Regulatory Information Conference
Palo Verde BMI Update
March 12th, 2014

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Arizona Public Service

Bare Metal Visual (VE)

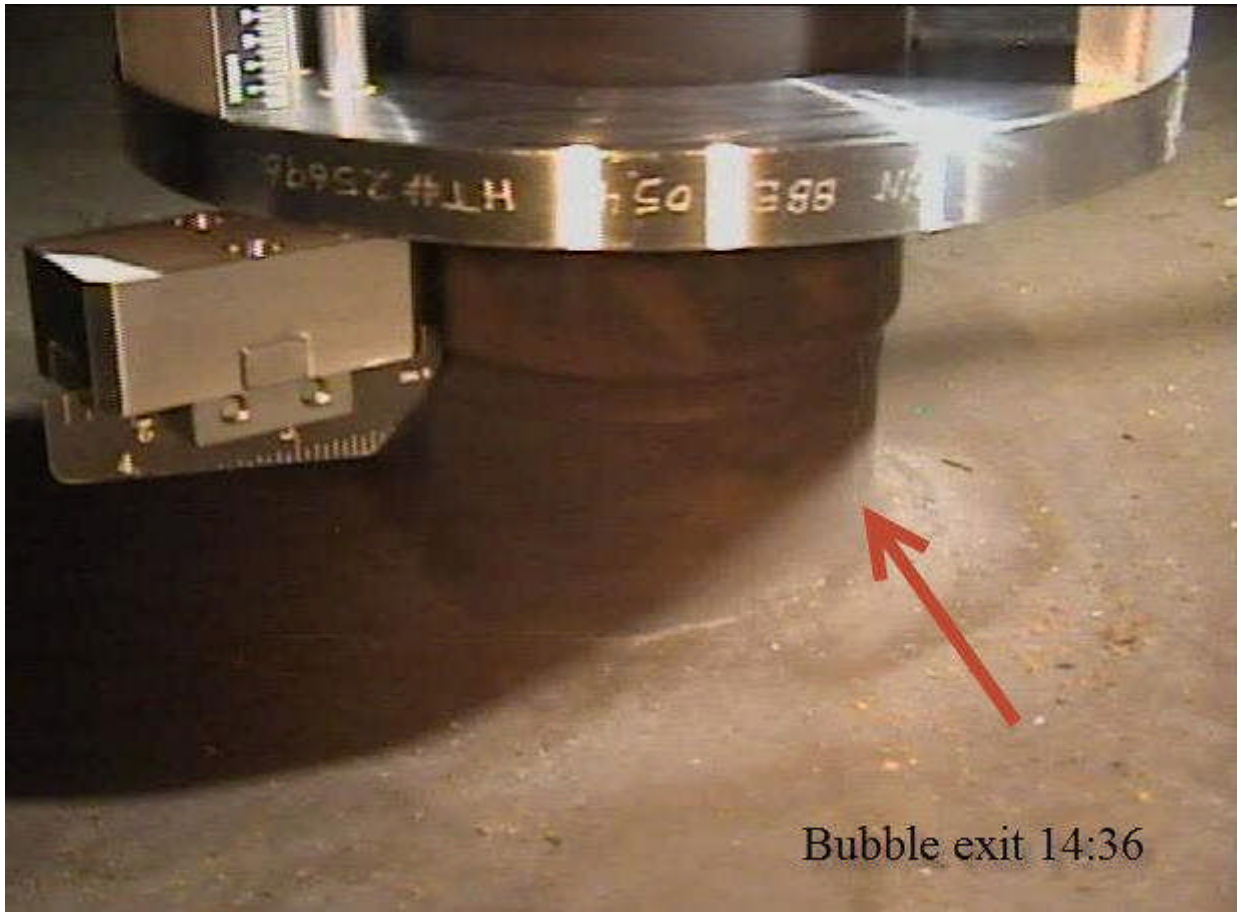
- Examinations performed per Code Case N722-1
- All 61 nozzles examined
- Nozzle #3 was the only one with leakage noted

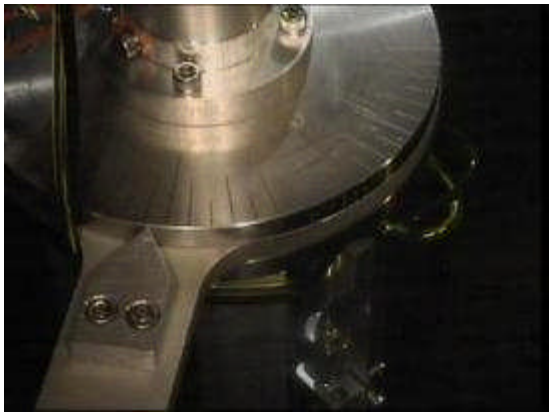
Wastage Examination

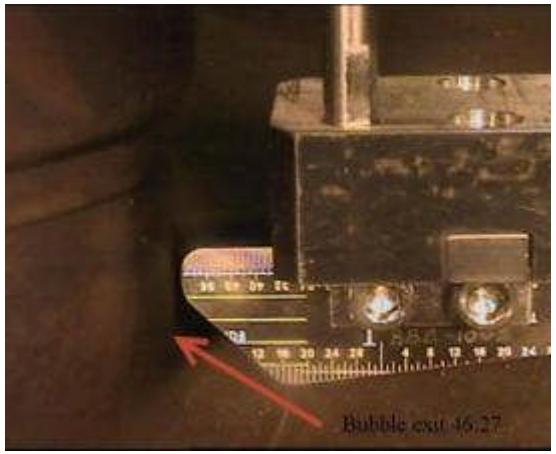
Nozzle #3 Results

- Phased Array Ultrasonic Testing
  - Conducted from the outside
  - Adjacent to Nozzle #3
  - Focus on degradation (wastage) in the vessel shell at the nozzle bore
- Examination demonstration:
  - STP mockup and technique
  - All mockup flaws were detected
- Examination results:
  - No indication of wastage was detected

Helium Bubble Test







Ultrasonic & Eddy Current Testing

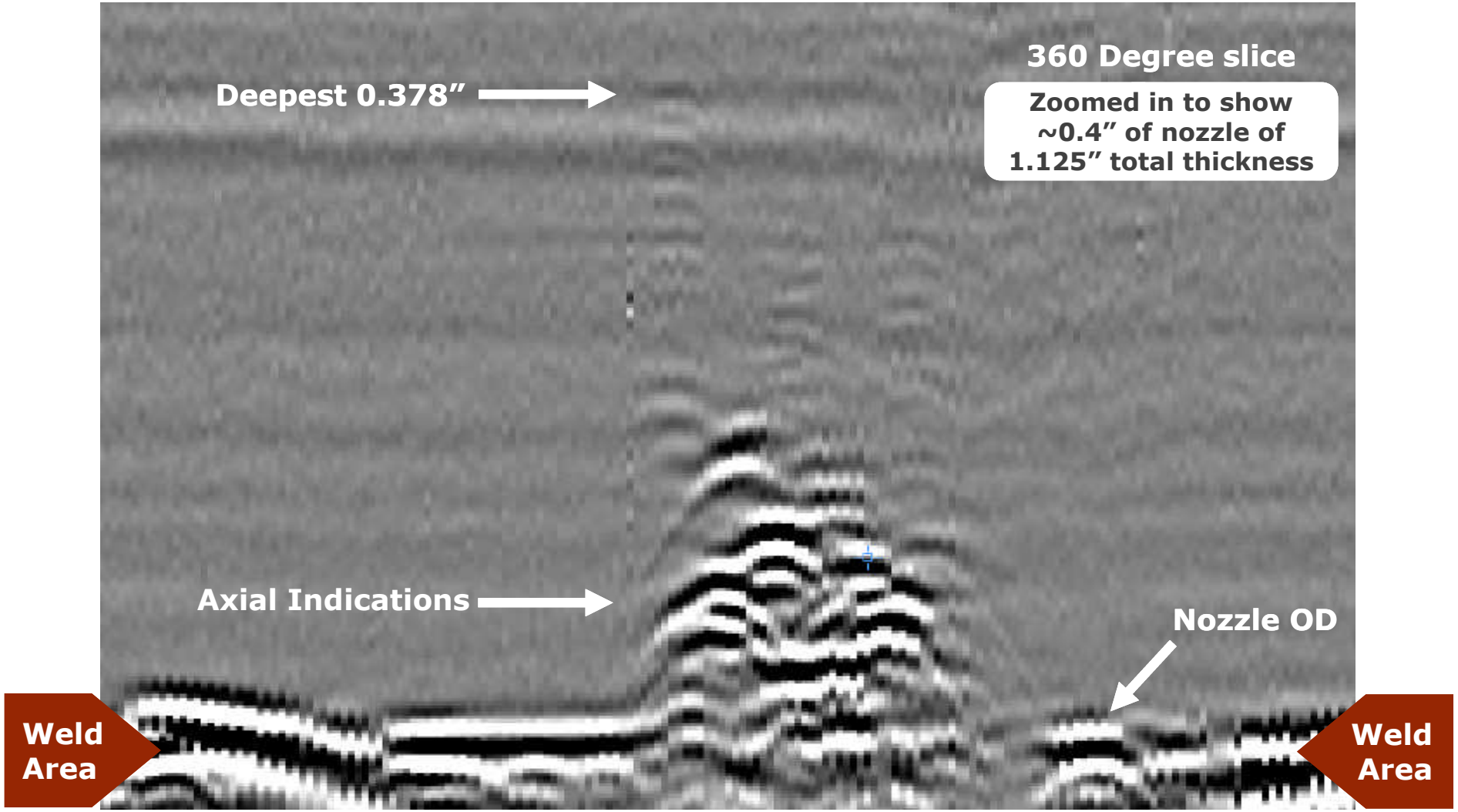
- Similar to reactor vessel closure head examinations
- Conducted from the nozzle inside diameter
- Single probe with multiple techniques
- Techniques demonstrated at EPRI:
  - TOFD (time of flight diffraction)
    - Both axial and circumferential
  - Additional techniques used:
    - Inside diameter eddy current
    - 45 degree shear-wave UT; looking down
    - Zero degree UT; looking perpendicular to the surface

