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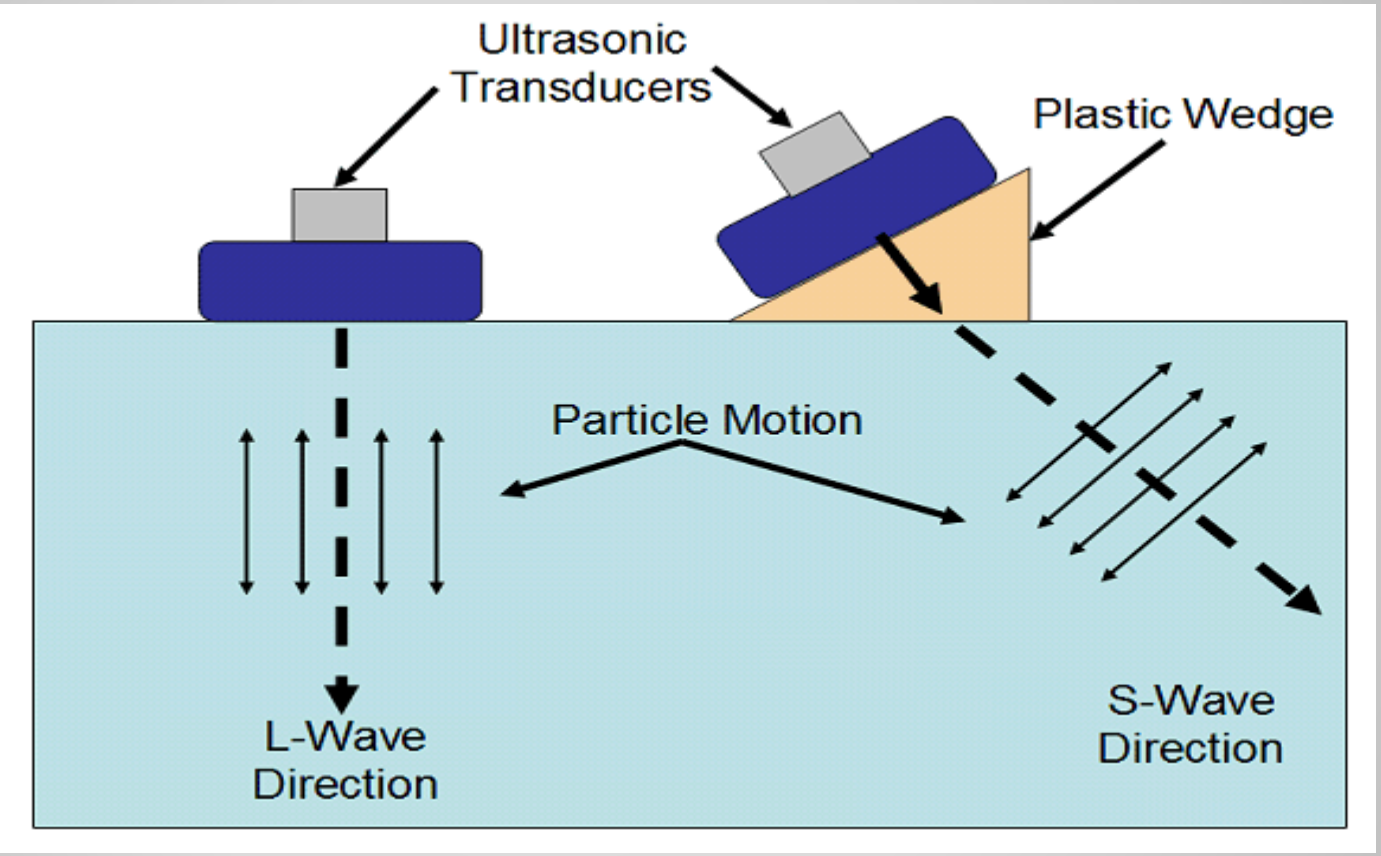
Field Application of Ultrasonic Phased Array for Structural Evaluation

September 5, 2013

CONVENTIONAL UT

- Reliable application to identify planar defects
- Single sound wave
- Single angle
- Transducer must be orientated in multiple directions
- Time consuming
- Results dependent on operator ability

