4th Conference on Aerospace Materials, Processes, and Environmental Technology

Manufacturing Challenges Implementing Material Changes for the Super Light Weight External Tank

A Welding Process Perspective

Kirby Lawless and Chip Jones

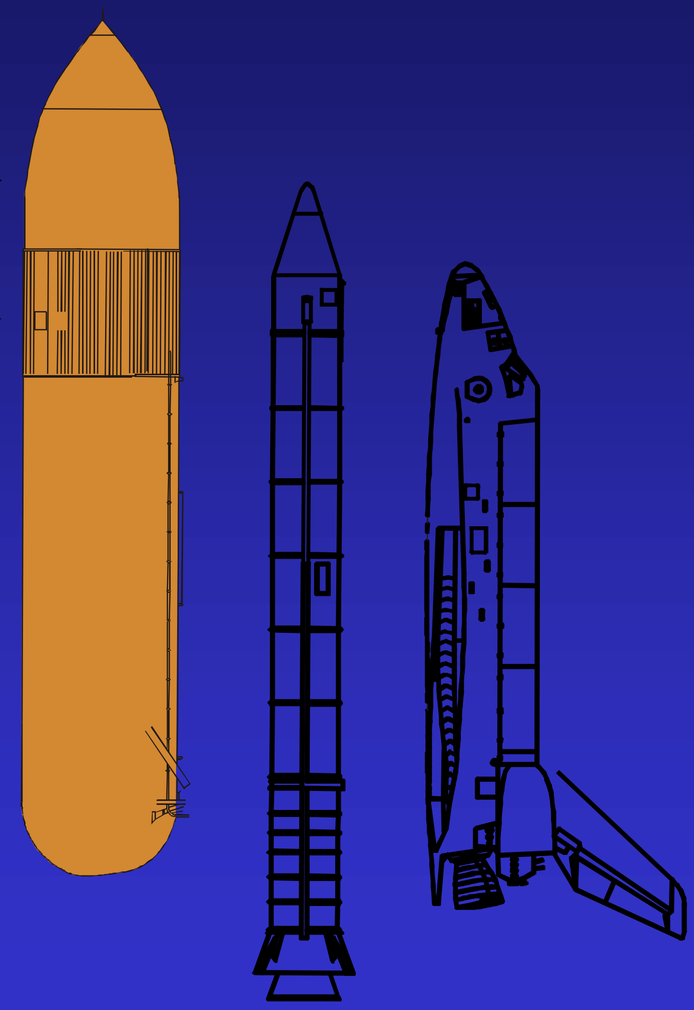
Super Lightweight External Tank

Al-Li Weight Savings

1791 Oxygen Tank

929 Intertank

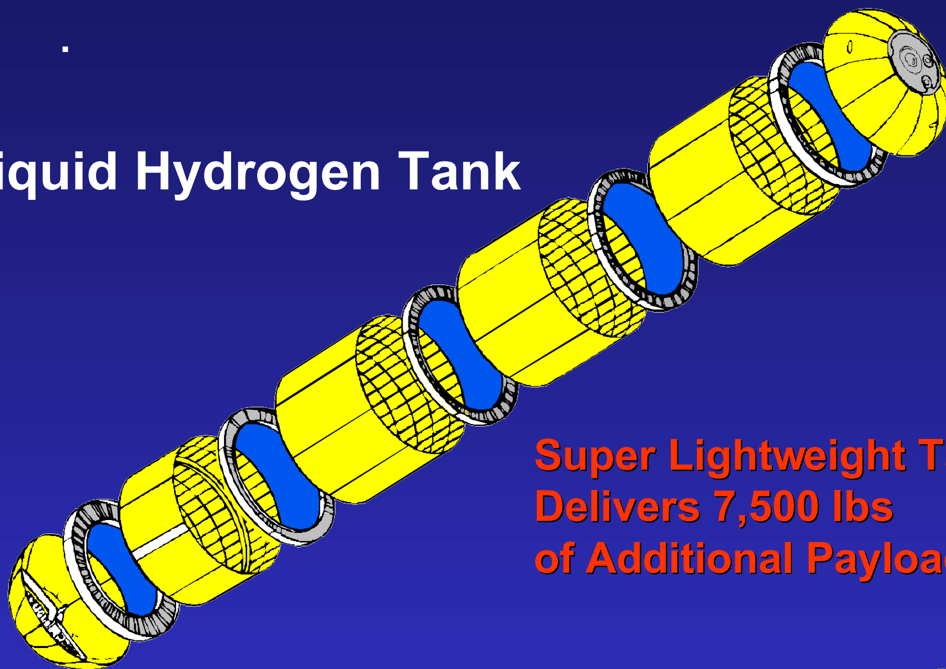
5283 Hydrogen Tank



8003 Pounds Total

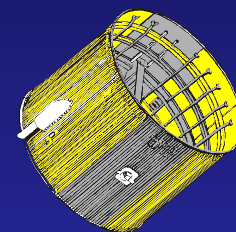
External Tank Configuration

Liquid Hydrogen Tank



- Substitute Al 2195 for Al 2219
- Redesign to Orthogrid Waffle
- Optimize TPS Application
- Weight Savings - 4,200 lbs

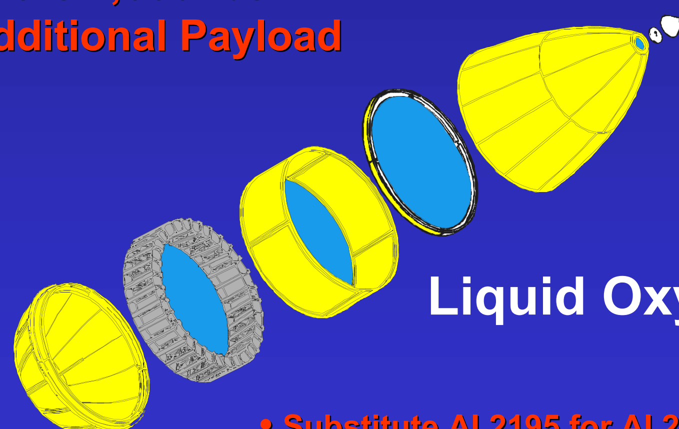
Intertank



- Substitute Al 2090 for Al 2024 and Al 7075
- Machine TPS After Application
- Weight Savings - 750 lbs

Super Lightweight Tank Delivers 7,500 lbs of Additional Payload

Liquid Oxygen Tank



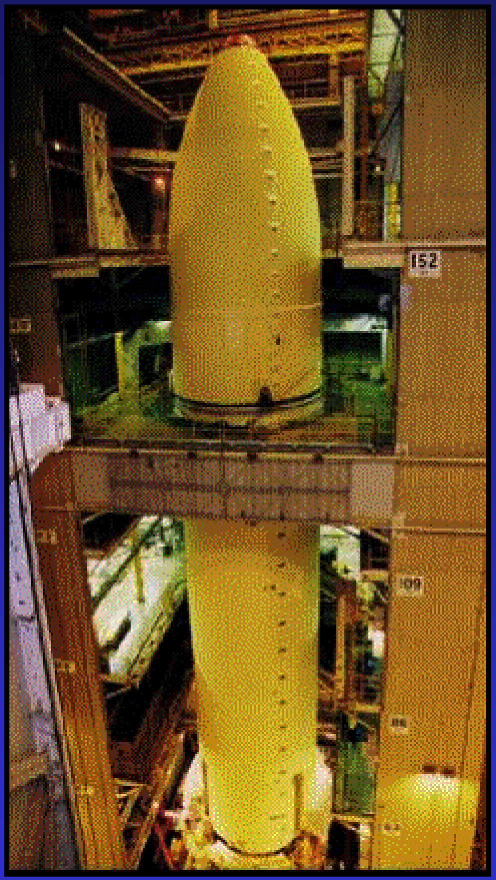
- Substitute Al 2195 for Al 2219
- Resize Panel Thickness
- Optimize TPS Application
- Weight Savings - 1,620 lbs