Ultrasonic Testing Demonstration

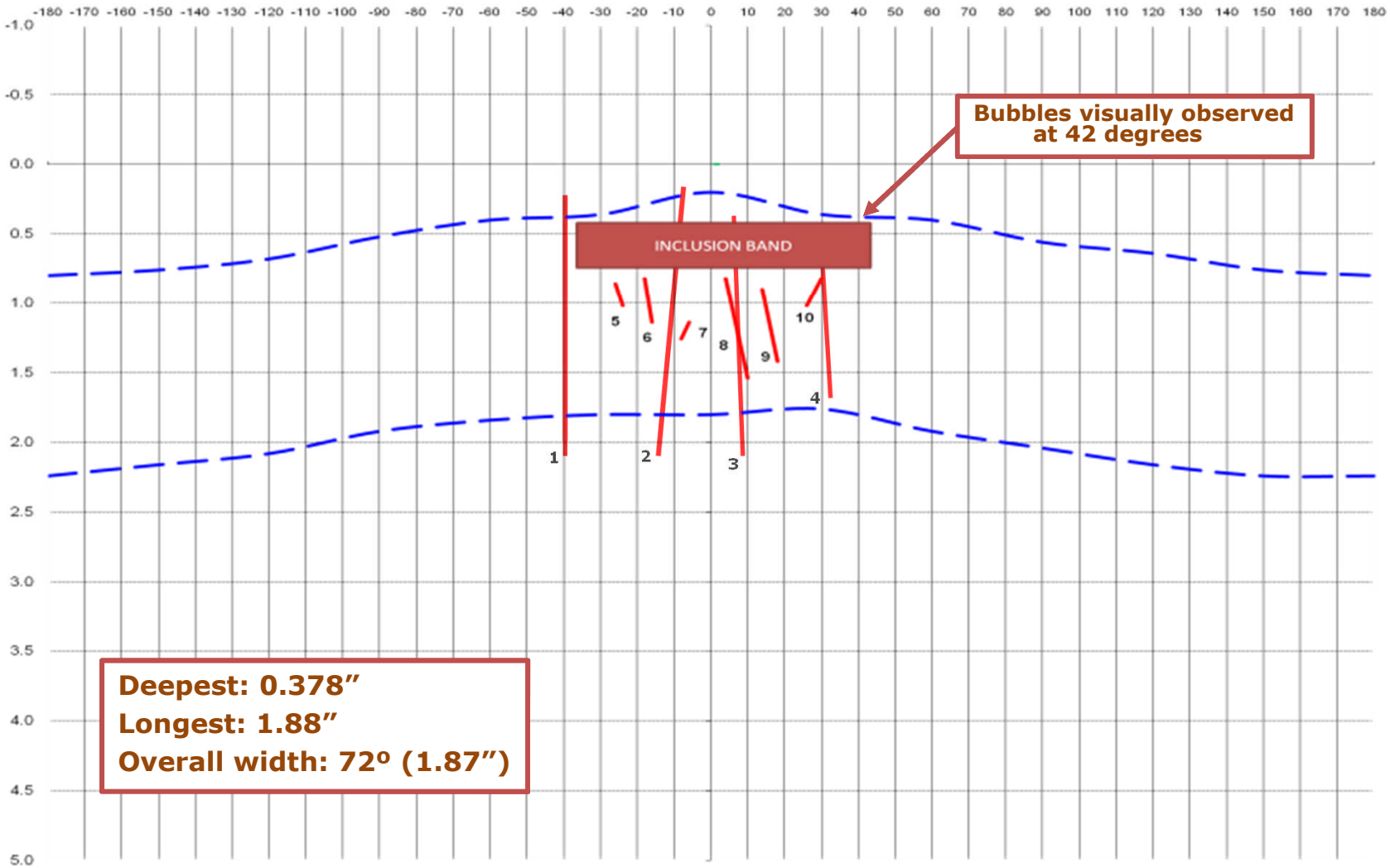
(EPRI NDE Center)

- Mock-up design and fabrication early 2013
  - Flaw locations: inside and outside diameter
  - Flaw orientations: axial, off angle, and circumferential
- Results: all flaws detected

Nozzle #3 TOFD Graphic



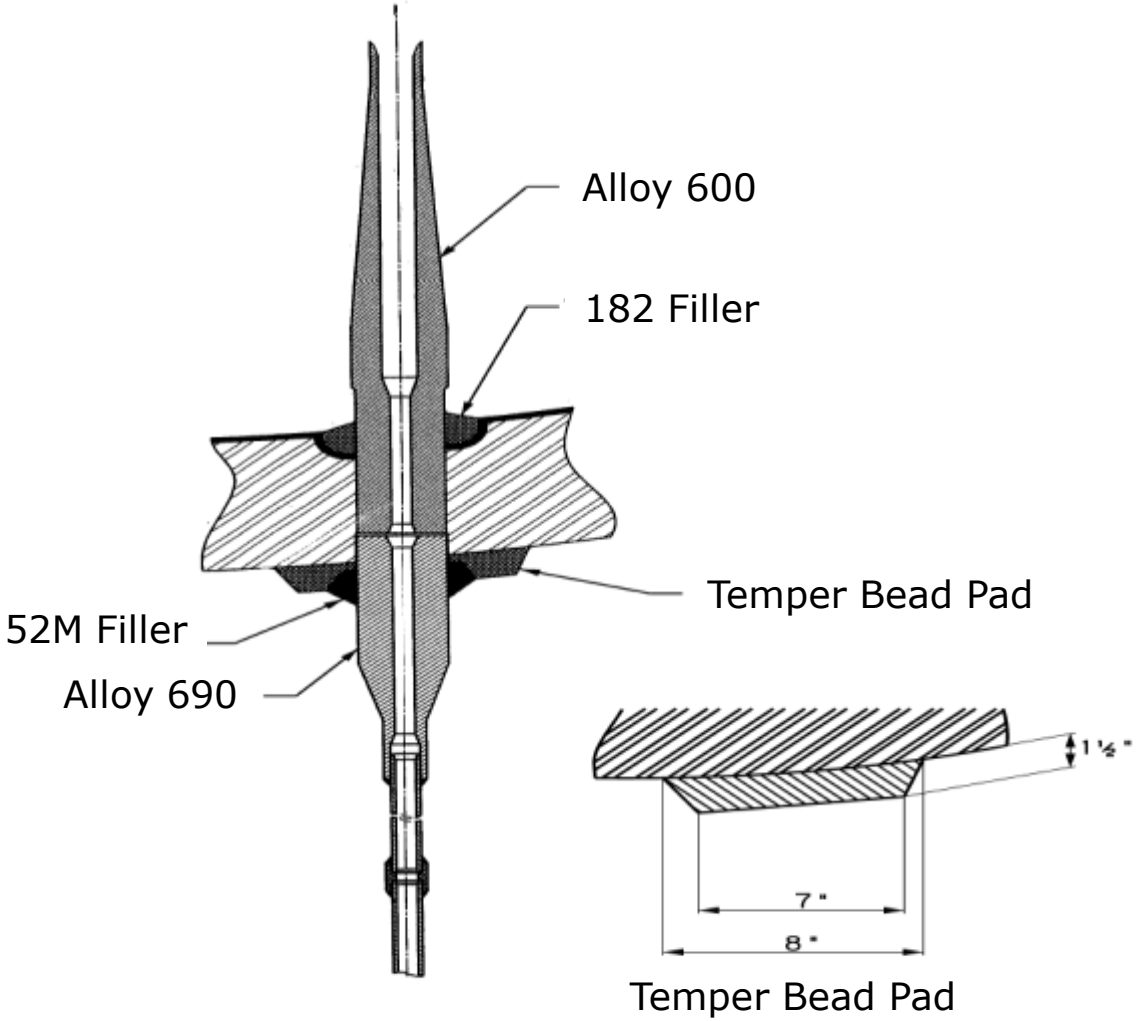
BMI Nozzle #3


Bubbles visually observed at 42 degrees
INCLUSION BAND
1
2
3
4
5
6
7
8
9
10
Deepest: 0.378”
Longest: 1.88”
Overall width: 72º (1.87”)