CONVENTIONAL UT



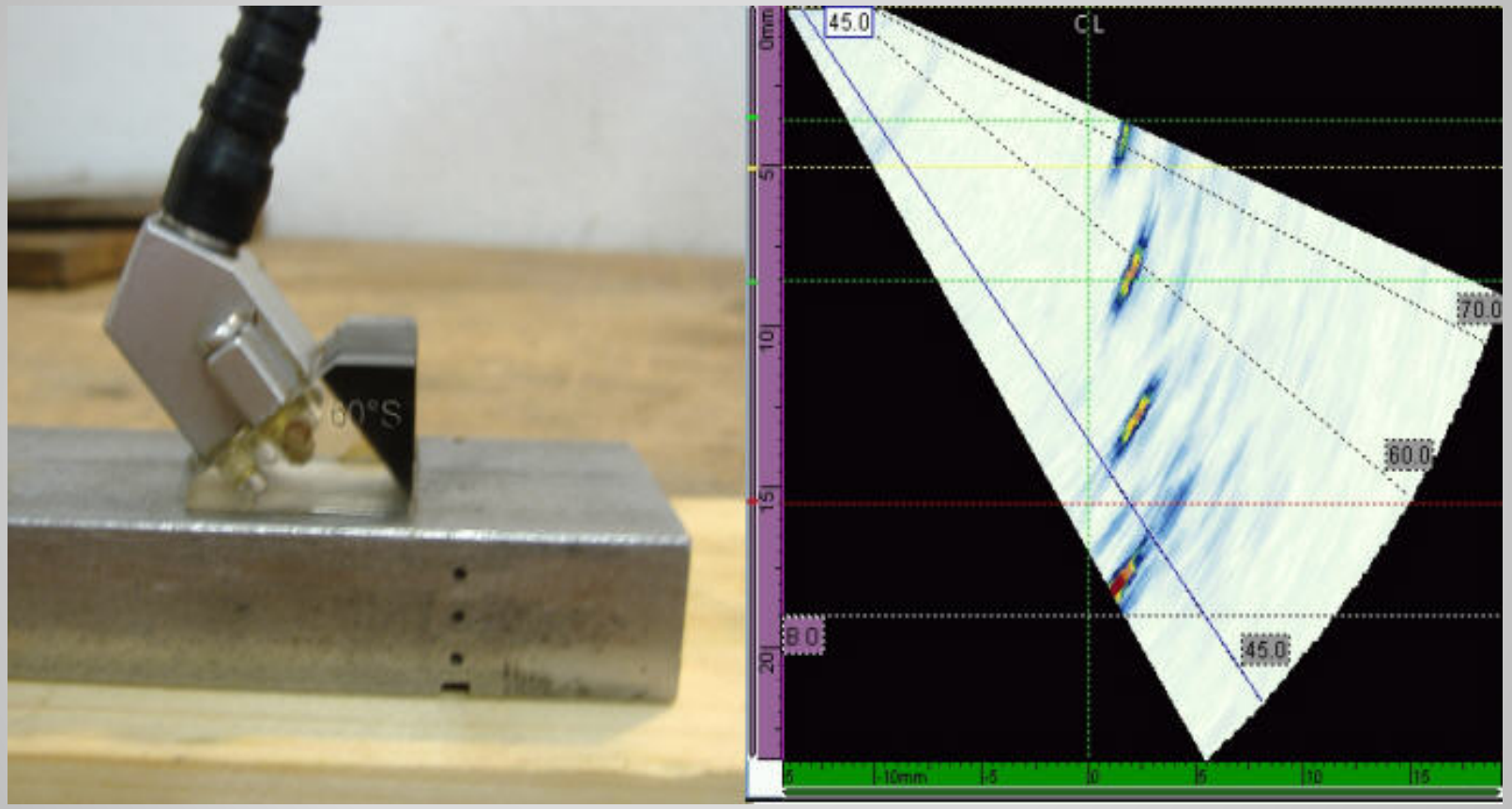
PHASED ARRAY UT

- Uses a multiple element probe
  - Typically 16 to 64 elements
- Time delays from ultrasonic pulses produce constructive interference
  - Occurs at a specific angle and specific depth
- Time delays are incremented over range of angles to sweep the beam
  - Allows beam steering and focusing

PHASED ARRAY UT

- May eliminate most radiographic testing needs
  - Especially important for field application due to uncontrolled environment
- Increases resolution and sensitivity over conventional UT
- Allows for cross-sectional “2D” view of indications
  - Sector Scan (S-Scan)

SECTOR SCAN (S-SCAN)



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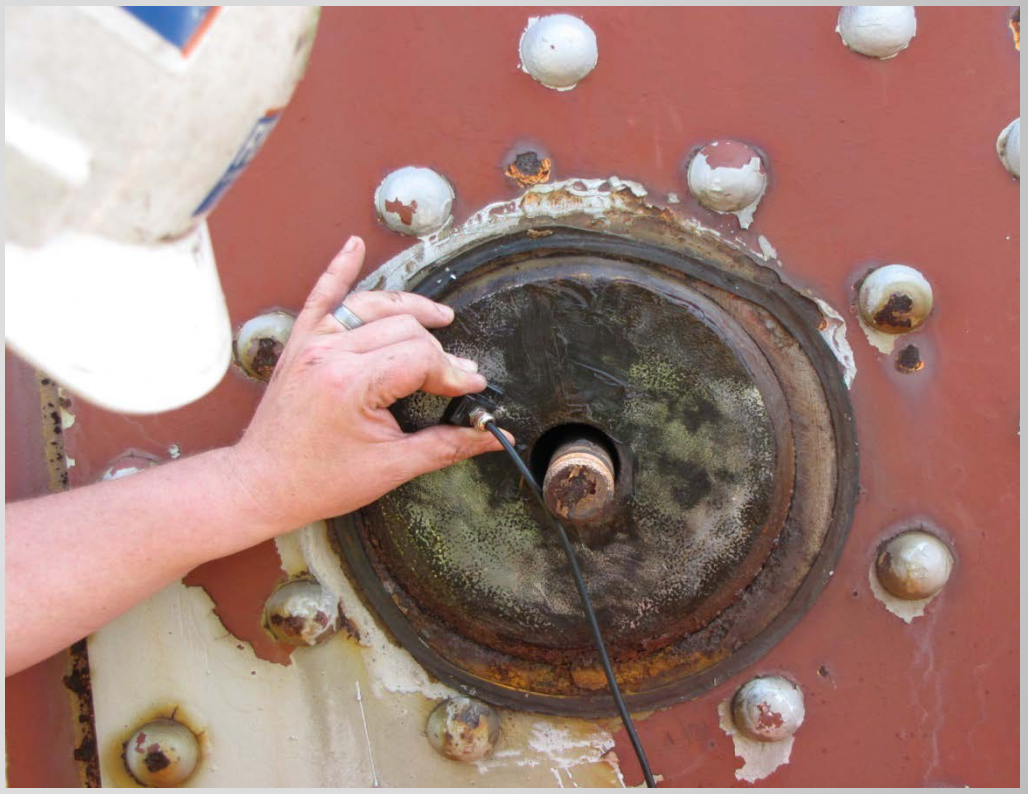
COMMON BRIDGE APPLICATIONS OF PAUT

