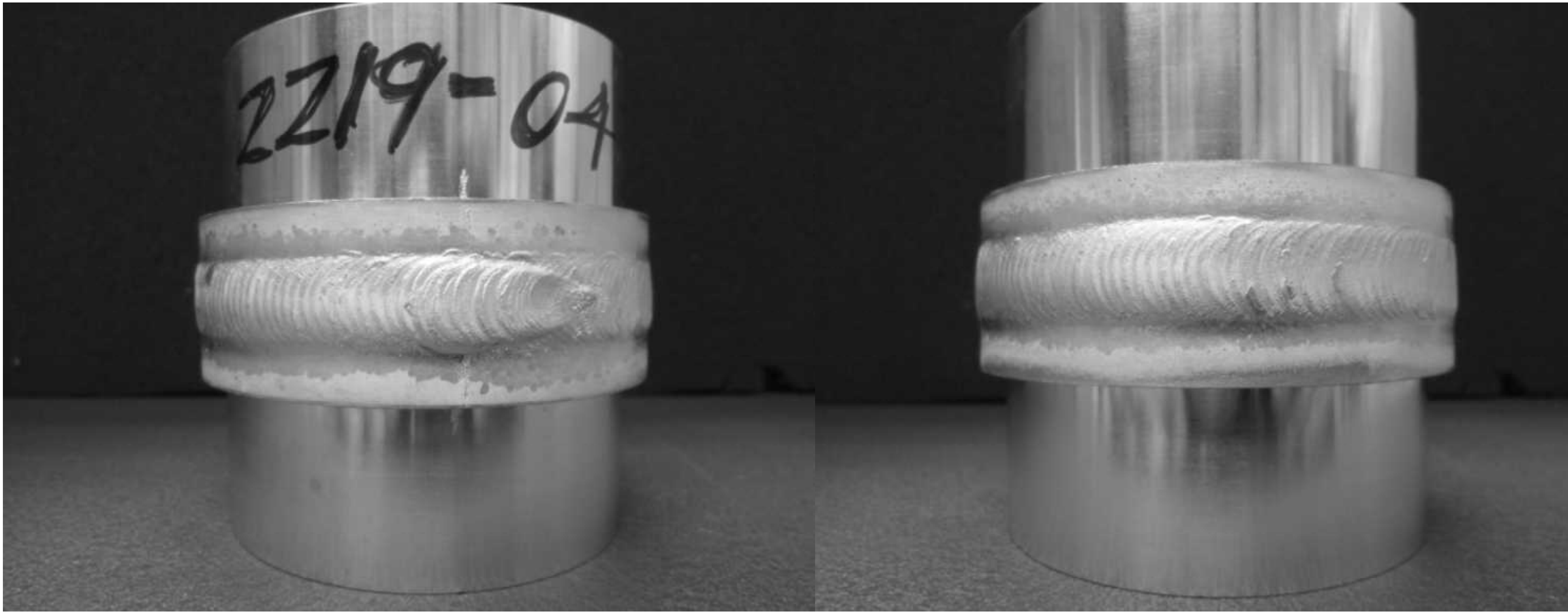
- **Evaluation (at SNL/CA) of prototype vessels**
  - Proof testing, hydrogen charging, burst testing, metallography
- **Develop pinch welding capability in SNL/CA**
  - Leverage resistance welding program with commercial vendor
    - Continued funding in FY12 for forge weld development
  - Probably multi-year task
  - Capital equipment request in place, and highly-ranked

Plans

- **Continued work on:**
  - Aluminum tensile testing, fracture testing, long-term stability
  - Post-weld heat treatment
  - Weld porosity characterization (Jon Madison LDRD, 1814)
  - Aluminum surface physics characterization (San Marchi LDRD, 8222)
  - Plasma arc welding