NDE Results

- BMI nozzle #3
  - Only visual leaking nozzle
  - Helium validated leak location
  - No inside diameter indications detected
  - Multiple axial ultrasonic indications
    - Two WesDyne Level IIIs
    - WesDyne Chief Engineer
    - EPRI independent reviewer
- All other nozzles (60)
  - No unacceptable indications

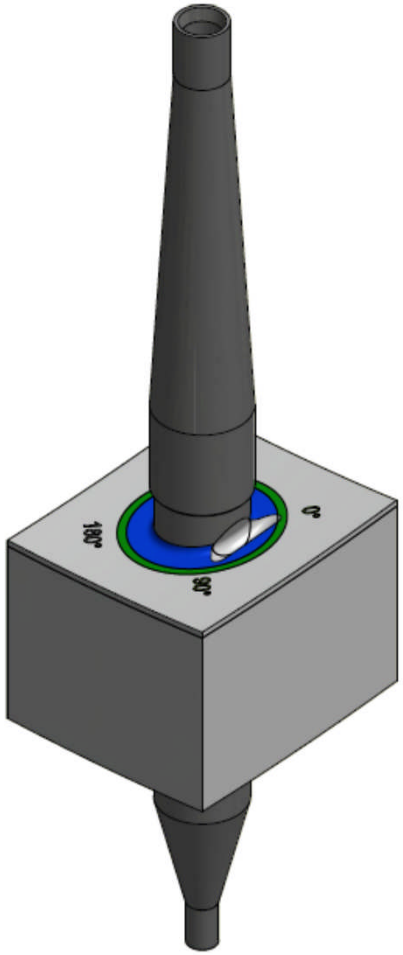
Half-Nozzle Repair



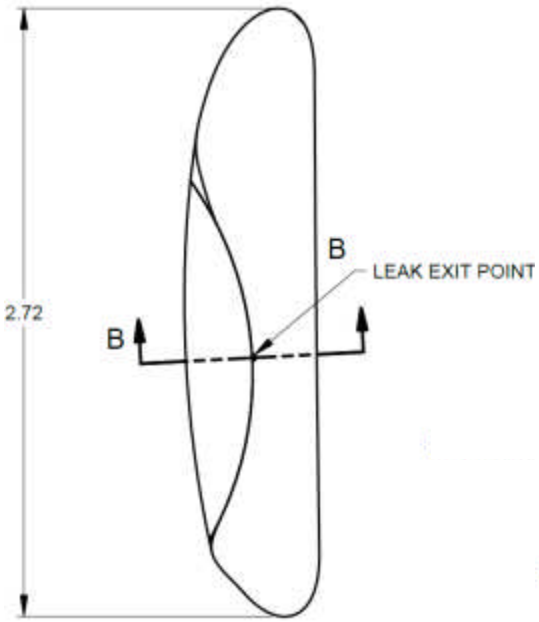
Completed weld repair

Root Cause

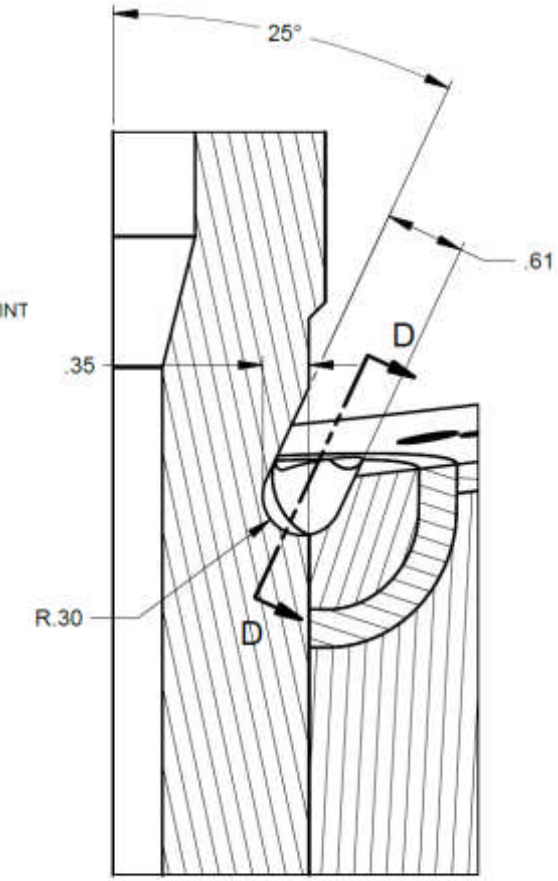
- Collection of Boat Sample
- Sample Content
  - RCS Leak Entrance Point
  - Weld Defect
  - Axial Crack
  - Area of high reflectivity
  - Unaffected Alloy 600 and 182 Material



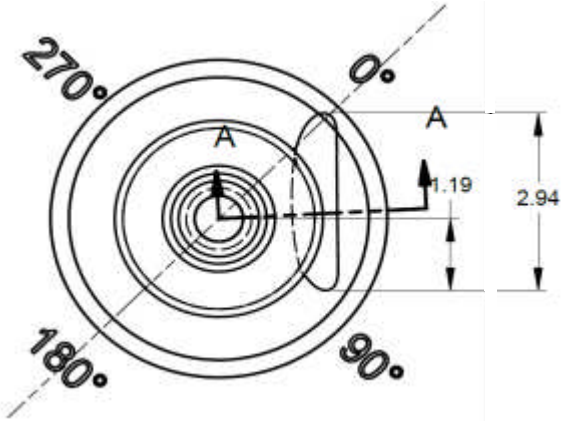
Boat Sample Dimensions

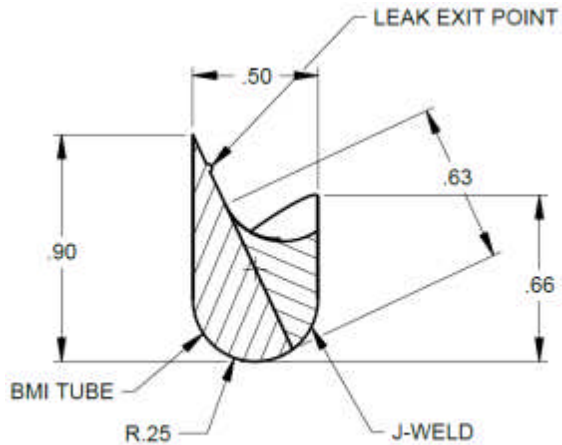


VOLUME: 0.39 in^3 EST
MASS: 0.118 lbmass EST



SECTION A-A





SECTION B-B

Destructive Evaluation Plan

Boat Sample

- Metallurgical Analysis and Test Plan
  - Visual inspections
  - X-ray radiography
  - High Resolution Replication
  - Scanning Electron Microscopy (SEM)
  - Energy Dispersive Spectroscopy (EDS)
  - Metallography

Industry Team

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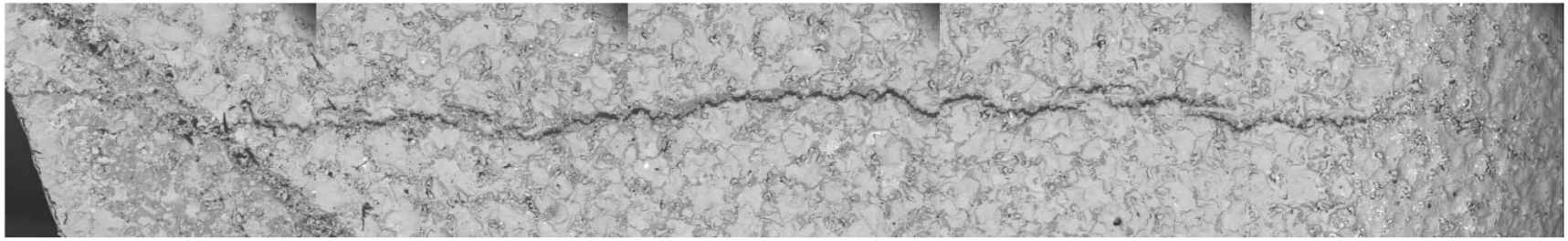
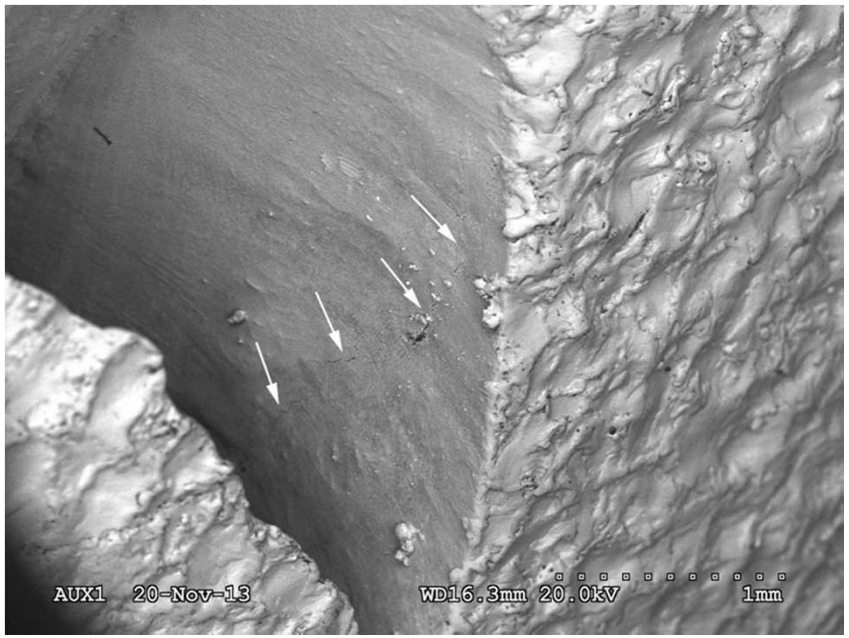
Mike McDevitt
Mike Gardner
Jean Smith
Sarah Davidson