- Welds
- Pins
- Hangers
- Section Loss
  - Gusset Plates
  - Connections



WELD TESTING

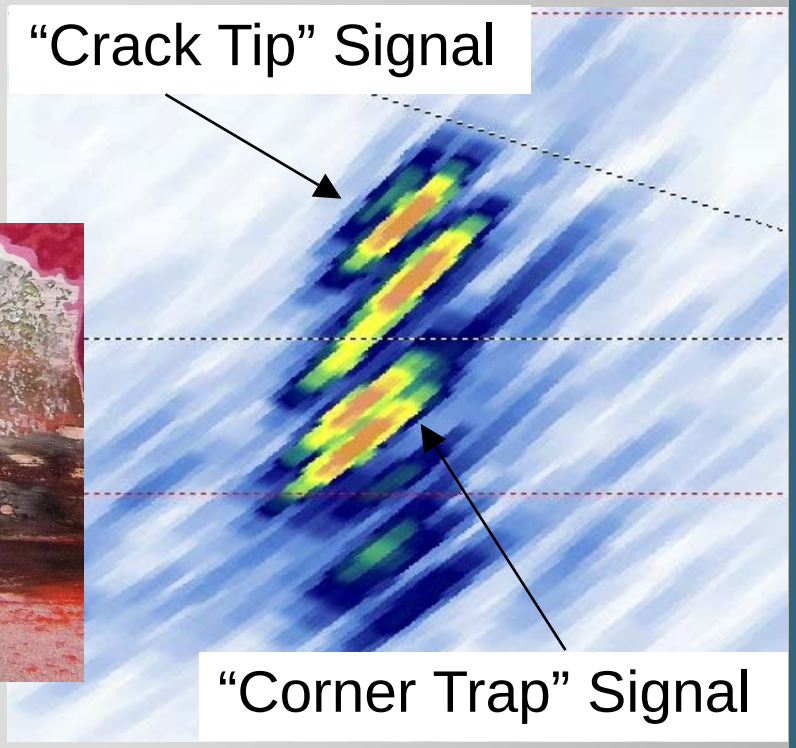
- Locate critical welds
  - Fracture critical welds
  - Electroslag welds
  - A514 “T-1” steel
- Scan along length of weld
- Test both full penetration and partial penetration welds
  - Check for internal discontinuities or cracking