= Al Li 2090, 2195

= Other Redesigned Parts

= No Change

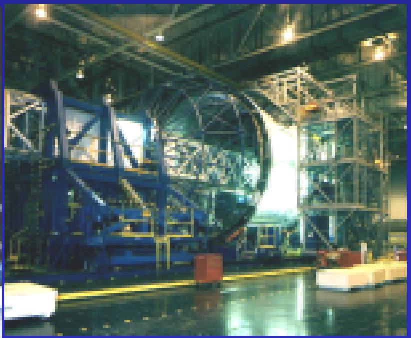
Super Lightweight Tank

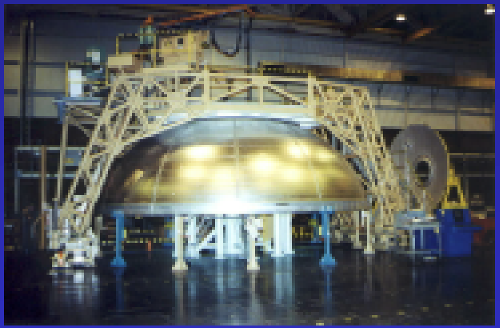


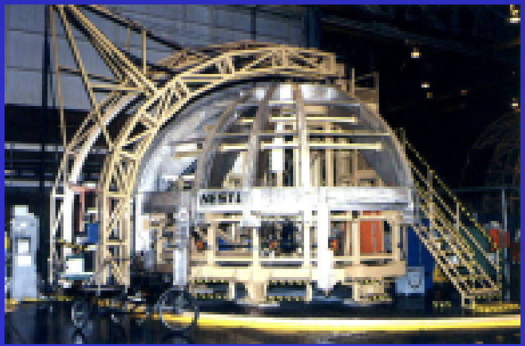
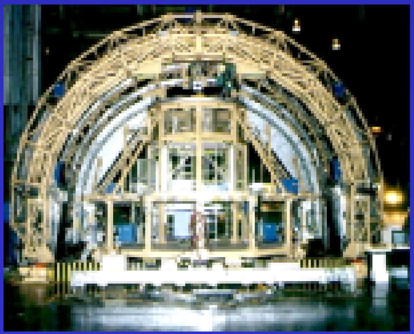
- One-Half Mile of Weld Joints per Tank
  - Thickness ranges from 0.140” to 0.991”
  - Plate,Extrusion, Forging Product Forms
- Initial Automated 3-Pass Weld Process
  - Four basic geometries:
    - Dome Gores, Ojives
    - Longitudinal
    - Circumferential
    - Circular Caps and Fittings
  - Repair Welds Manual GTA Process
  - Inspected with Visual, Radiography, Penetrant

Weld Purging Equipment

- Inert gas purge required on both sides of weld joint for 2195 alloy
    - Existing tooling retrofitted
    - Narrow tooling gaps provided major challenges
    - Circumferential weld tools required very complex devices
- Mixture of Helium and Argon purge gas required on root side shield
- Pre-weld test developed for gas coverage adequacy