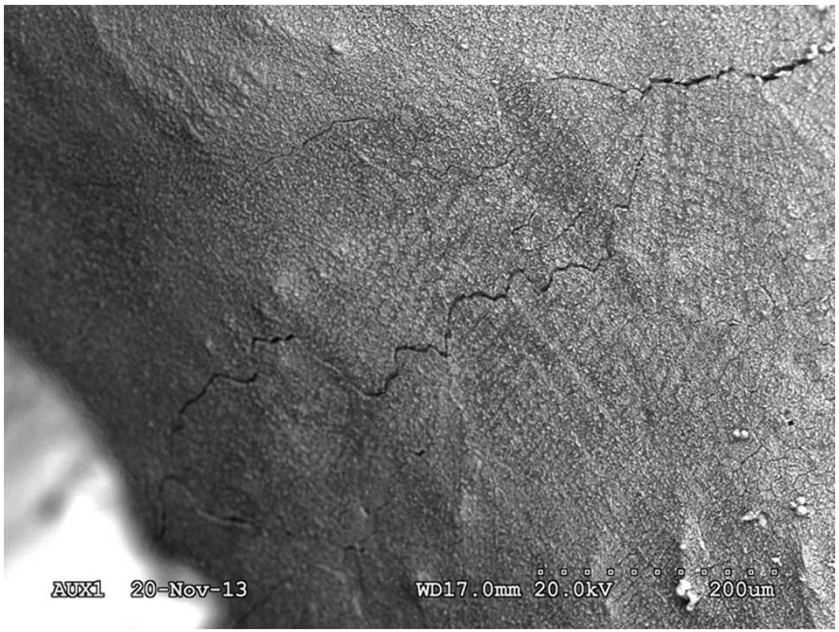
Boat Sample

SEM

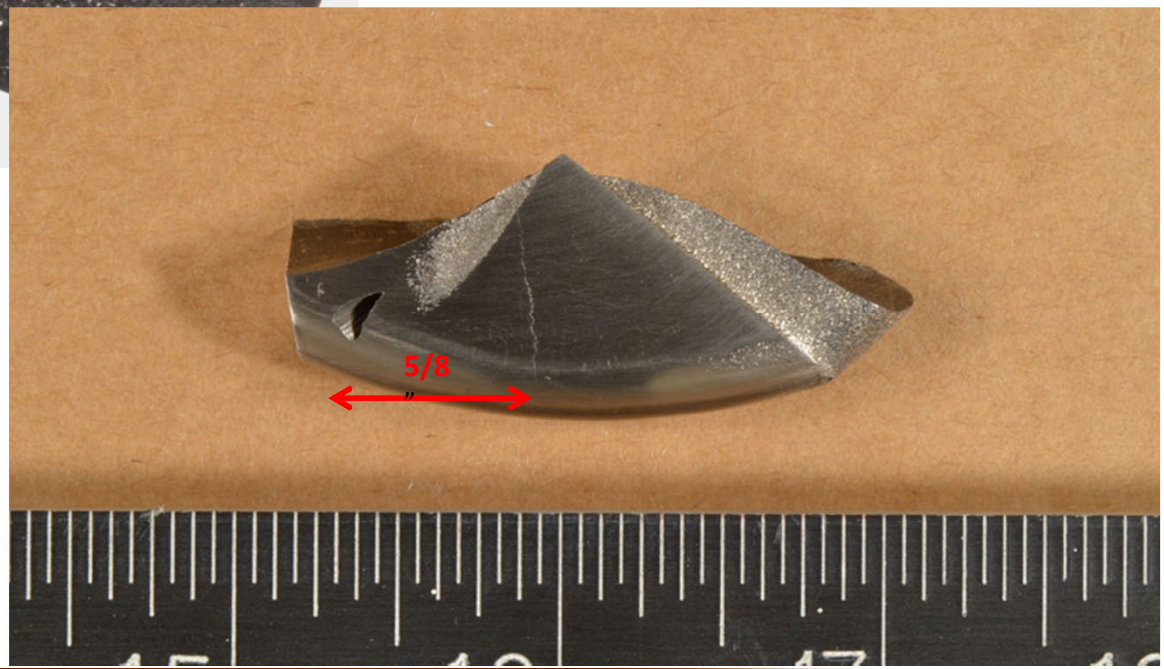


SEM

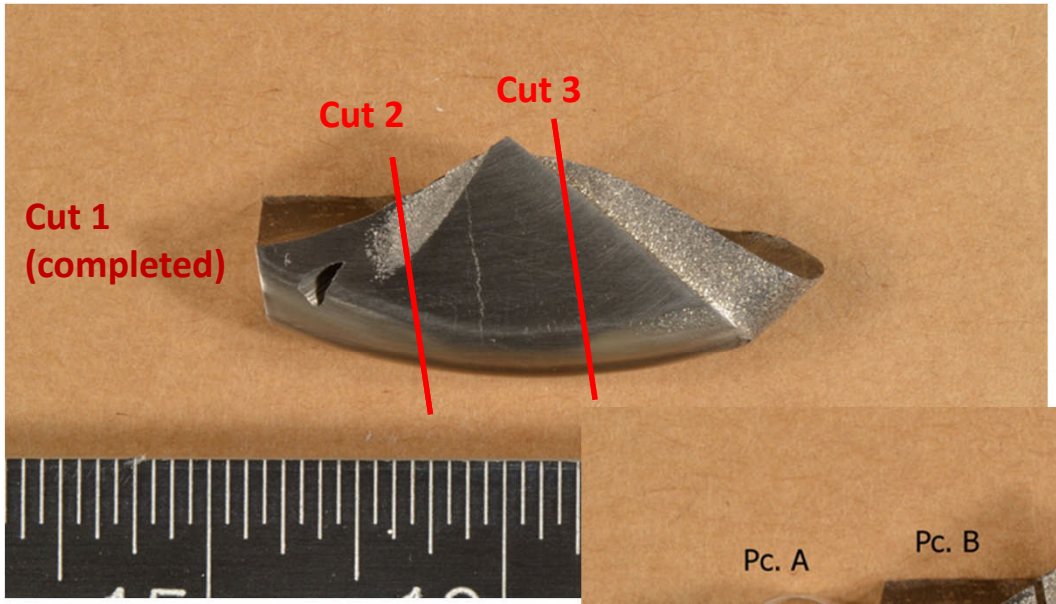

AUX1 20-Nov-13
WD16.3mm 20.0kV
1mm

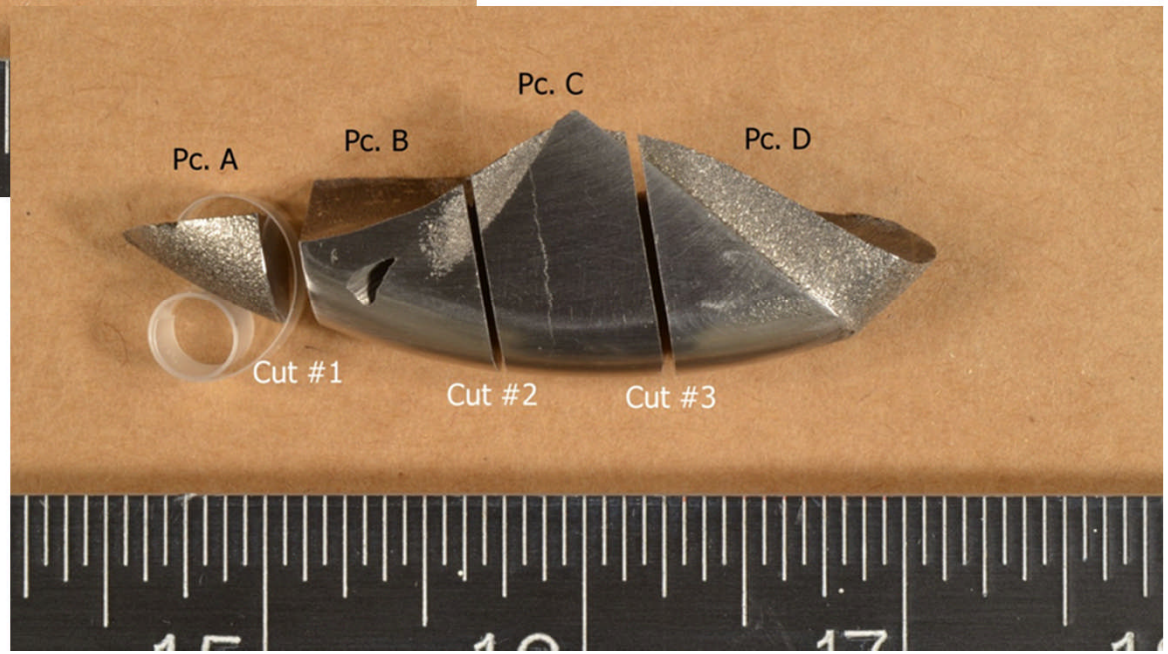