WELD TESTING

- Hydrogen cracking of A514 “T-1” web-to-flange welds

Scanning parallel with weld axis

MT Indication



S-Scan Data

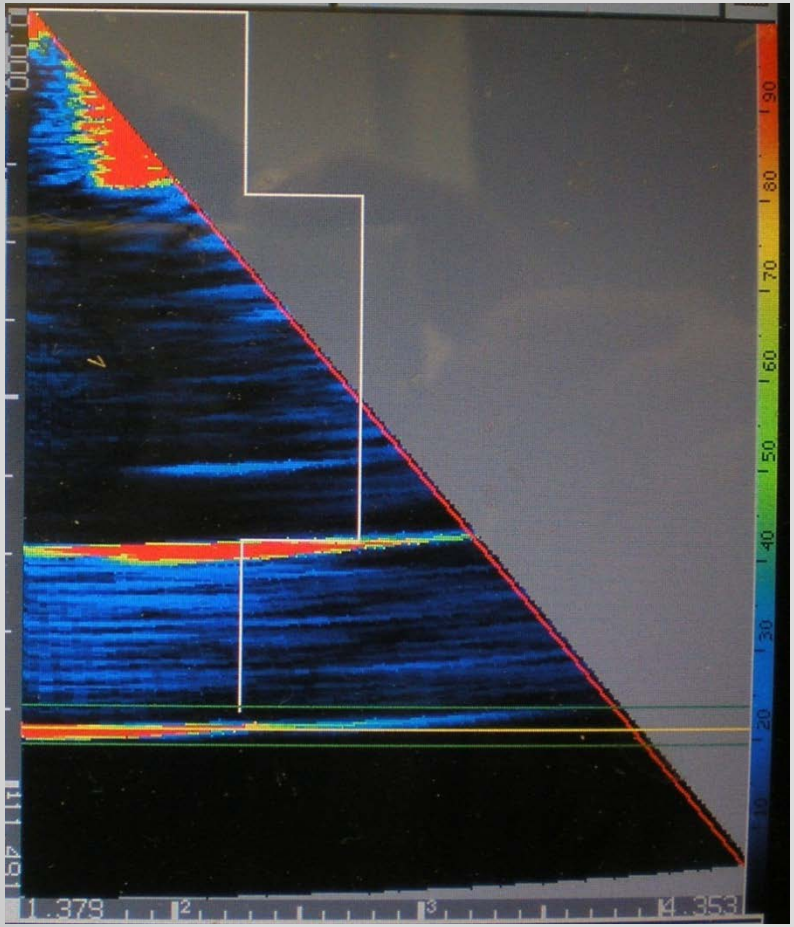
WELD TESTING SUCCESSES

- Increased sensitivity
  - Can even pick up weld prep on electroslag welds
  - Need to be careful not to oversaturate with gain
- Increased sizing and location data
  - Help to identify type of flaw

PINS AND HANGERS

- Test pins on both ends when possible
  - Sectorial view of pin
  - Rotate transducer for full coverage
- Test hangers and link bars around pin hole
  - Check for cracking

PINS AND HANGERS



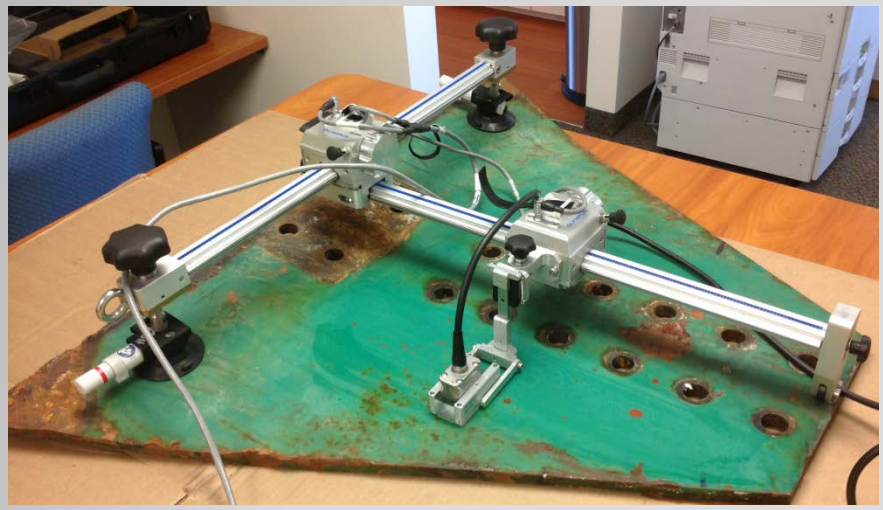
PIN AND HANGER SUCCESSES

- Increased sensitivity
- Clearly distinguish flaws and determine size
- Reduces error from acoustic coupling
  - Distinguish outside pin surface

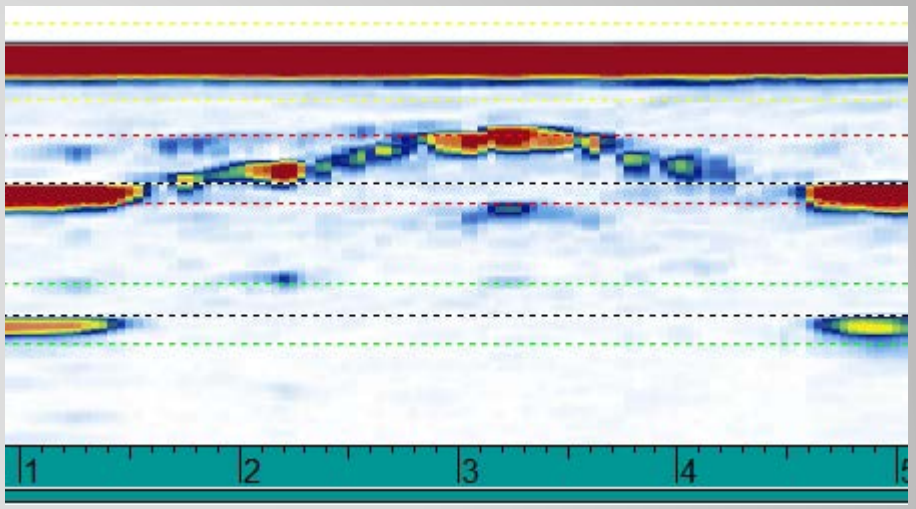
SECTION LOSS

- Gusset plates
  - Scan plate along outside edge of connecting members
  - Encode thickness profile
- Connections
  - Remaining thickness of outside plies