Gas Transfer Systems

2219 / 2319 GTA girth weld



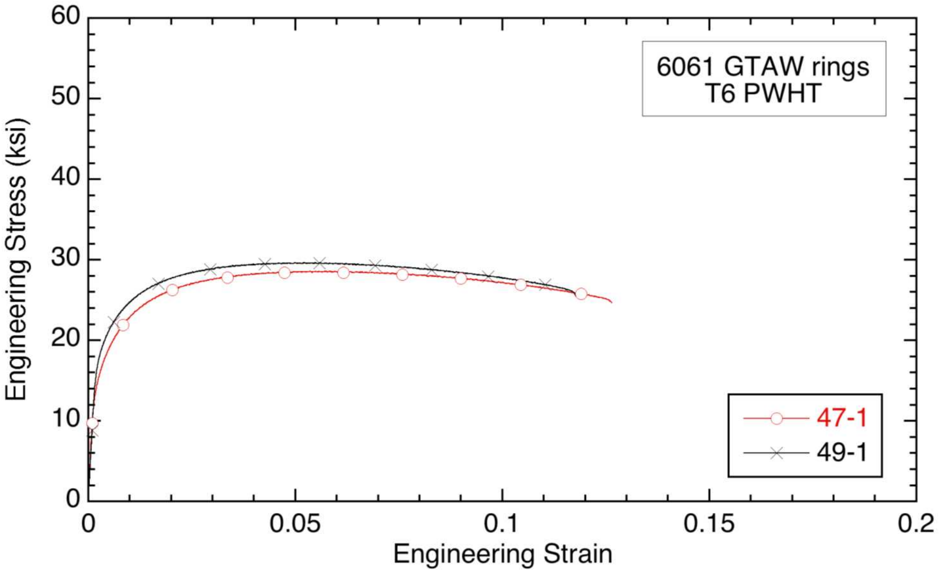
- **Initial attempts at 2219 welds look excellent**
  - Development work on 6061 supported quicker progress on 2219
  - Welds are currently being examined by radiography

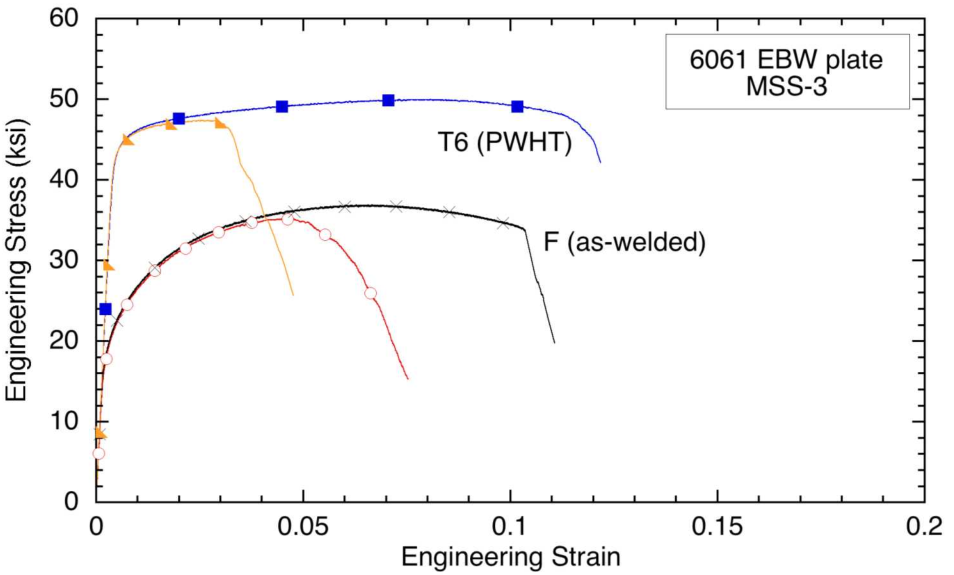
2219 / 2319 GTA girth weld

- **Weld underbead also looks excellent**
  - Uniform shape, good tie-in, easily inspectable by boroscope

Mechanical testing

- **Post-weld heat treatment (PWHT) does not appear to be effective in 6061 GTA welds with 4000-series filler.**
  - PWHT may be effective in EB welds because there is significant dilution, allowing the fusion zone to be a mixture of 6061 and filler.
  - In GTA welds, the amount of filler is much larger than the volume of 6061 material that is melted, thus PWHT response is diminished
  - PWHT should be more successful in 2219 / 2319 welds