AUX1 20-Nov-13
WD17.0mm 20.0kV
200um

Replication

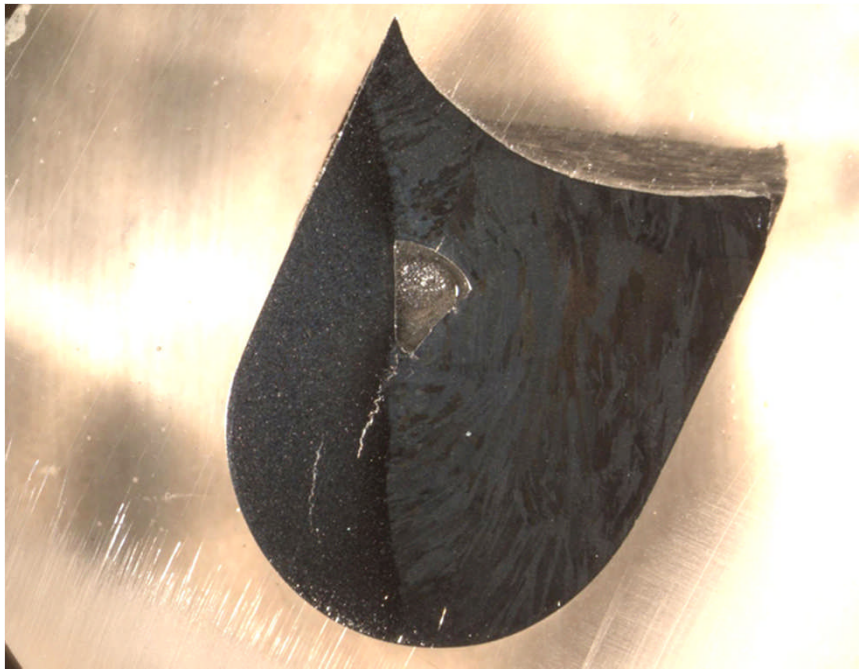


Sectioning

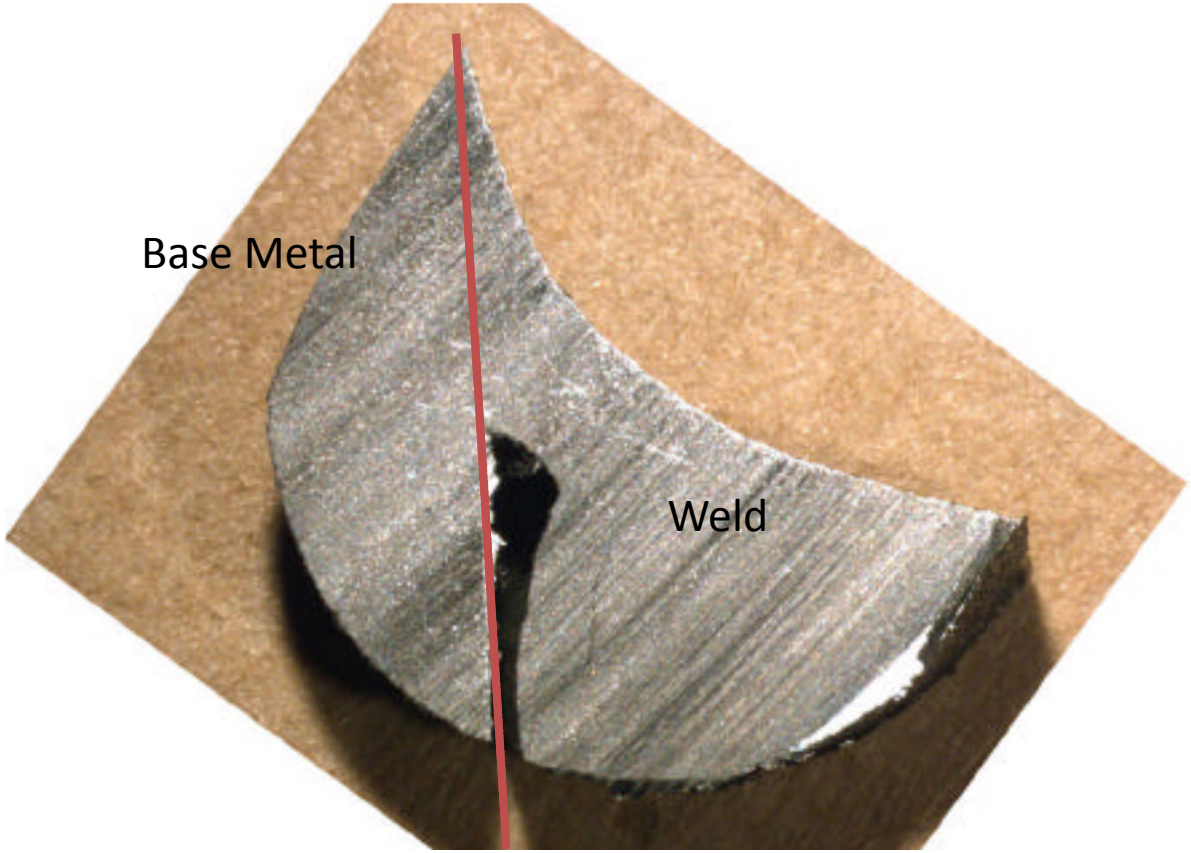




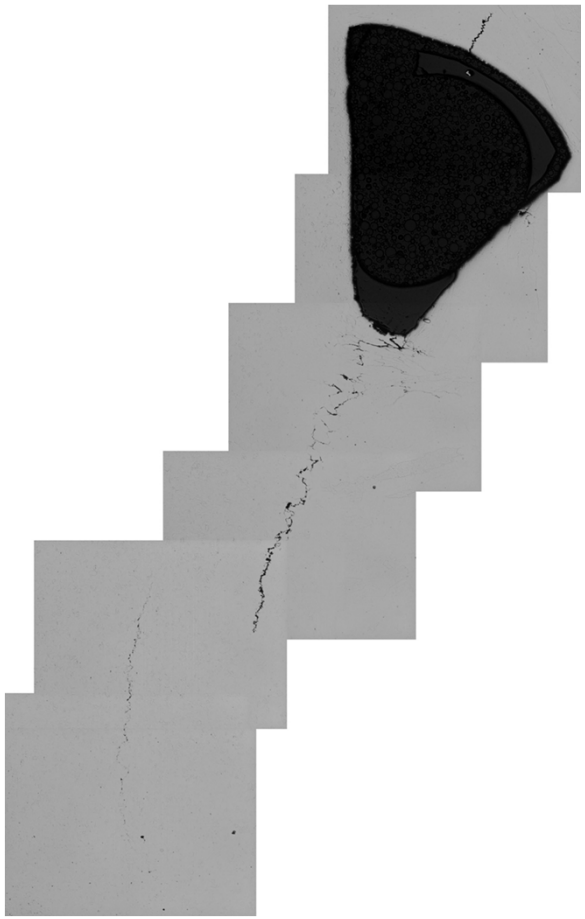
Sectioning (Piece B cut 2)