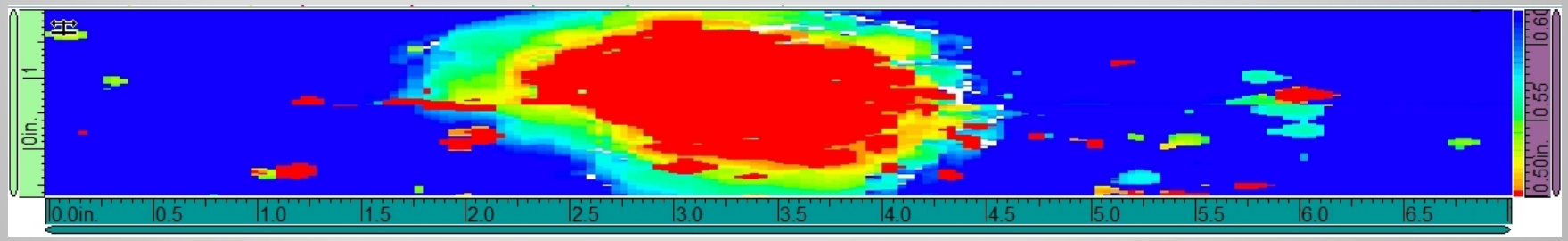
SECTION LOSS



Corrosion Scanning



Corrosion B-Scan



Corrosion C-Scan

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SECTION LOSS SUCCESSES

- Gusset plates
  - Encoded variable section loss profile
- Plate material
  - Increased sensitivity and ability to size inclusions/stringers

FIELD APPLICATION TECHNIQUES

- Scan plans
  - Sound coverage
- Calibration
  - Attenuation
  - Flaw Size
- Encoding
- Interpretation

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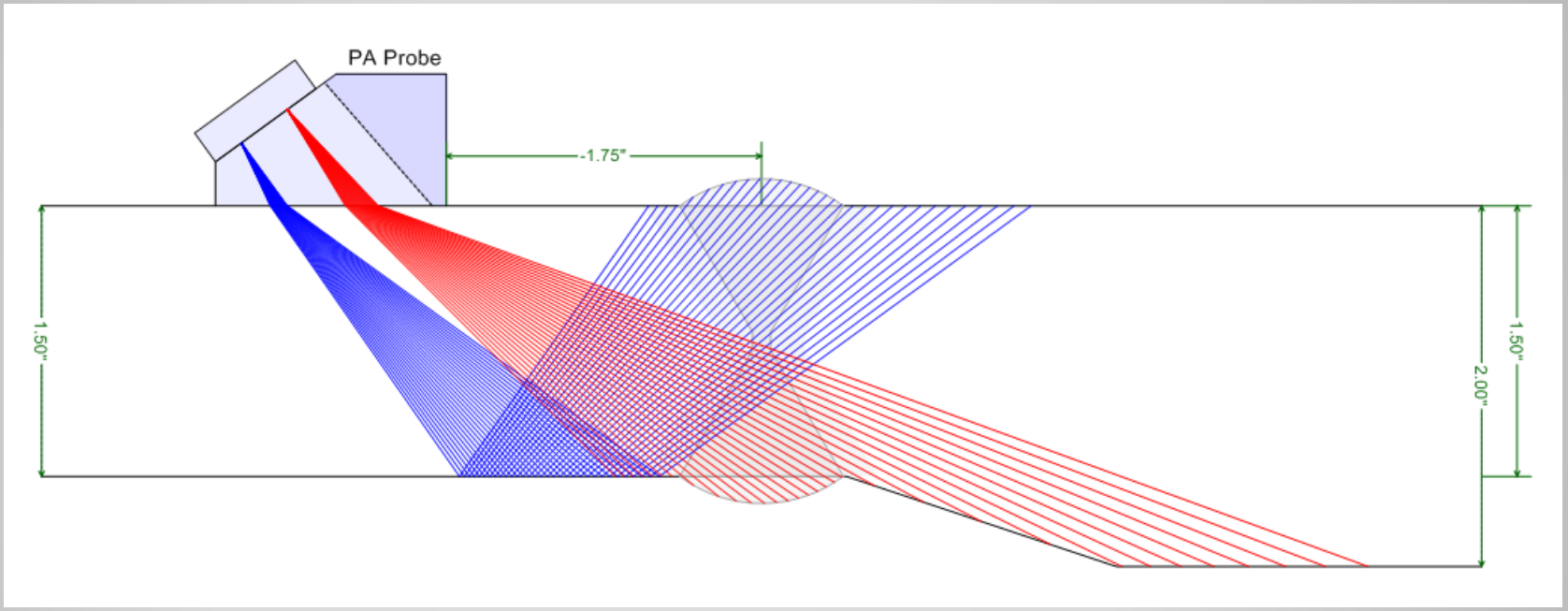
SCAN PLANS FOR WELD TESTING

- Sound coverage
  - Scan offset
  - Angle range
  - Single or multiple group of elements
  - Location of first element in array
- Two or more scans for complete coverage with multiple angles

SCAN PLANS FOR WELD TESTING

- Account for weld reinforcement
  - Sound scattering off reinforcement in 2nd leg
  - Cannot scan overtop of weld to cover weld in 1st leg
- Sketches or software are needed in developing weld testing scan plans