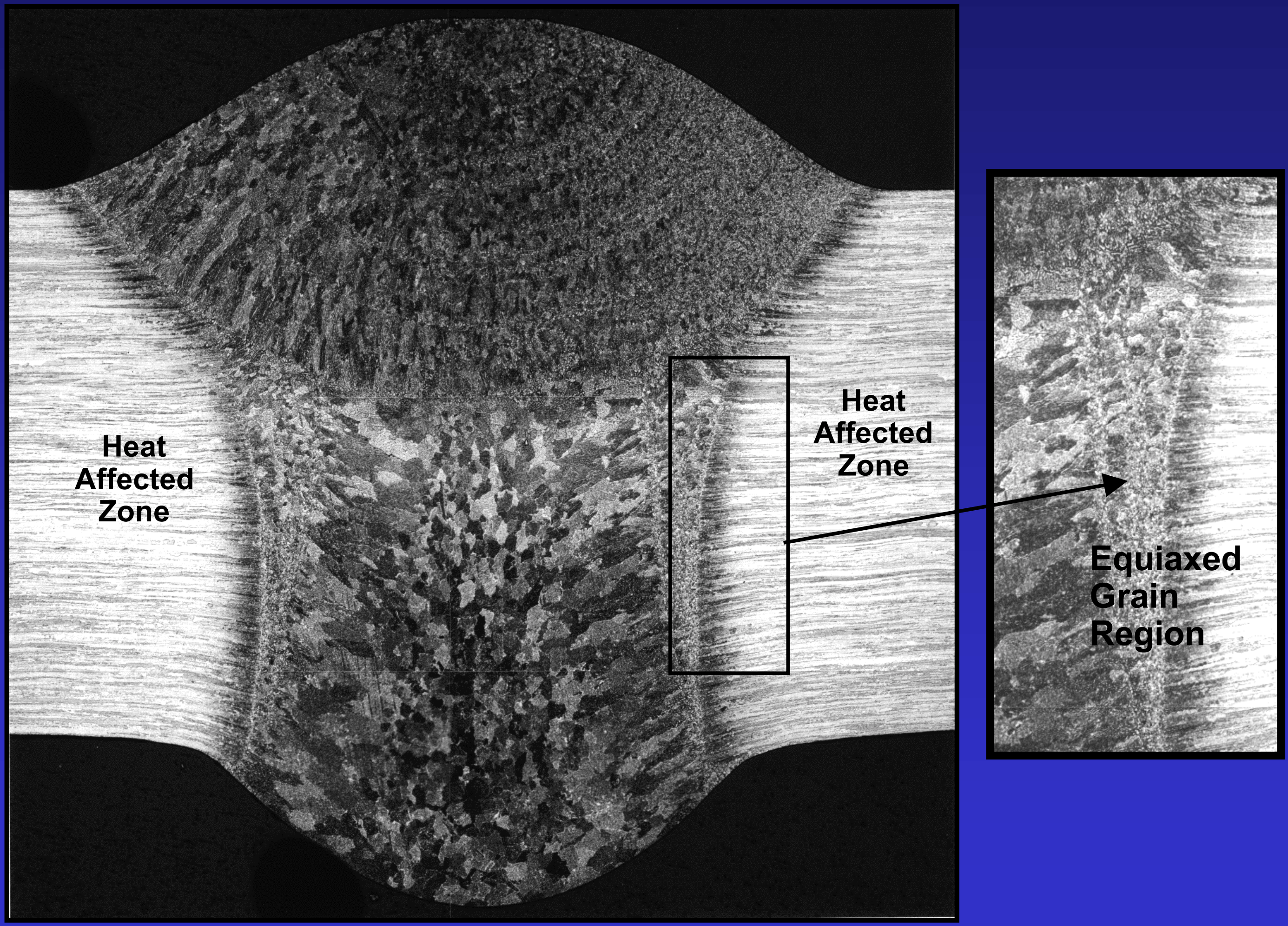


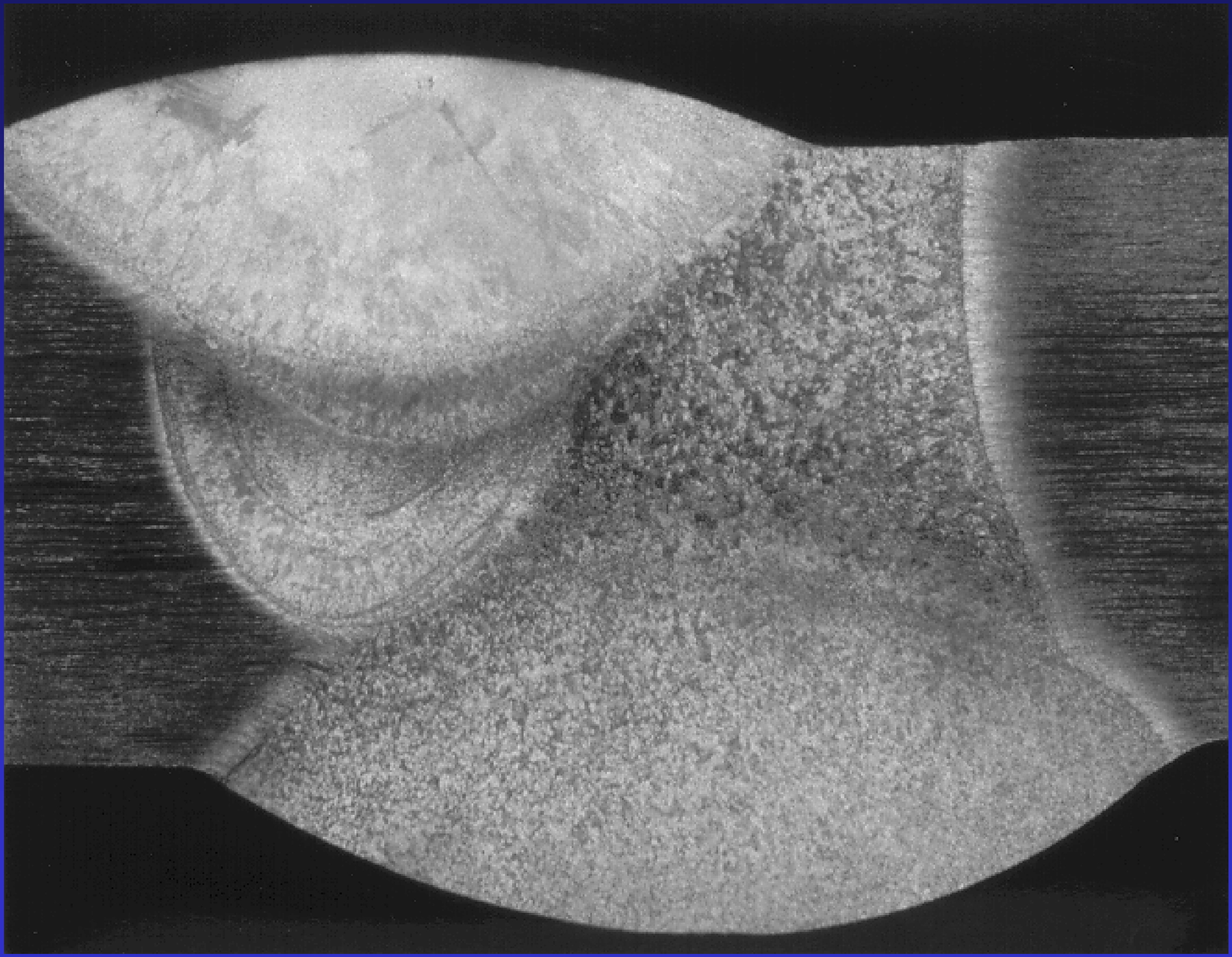
Selection of Weld Filler Wire Alloy

- Baseline 2319 Aluminum Filler until repair cracking discovered
- Survey/Testing conducted of Commercial Alloys
- 4043 Selected
  - Adequate Weld Strengths
  - Liquation Cracking Backfill/Healing Properties
  - Consistent Properties at Cryo Temperatures after significant cold work
- New NASA/LMC/McCook alloy B218 with higher ductility nearing maturity for implementation

Initial Weld Microstructure

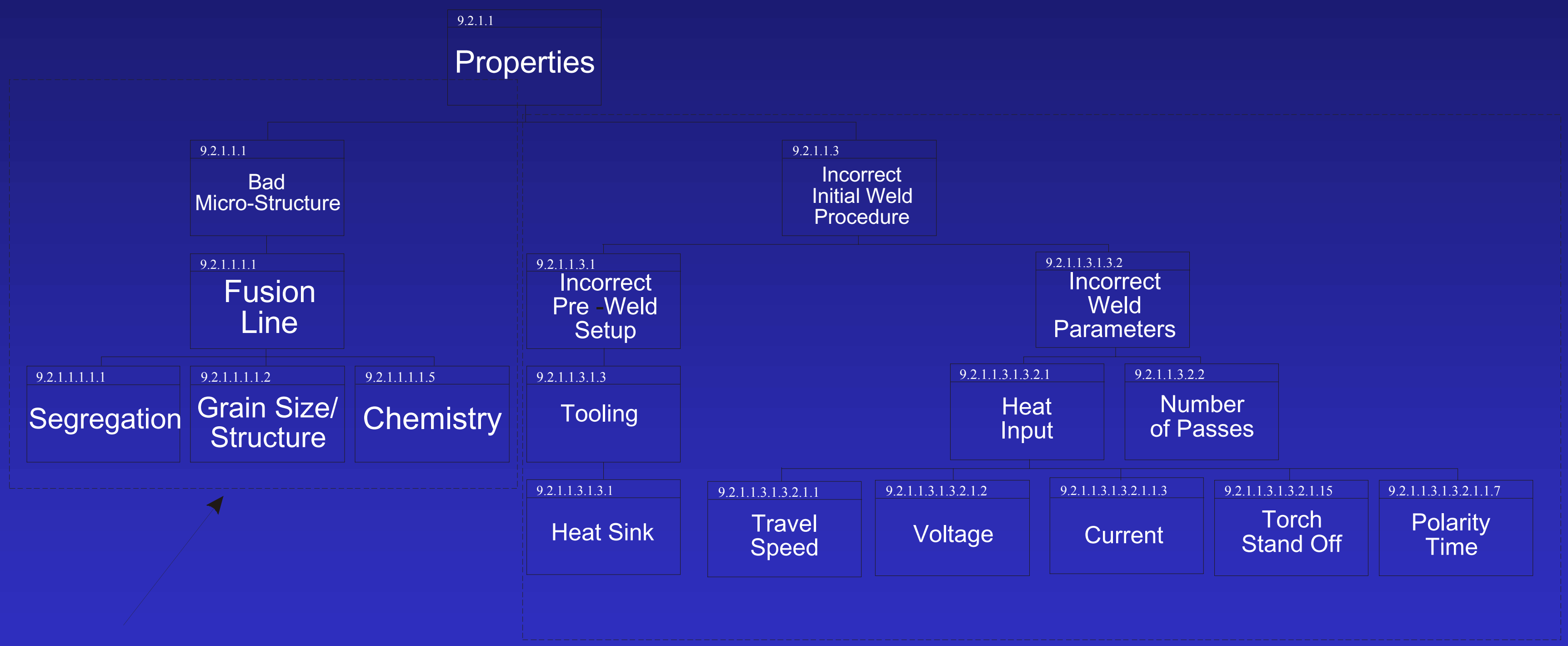


Repair Weld Microstructure



Fault Tree Approach to Resolution

Initial Weld Fault Tree Entries with Contributor "Yes"