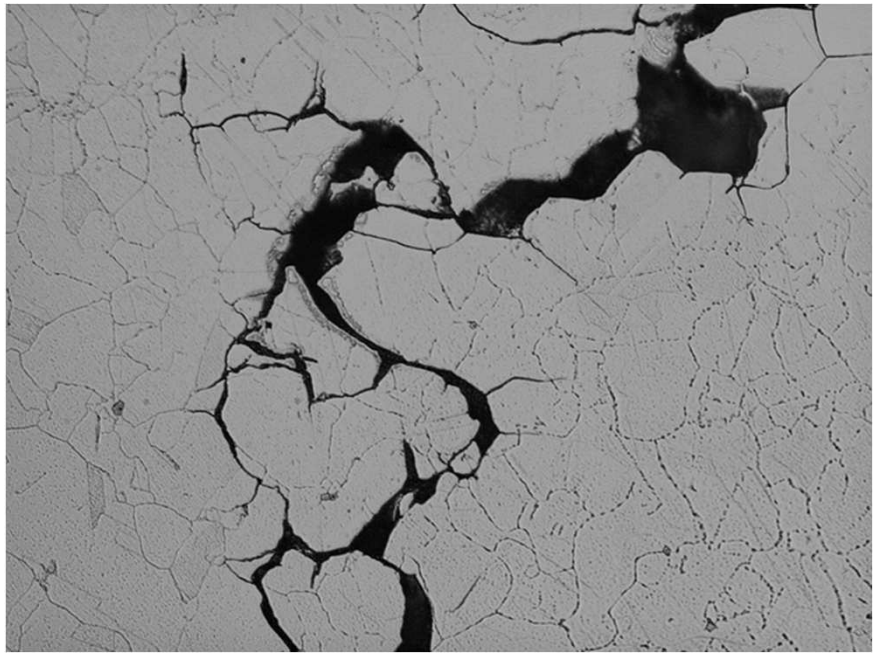


South Texas Project Boat Sample

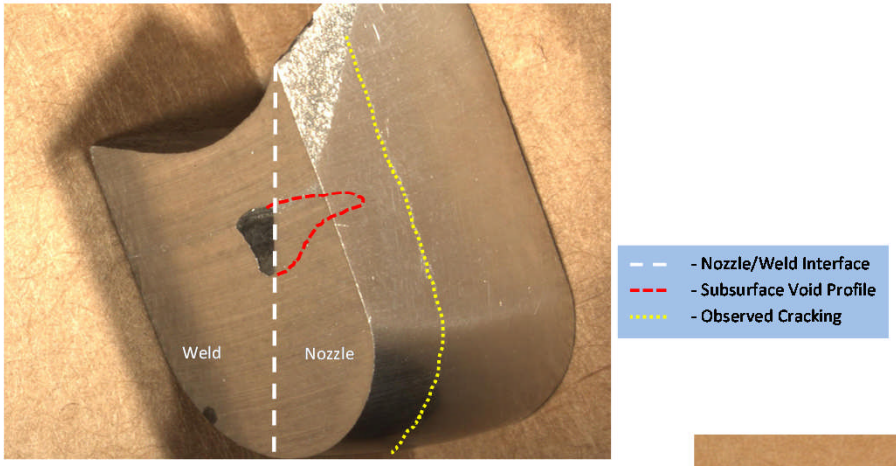


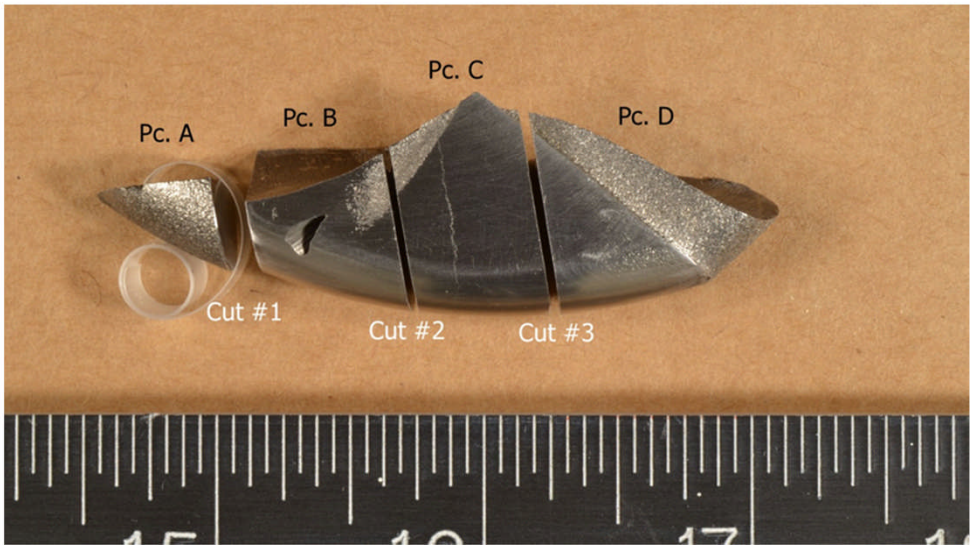
Sectioning (Piece B)



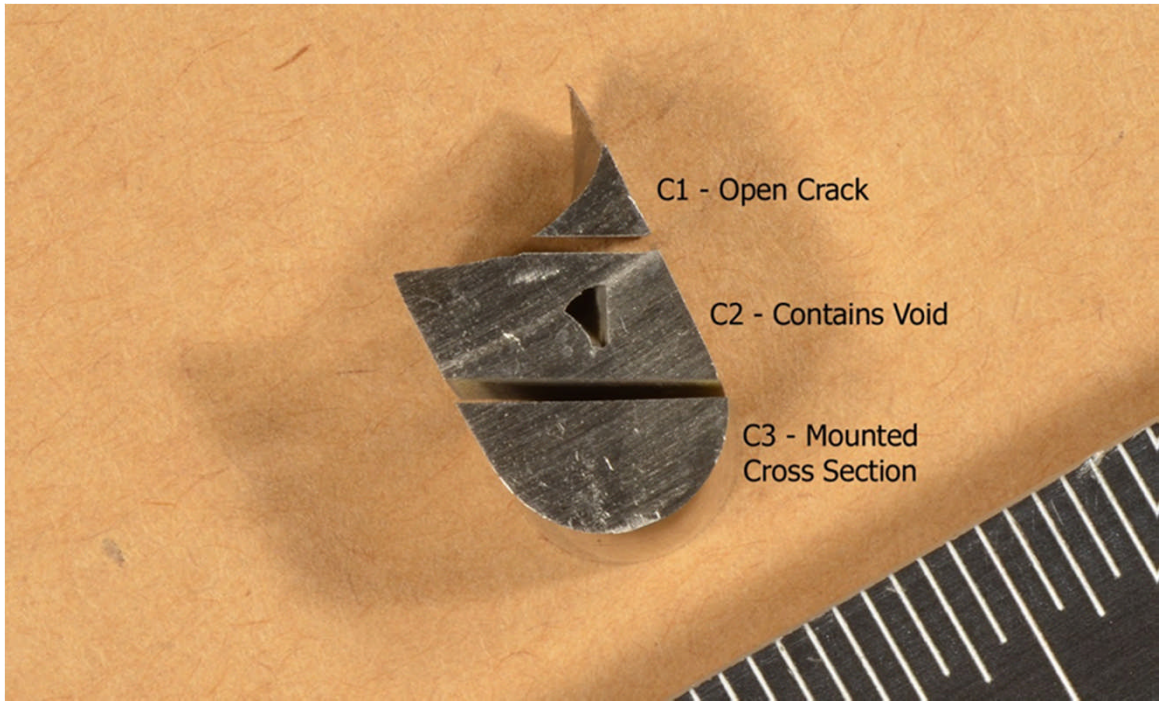


Sectioning (Piece C cut 2)

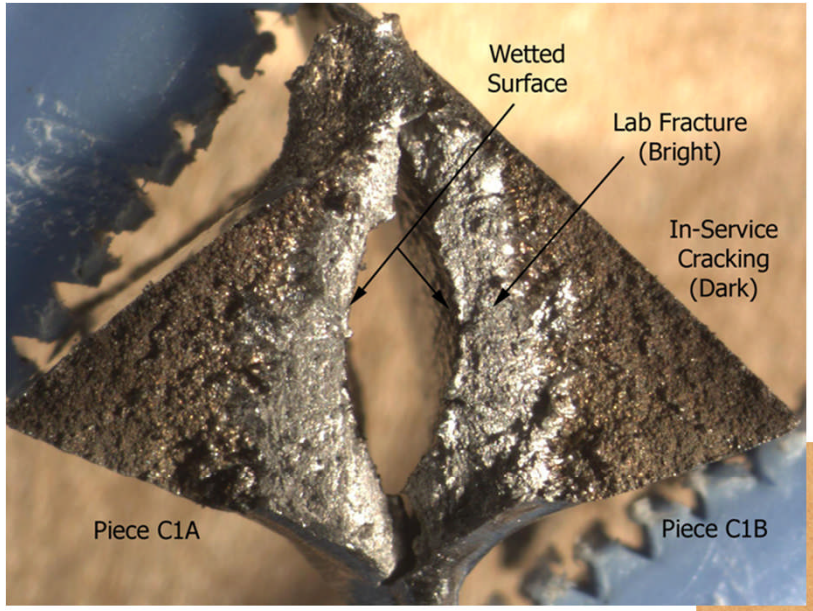


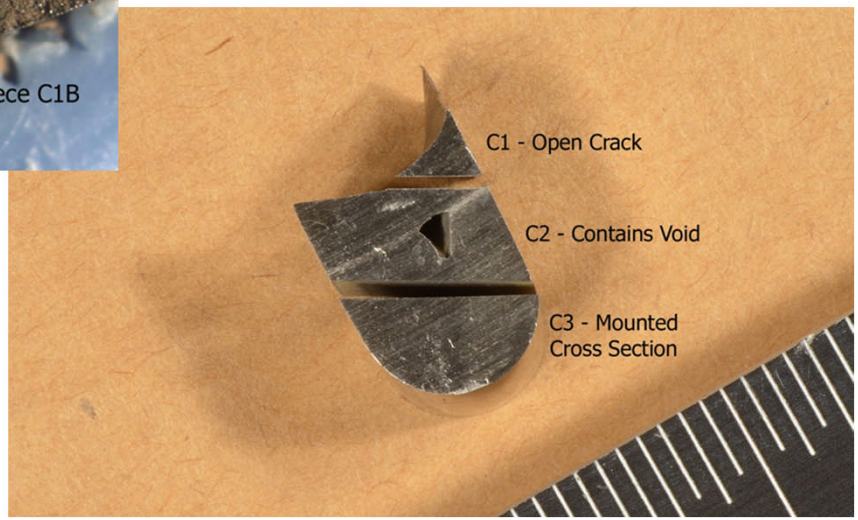


Sectioning (Piece C)