SCAN PLANS FOR WELD TESTING



- Beam 1 – 2nd leg, 8 elements 35°-55°
- Beam 2 – 1st leg, 8 elements 45°-70°

SCAN PLANS FOR PIN TESTING

- Scan coverage
  - Testing from both sides, if possible
  - Shoulder may block region of pin if testing from one side
  - Angle range
- Room on pin end for transducer

CALIBRATION

- Larger calibration blocks
  - Time Corrected Gain (TCG) requires calibration blocks thicker than tested plate
  - Cannot receive signals from multiple reflectors when sweeping through all of the angles
  - Often cannot change input gain when performing calibration

CALIBRATION

- Flaw sizing
  - Need test samples with accurately known flaws
  - Need to closely represent actual indications in shape

ENCODING & TEST FIXTURE

- Need to encode transducer location
  - Section loss requires X-Y location
  - Weld scan requires location along weld
  - Pin requires rotation θ
- Test fixture needed for consistent and documented scanning
  - Magnetic guide
  - External frame

ENCODING & TEST FIXTURE

- Needs to function on rough surface
  - May need to rescan to get skipped data
- Bolts and rivets in the way
- Couplant on surface
  - String encoders better than wheel encoders

INTERPRETATION & ACCEPTANCE CRITERIA

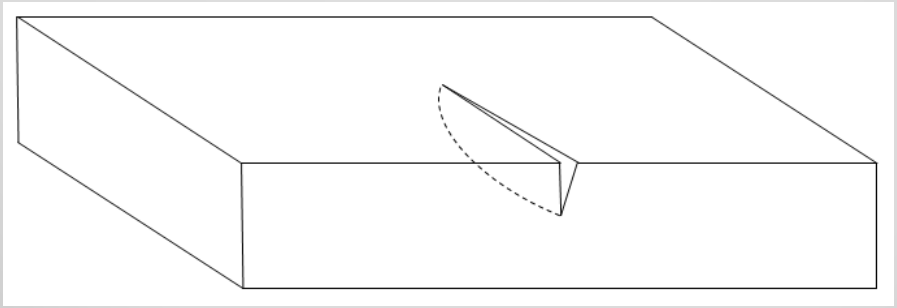
- Welds
  - AWS currently based on amplitude of response at only given angles
  - Maximum amplitude from PAUT will often occur at an angle different than conventional UT
  - Flaw sizing from PAUT
  - Comparison to calibration and flaw sizing blocks

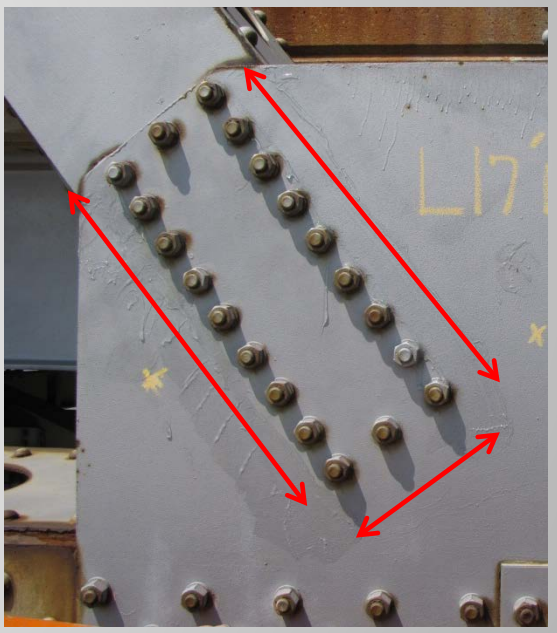
INTERPRETATION & ACCEPTANCE CRITERIA

- Pins
  - No standard acceptance criteria
  - Often too long for TCG calibration blocks in the field

CRITICAL INFORMATION

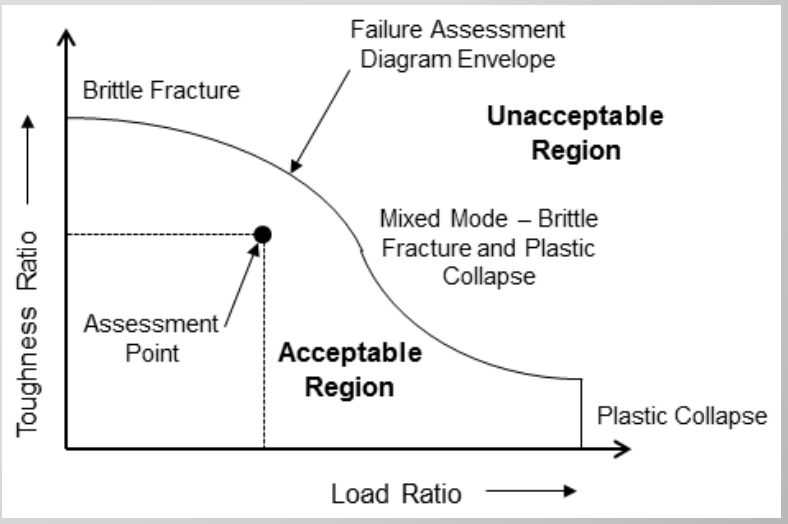
- Section loss profile
  - Calculate percentage of remaining section
  - Perform structural capacity check
- Flaw size and location
  - Flaw height and length
  - Location and depth in member