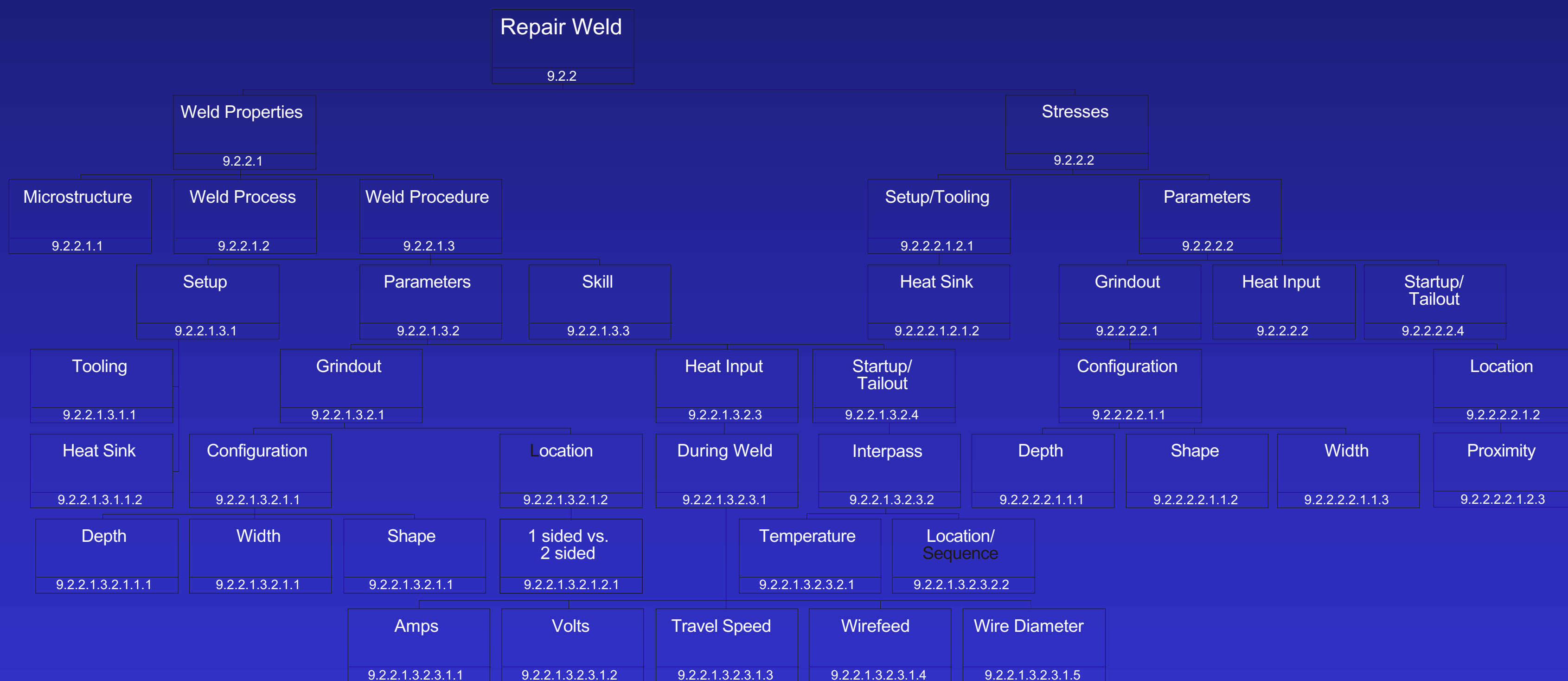


The Initial Weld Fusion Line Microstructure was determined to be a major contributing factor for repair weld cracking.

The Initial Weld procedure and parameters were minor contributors as they affect "Time-at-Temperature which contributes to the amount of segregation that occurs.

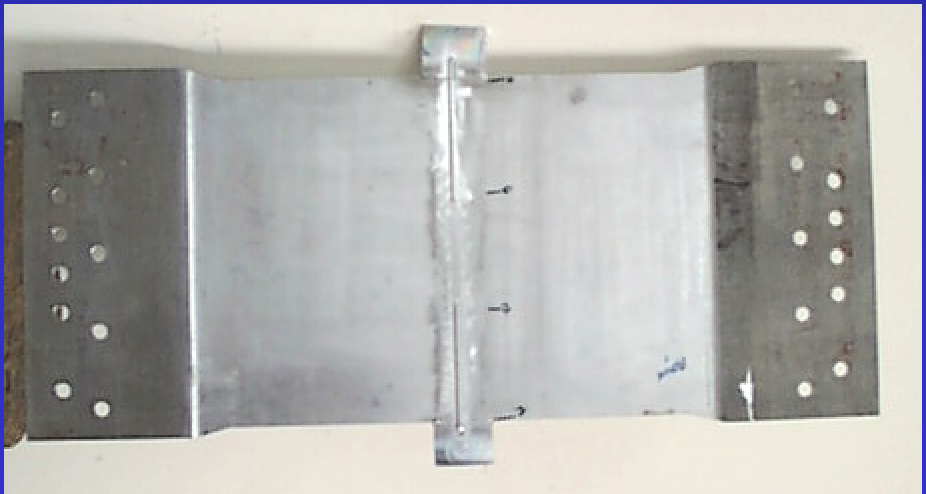
Fault Tree Approach to Resolution

Repair Weld Fault Tree "Yes" Contributors



Wide Panel Tensile Testing

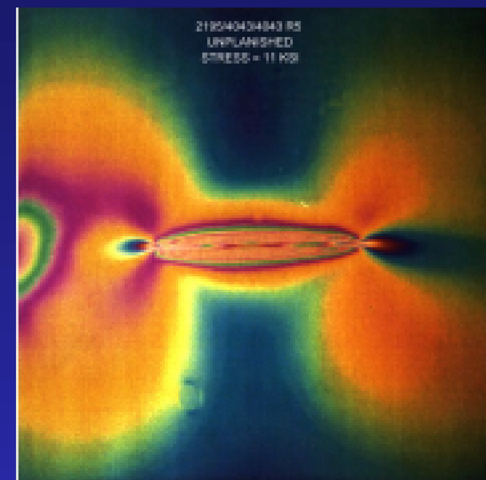
- Small Structural Article developed to reveal stress distribution around repairs
- Instrumented with strain gauges and photoelastic material
- Results indicate residual stresses too high in repair for adequate load redistribution
- Some Wide Panel Tensile Testing data is now required for all 2195 weld repair development

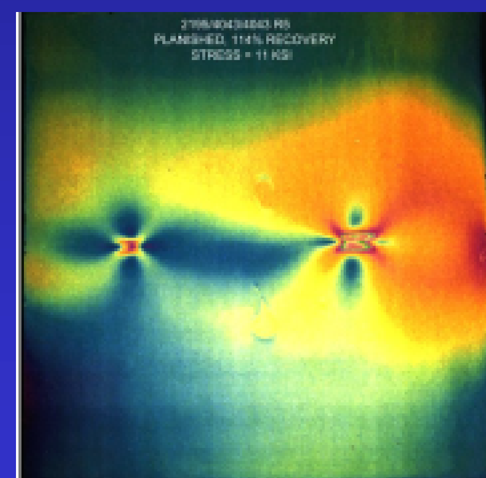


Wide Panel Tensile Specimen

Planishing

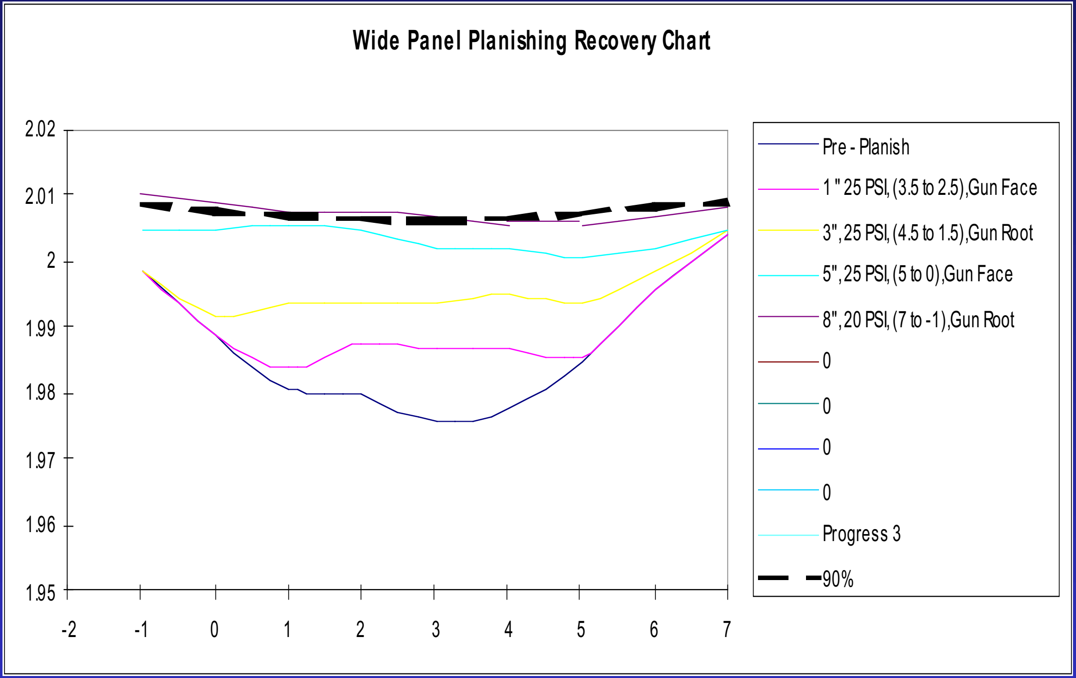
- Planishing Required for all 2195 weld repairs
- Relieves Tensile residual stresses
- Drives Compressive stresses into repair
- Allows for stress redistribution around repair