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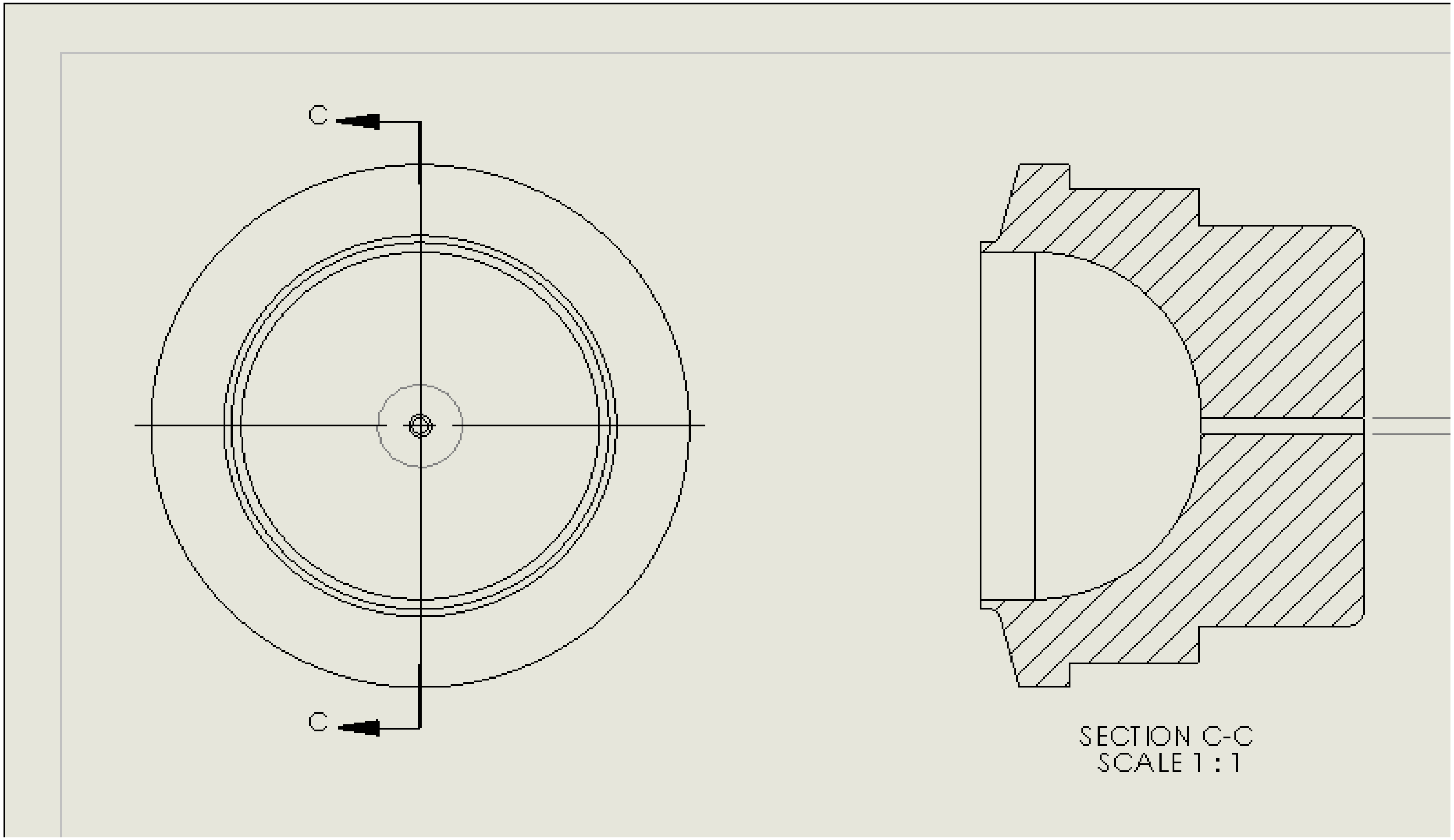
Sample Vessel Half



Comparison of Weld Samples

Discussion

- Heat transfer Differences
- Material Heats
- Wire Burn back
- Wire Hardness