APPLICATION TO ENGINEERING EVALUATION

- Fitness-for-service (FFS)
  - Quantitative evaluation accounting for flaw
  - Requires stress, material properties, and flaw characterization
  - Considers fracture potential and fatigue life



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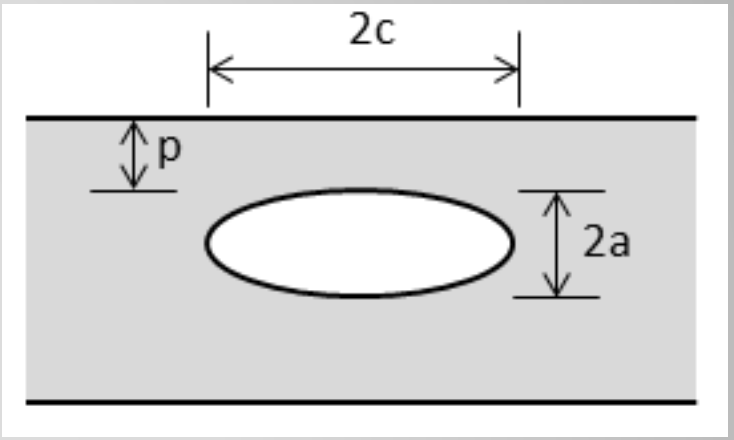
APPLICATION TO ENGINEERING EVALUATION

- Flaw characterization for FFS
  - Interaction of nearby flaws
  - Size and shape
    - Height, Length
  - Flaw location & type
    - Location along length of member
    - Location within the thickness of the member
    - Classifications: Surface flaw, Edge flaw, Embedded flaw, Through-thickness flaw