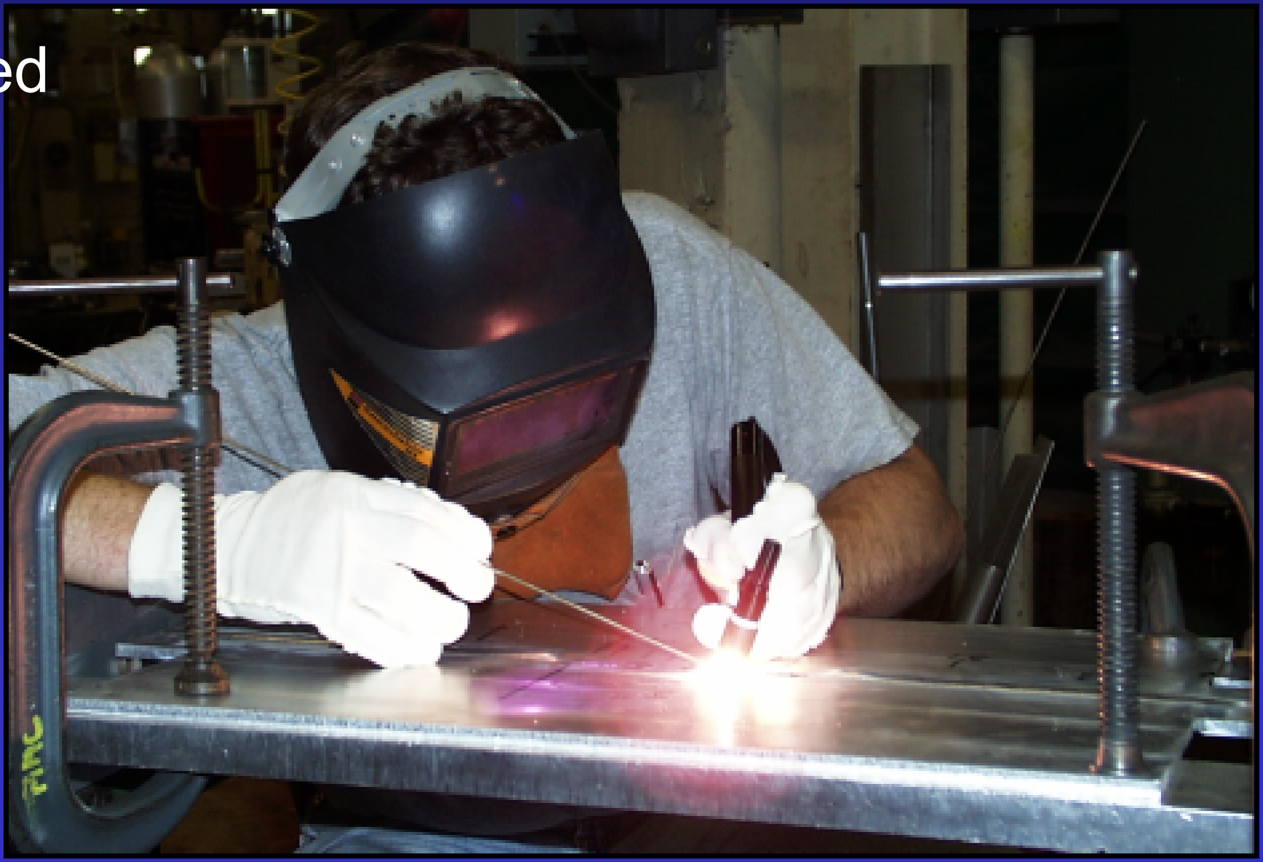
New Metrics Developed for Planishing

- Planishing originally used on ET for distortion removal
- No metric existed other than removal of distortion
- Transverse Shrinkage Reduction Became new metric
- Adequate Strengths developed with 70% to 110% recovery



Manual Welder Training

- Smaller Grinds
- “Fast Hand” Technique
- Continuous wire feed
- Special Start/Stop Technique