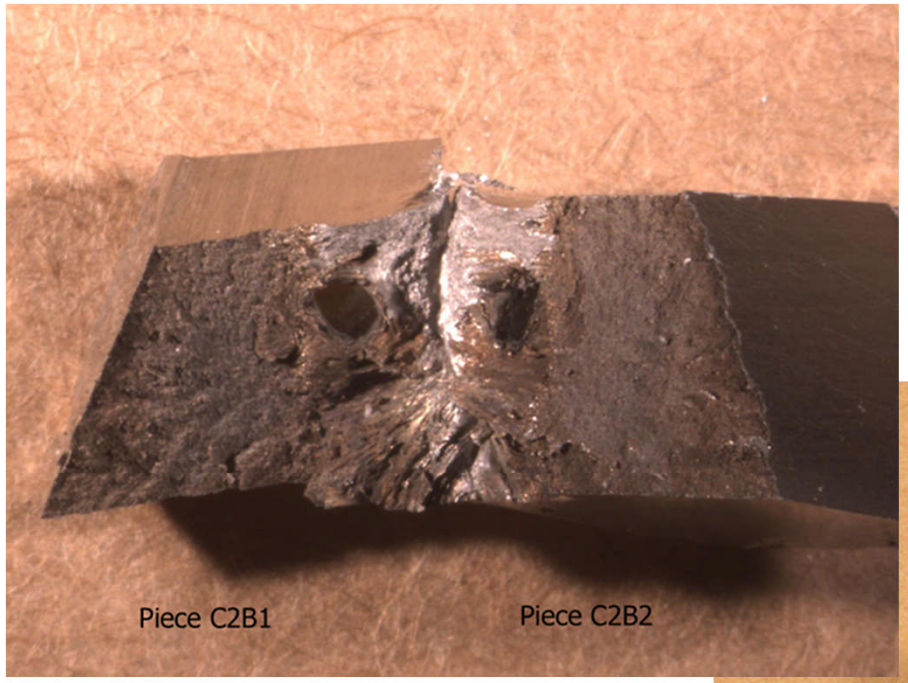


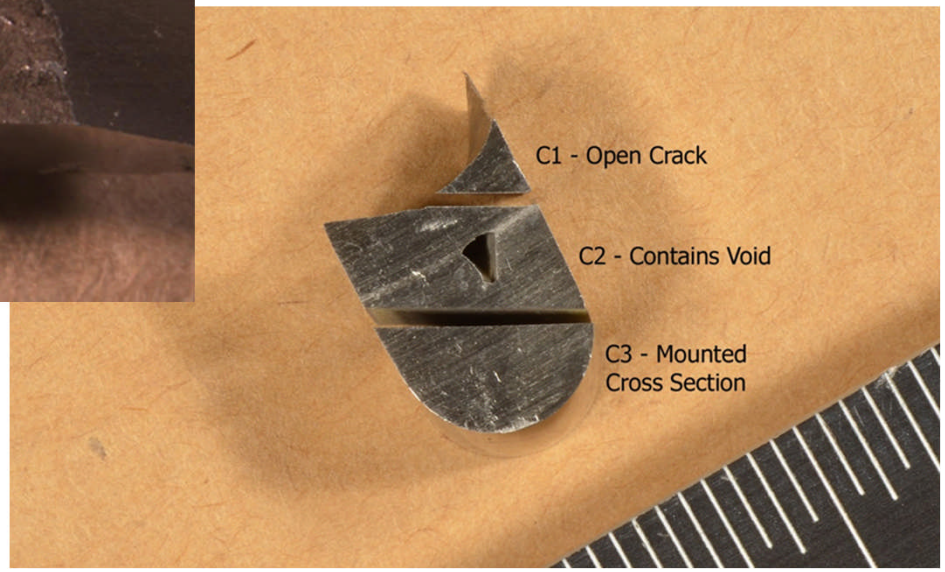
Sectioning (Piece C1)



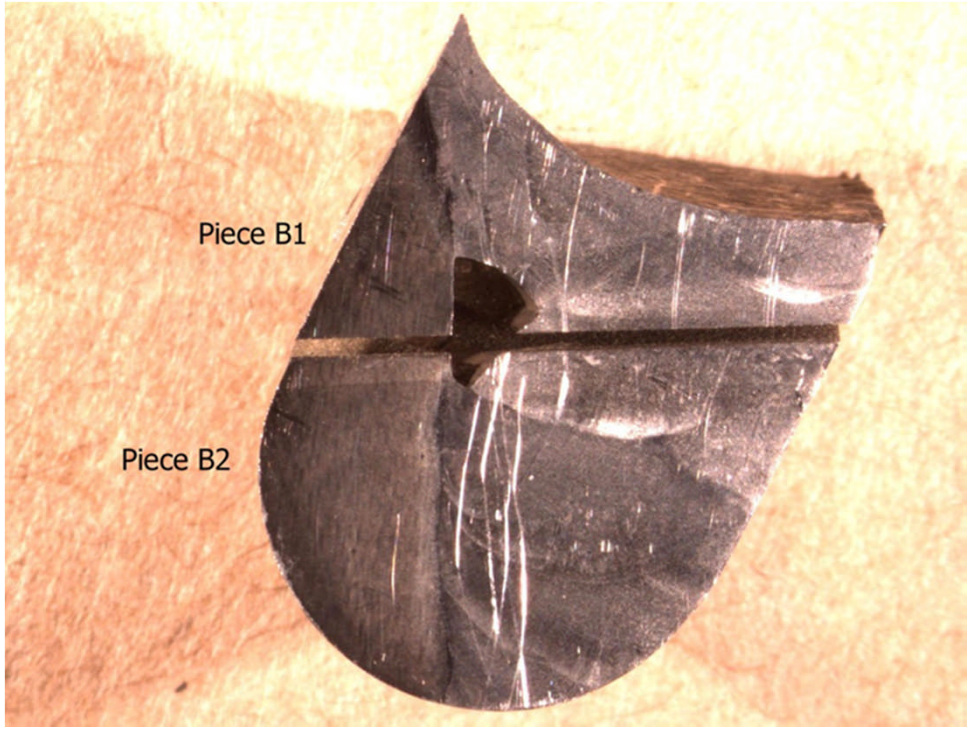


Sectioning (Piece C2)