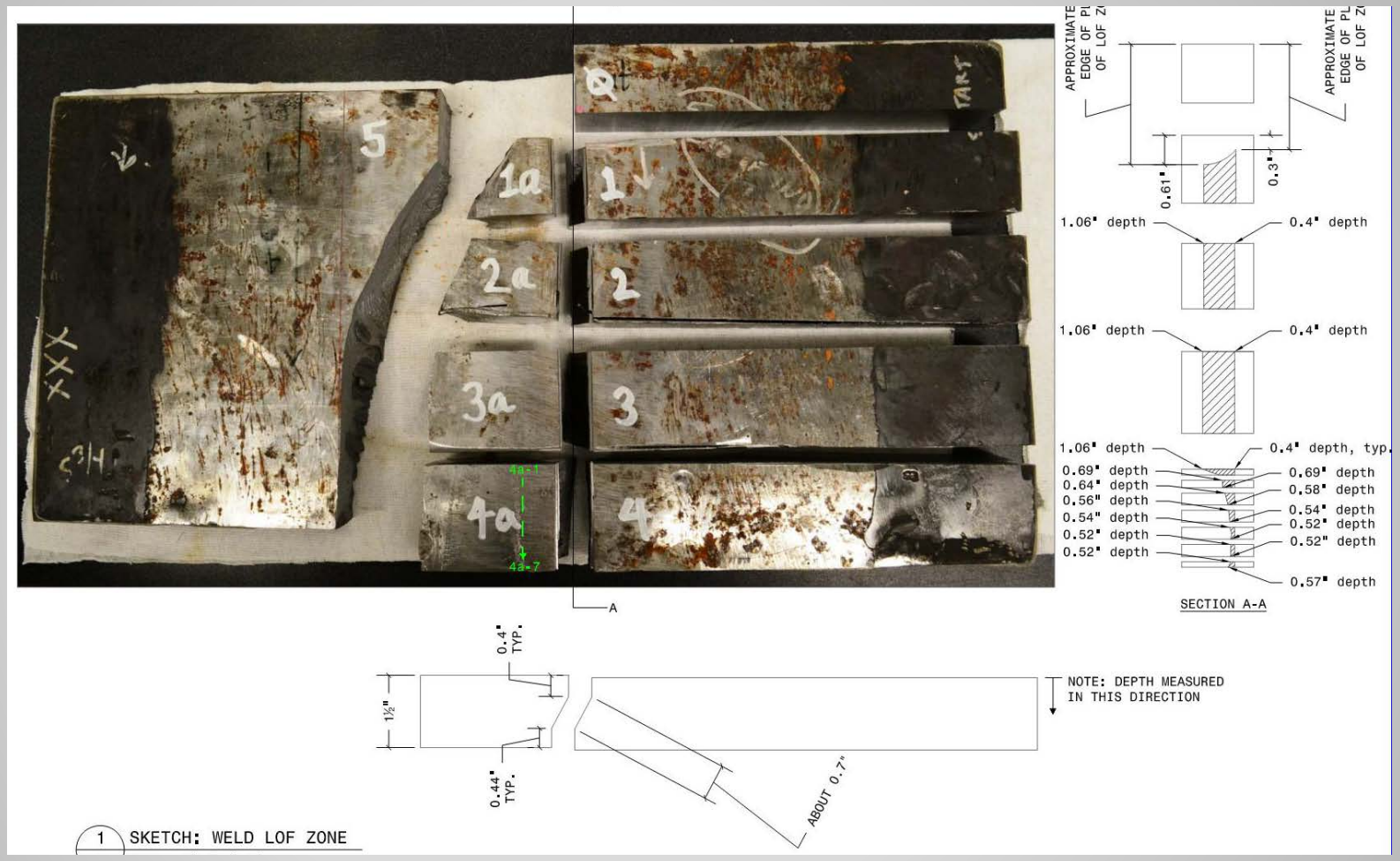
APPLICATION TO ENGINEERING EVALUATION

- Sensitivity to error in flaw sizing
  - Fracture potential
    - Error in flaw size is not as sensitive as errors in stress and material properties
  - Fatigue crack growth
    - Error in flaw size effects fatigue life through initial size and crack growth rate calculations

CURRENT RESEARCH PROJECT

- Artificial flaws in butt weld samples
  - Lack of sidewall fusion
  - Lack of penetration
  - Inclusion
  - Internal weld crack
- Break plates open and compare results to PAUT

SAMPLE 1: LACK OF FUSION



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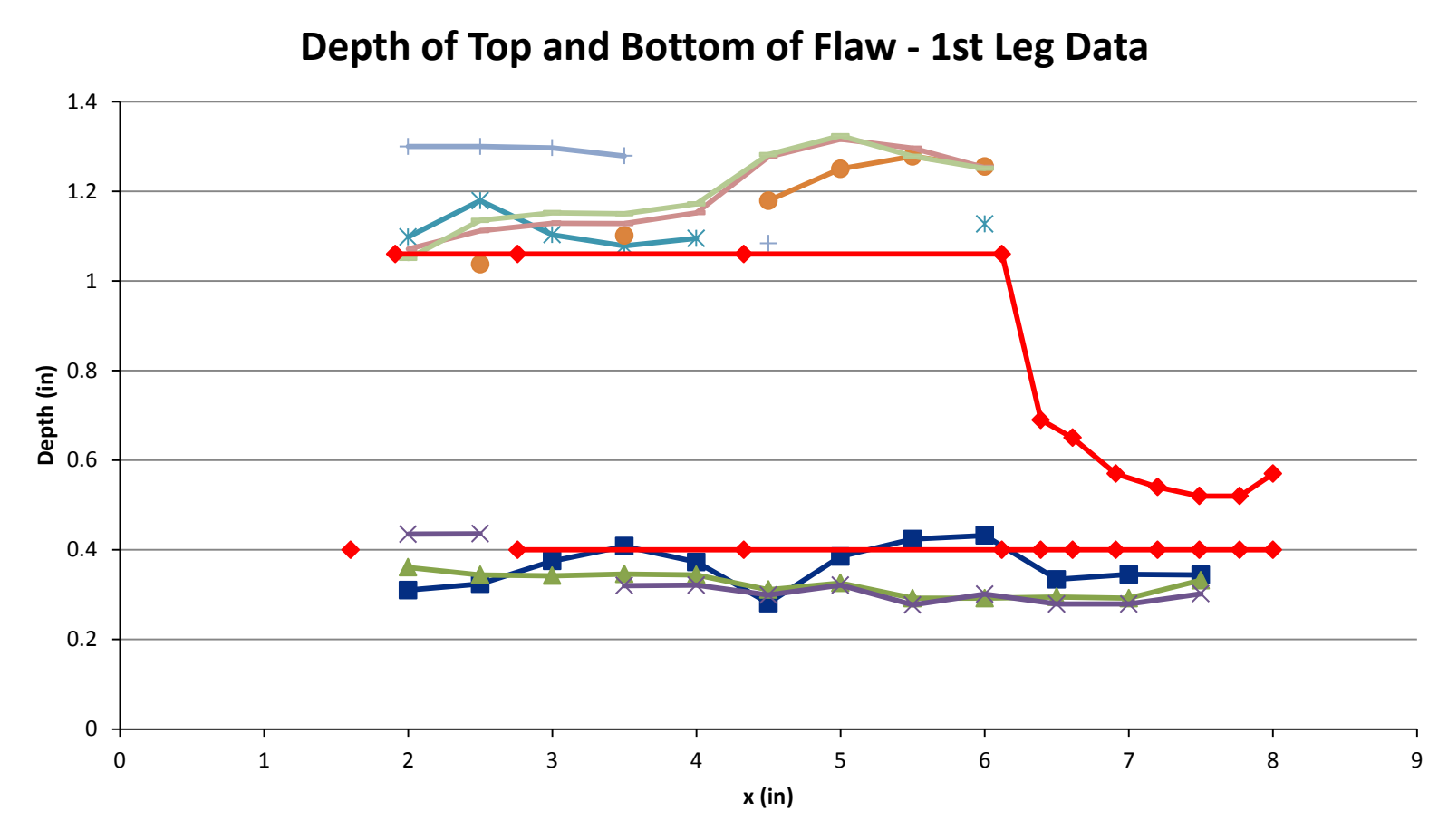

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QUESTIONS?

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