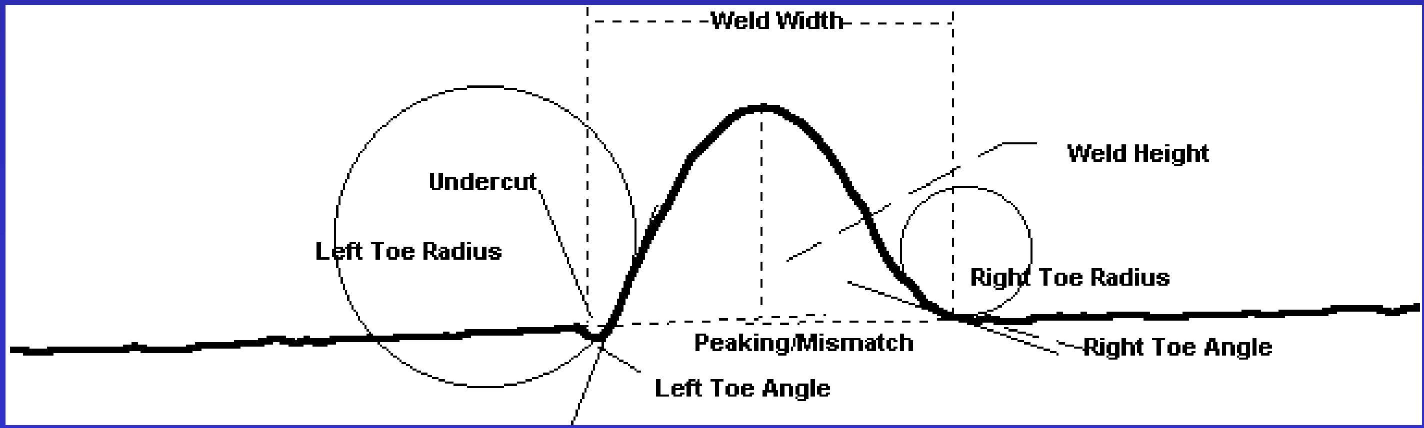


Special Tooling for Weld Repairs

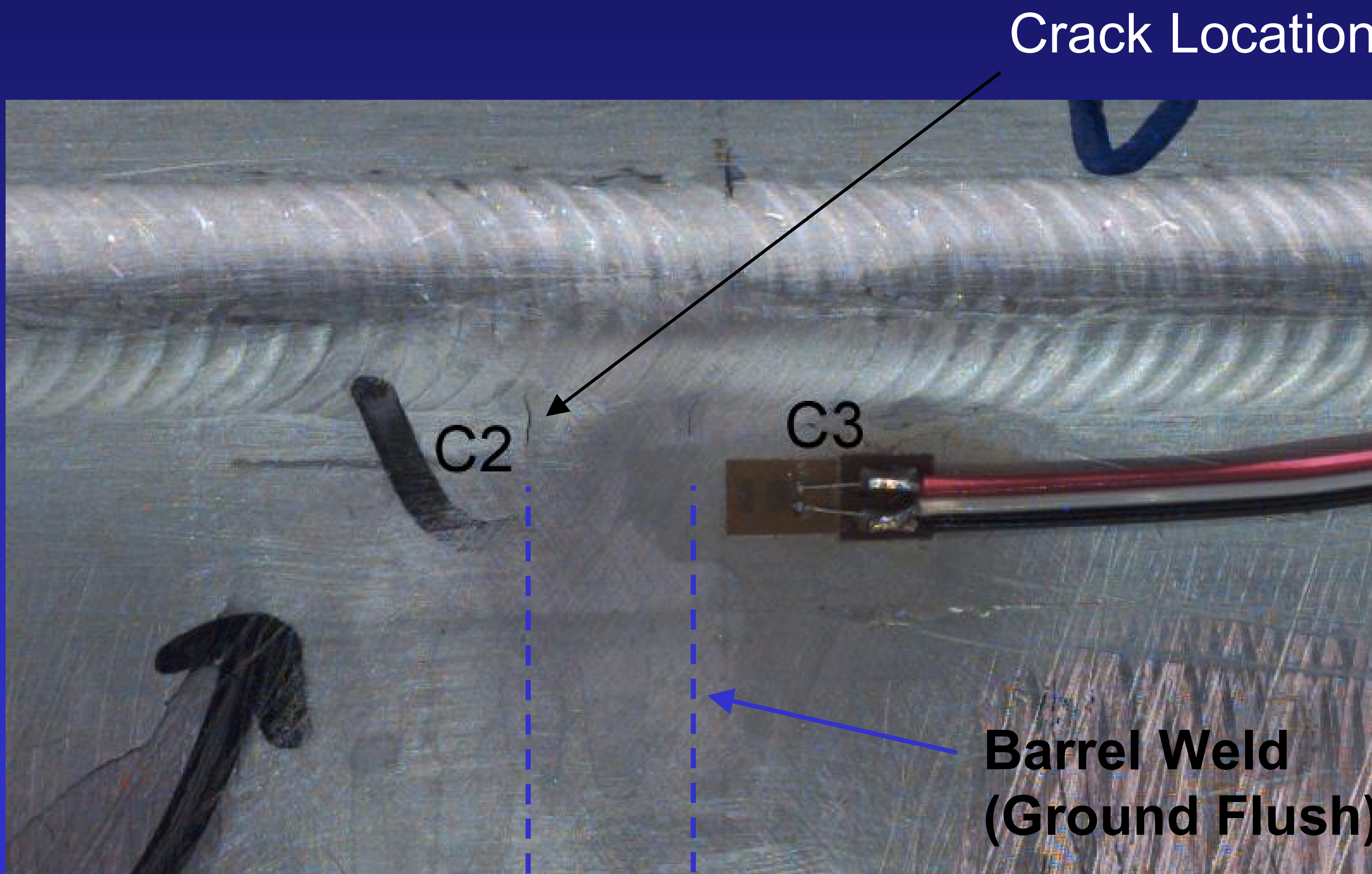
- Flat Position Determined Optimal Repair Position
- Vertical Position as a maximum case without defects