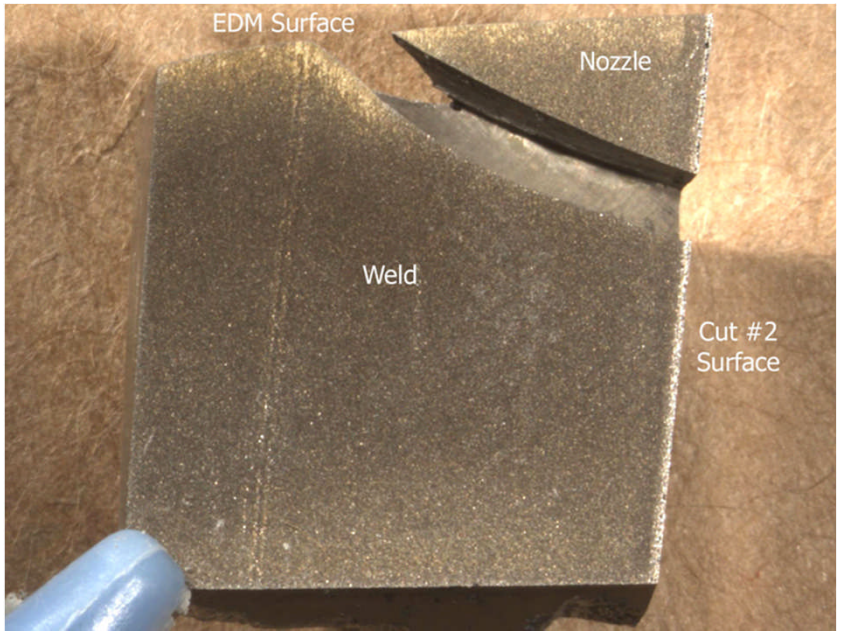


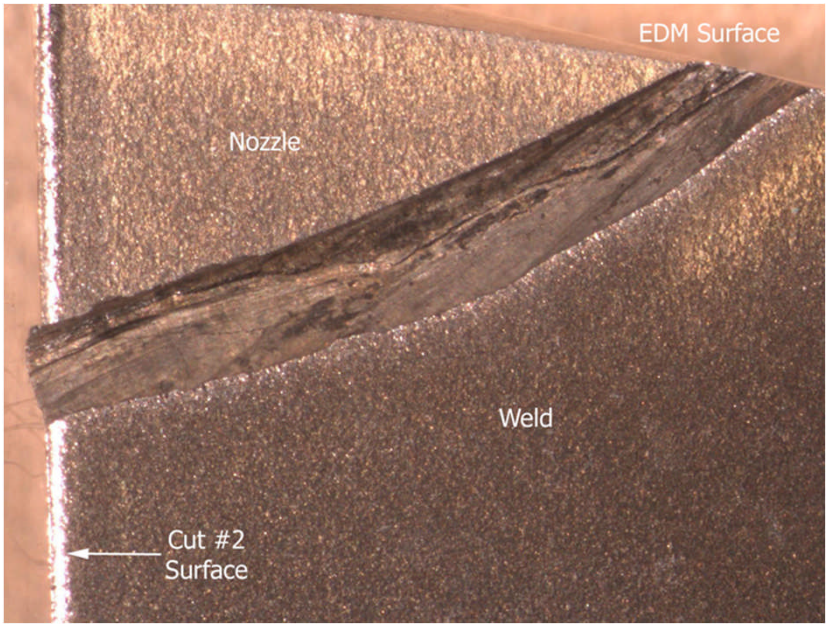


Sectioning (Piece B)

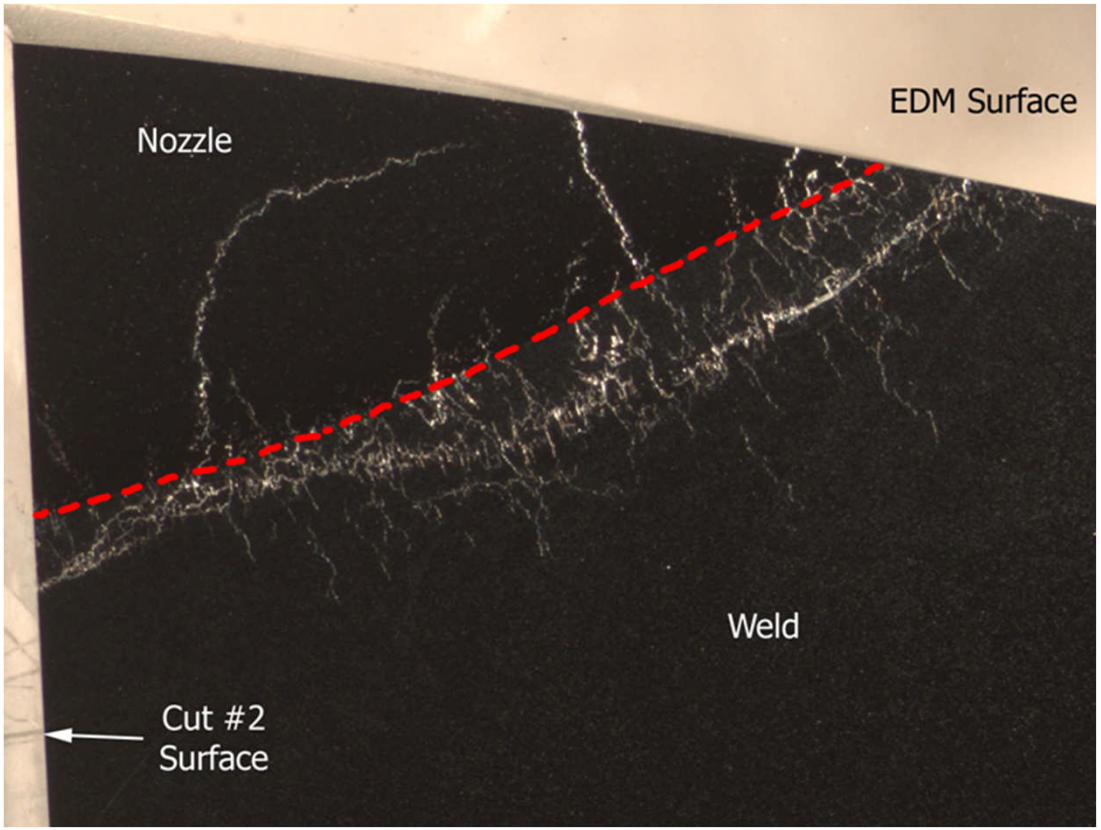


Sectioning (Piece B Upper and Lower)

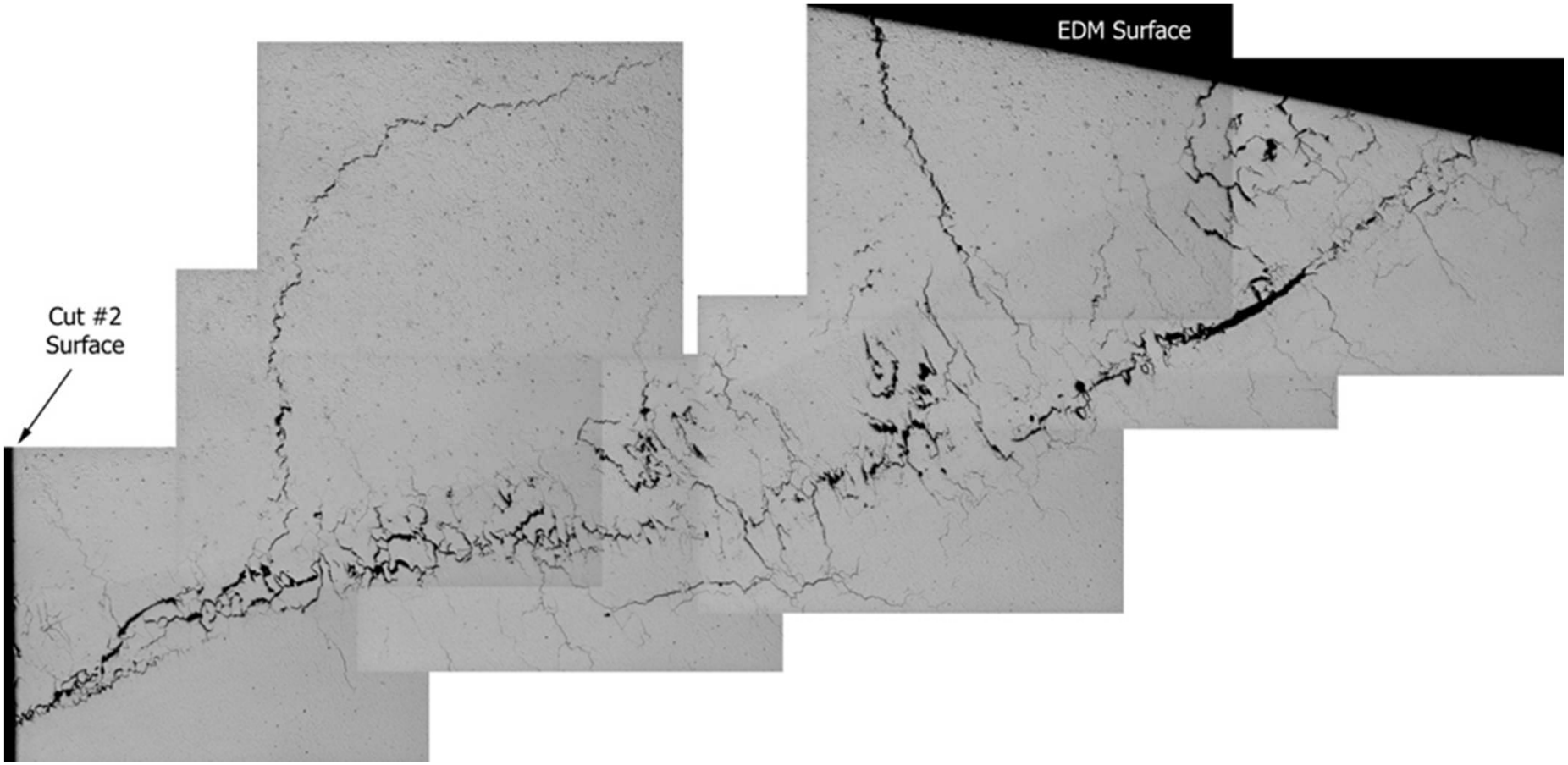




Sectioning (Piece B As polished below void)



Sectioning (Piece B below void)



Root Cause Summary

- Cracks are characteristic of PWSCC
- All cracks were found to be associated with the void.
- No obvious connection from void to wetted surface.