Sensor Technology Implemented

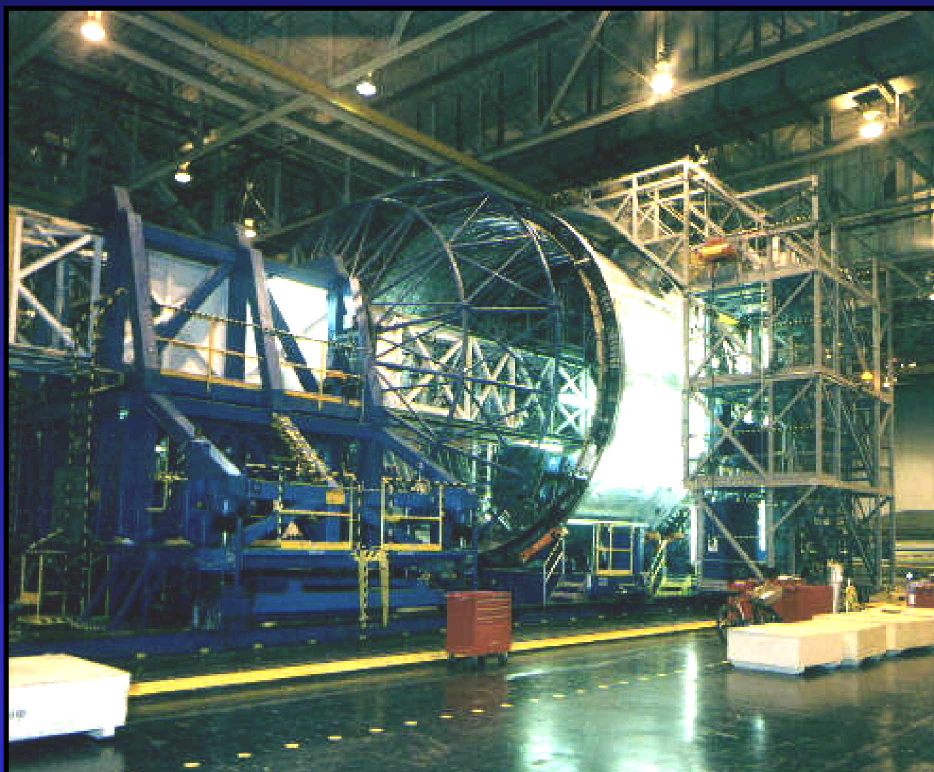
Optical/Laser based sensor system



Intersection Cracks



Intersection Crack Affected Tools

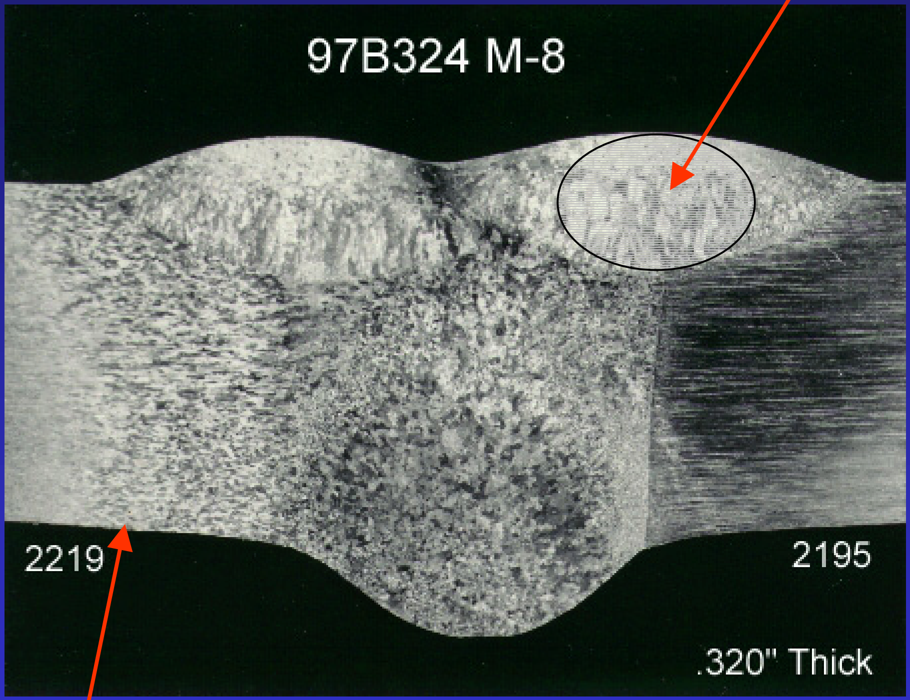


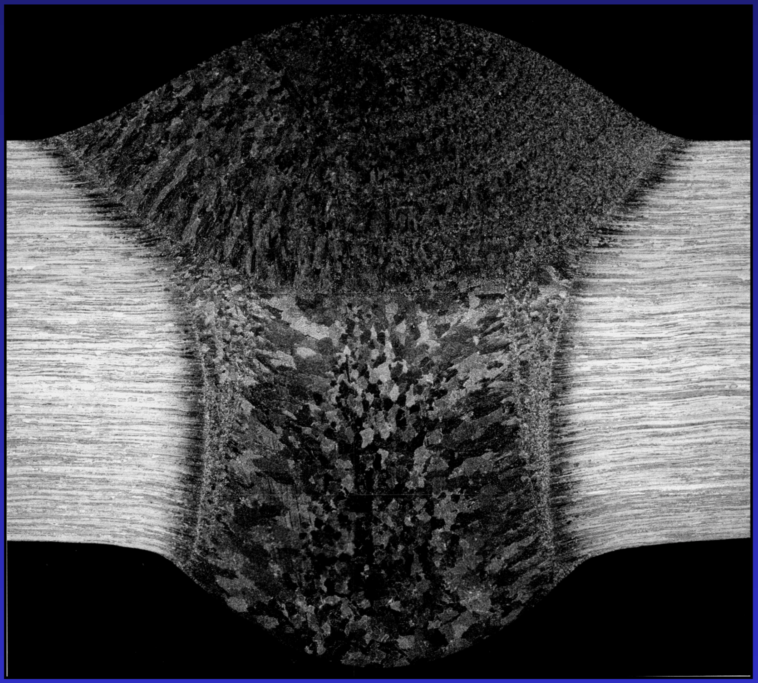
Hydrogen Tank Final Assembly Tool

Oxygen Tank Final Assembly Tool

Photomicrograph of Dual Cover Pass

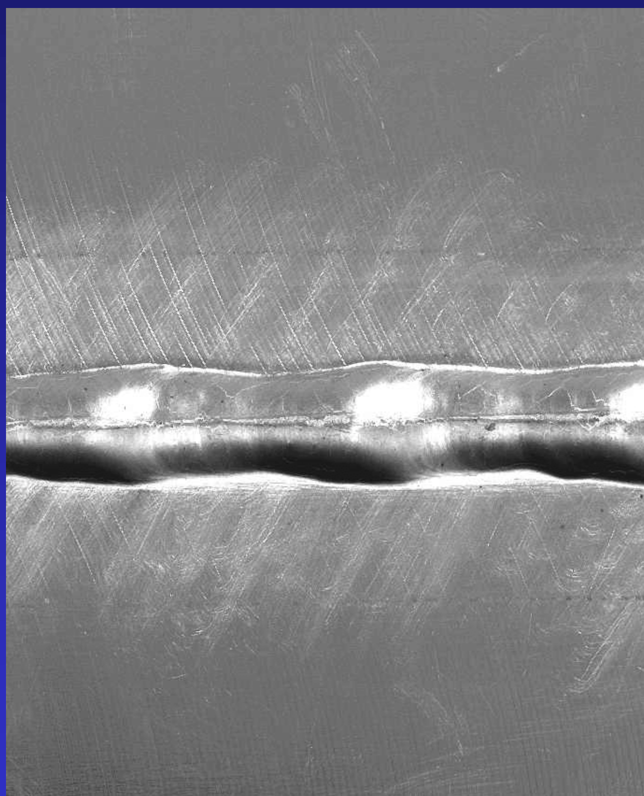
Crack Susceptible Region Setup by Intersection



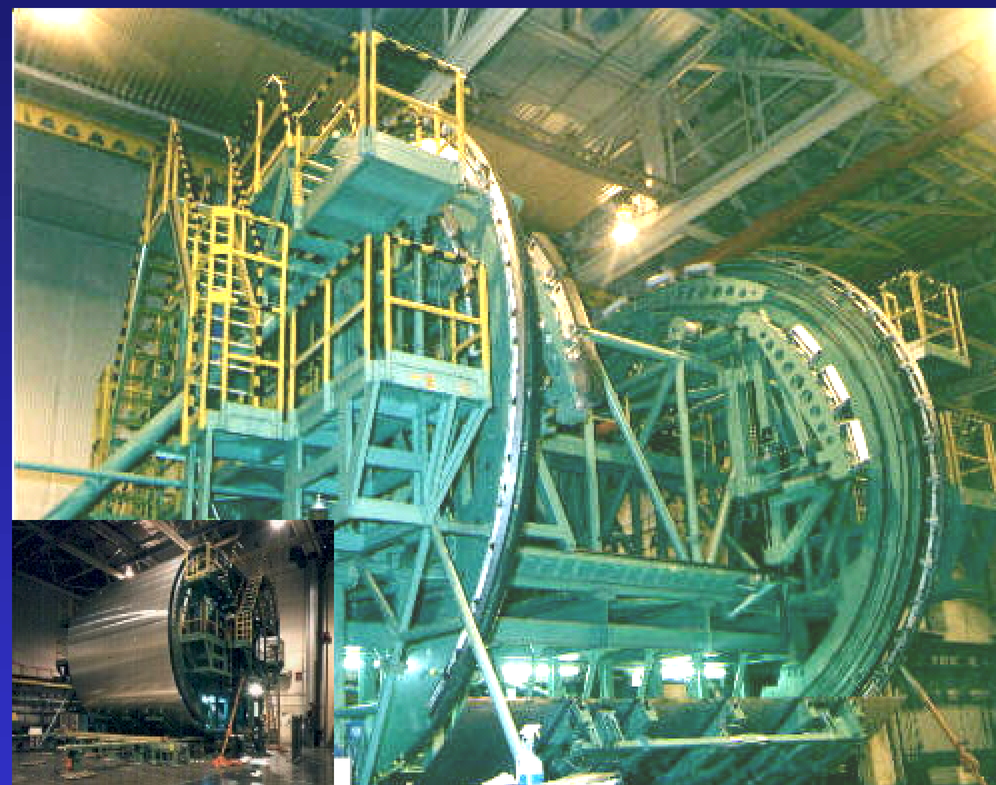


2219 Material
No Problem on
Frame side

Weld Lack of Penetration Issue

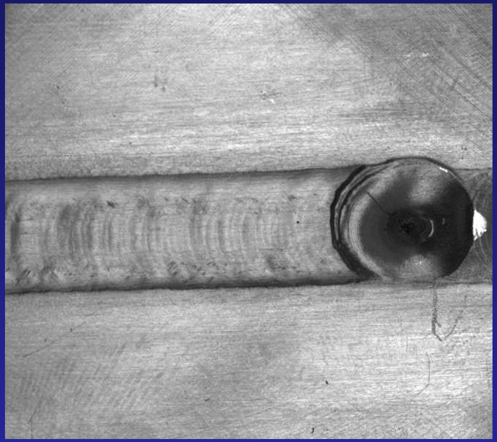


Weld Root



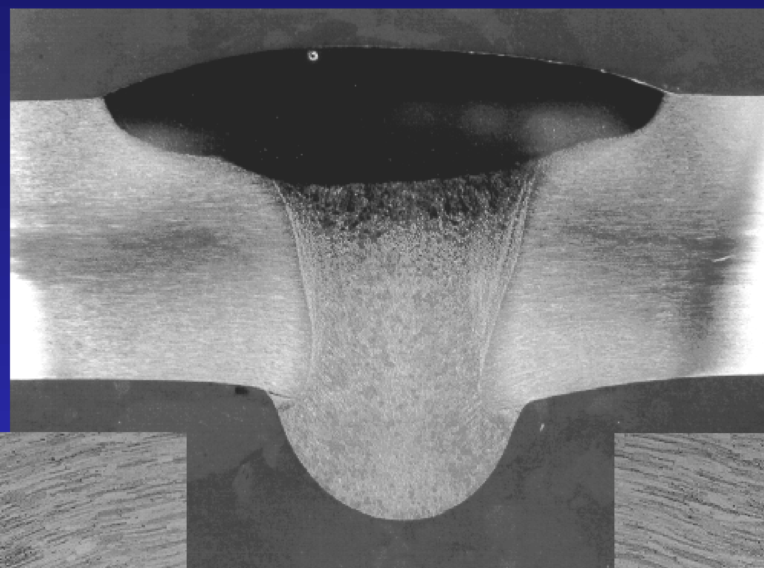
Hydrogen Tank Barrel Weld Tool

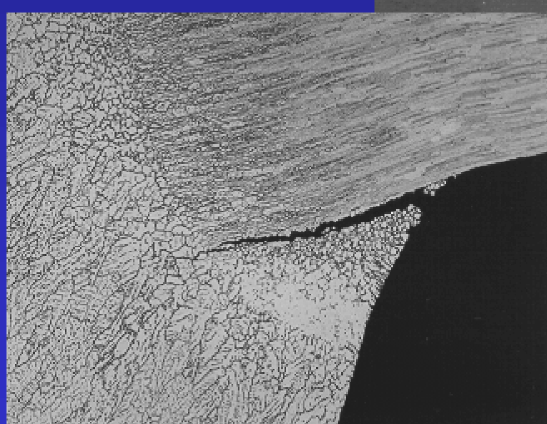
Development of Standoff Control



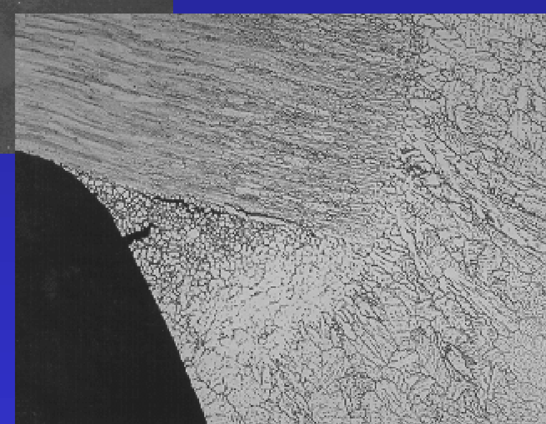
Downhand SPAW with Trailing Wheel Mechanical Standoff
5016 Barrel Tool Configuration for SLWT

Toe Cracks Investigation





ROOT TOE 50X ORIGINAL MAG.



ROOT TOE 50X ORIGINAL MAG.

Forward Ogive Welding

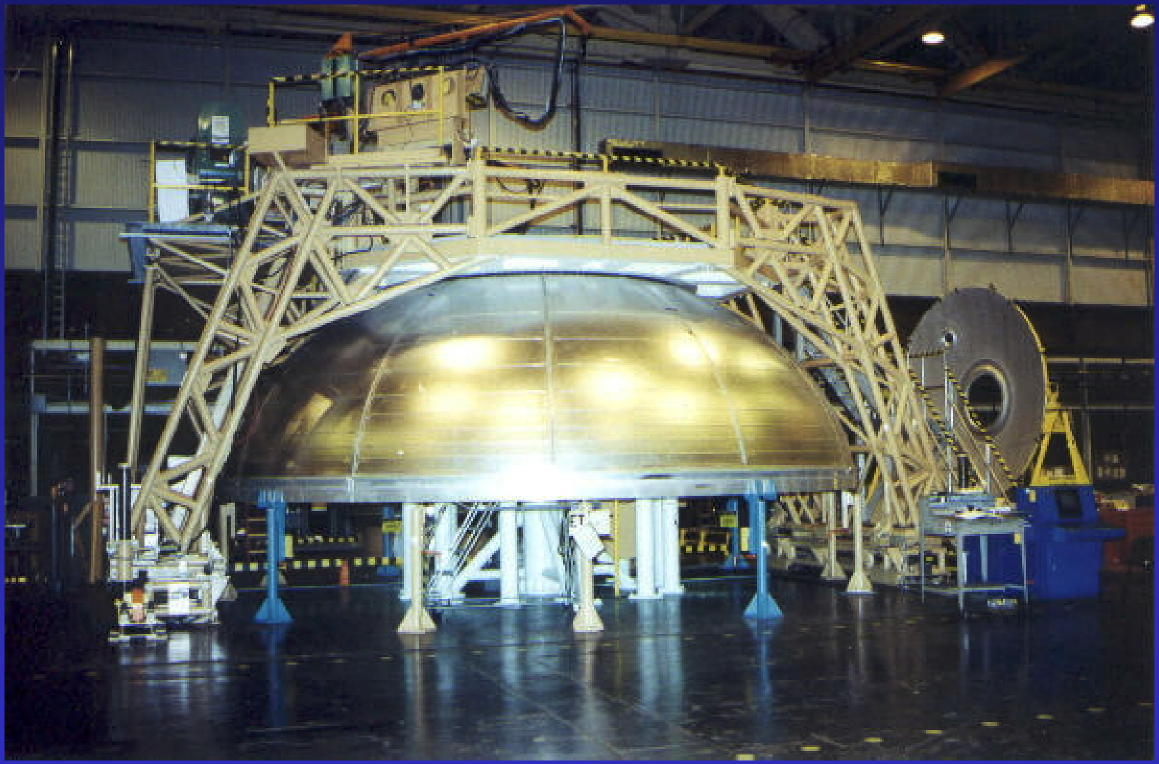
0.190” –0.220” thick tapered welds

- VPPA power supply has inconsistent reverse current
- Repairs require even faster manual repair travel speeds and narrow grinds

5012 Forward Ogive tool

Dome Cap Welding

- Oxygen Tank Dome Cap most challenging weld
- Hydrogen Dome Cap a close second.
- Peaking at intersections creates welding challenge



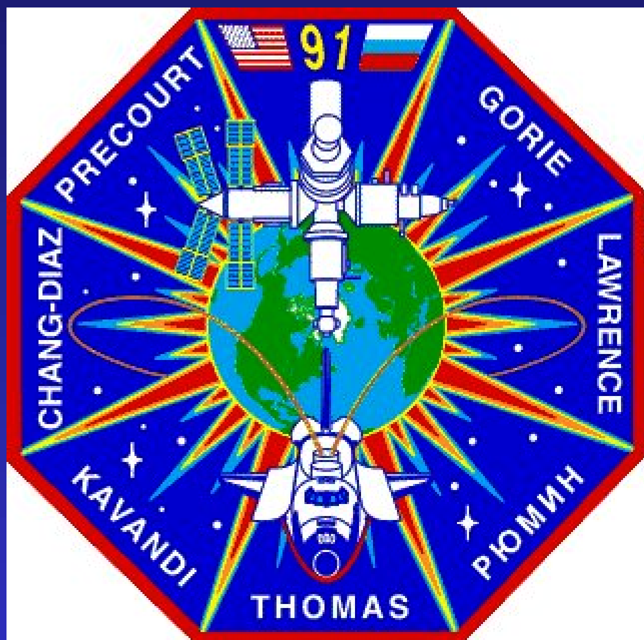
Dome Cap to Body Weld Tool

Al 2195 Welding Summary

- Alloy Is More Reactive
  - Root-side Inert Gas Purging Required
  - Improved Cleanliness Helpful
  - Automatic Arc Voltage Control More Sensitive
- Alloy Is Crack Sensitive
  - Reduced Heat Input Beneficial
  - Filler Alloy Critical
- Minimize Repair Grindouts
- Planishing Required If Filler Alloy Strength Is Mismatched

First SLWT Launched June 2, 1998

STS 91



- Eight Super Lightweight Tanks have flown

Developments to Improve Productivity

- Domes & Ogives return to 2219
- Friction Stir Welding to be implemented on Barrels
  - Lower Manufacturing Cost
  - Higher Weld Strength Margins/Less Variability
  - Lower defect rate
- Friction Plug Repairs
  - Higher Strength
  - Automated
- New Filler Alloy Developed
  - Improved Strength
  - Planishing Not Required