# Managing Challenges with Pipeline Seam Welds

## Identifying Gaps in Technology

- **Current ILI technologies applied to seam weld threat**
  - Detection and Characterization
  - Effectiveness and Limitations
- **Understanding ILI performance applied to seam weld threat**
  - Industry Experience
  - Current Industry Guidance
  - Current Research

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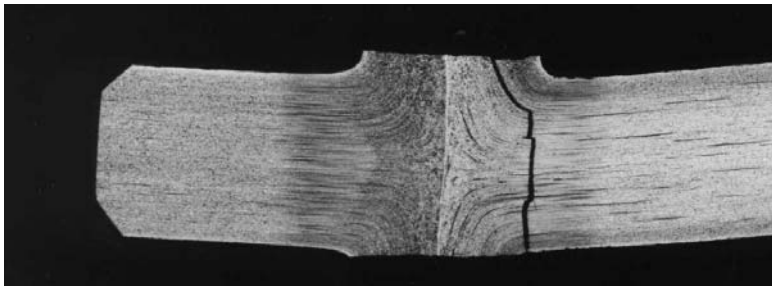
# Fundamental Considerations

- A seam weld - good, bad, deteriorating - provides a signal
  - Detection: Is the signal coming from a potentially critical anomaly or a benign condition?
  - Sizing: Does the anomaly need in the ditch assessment?
- Parameters that effect detection and sizing
  - Length
  - Depth
  - ID or OD
  - Straight or curved, angled
  - Crack opening, stitched weld
  - Diameter and wall thickness
  - Pipe material, inclusions
  - Inspection conditions and cleanliness

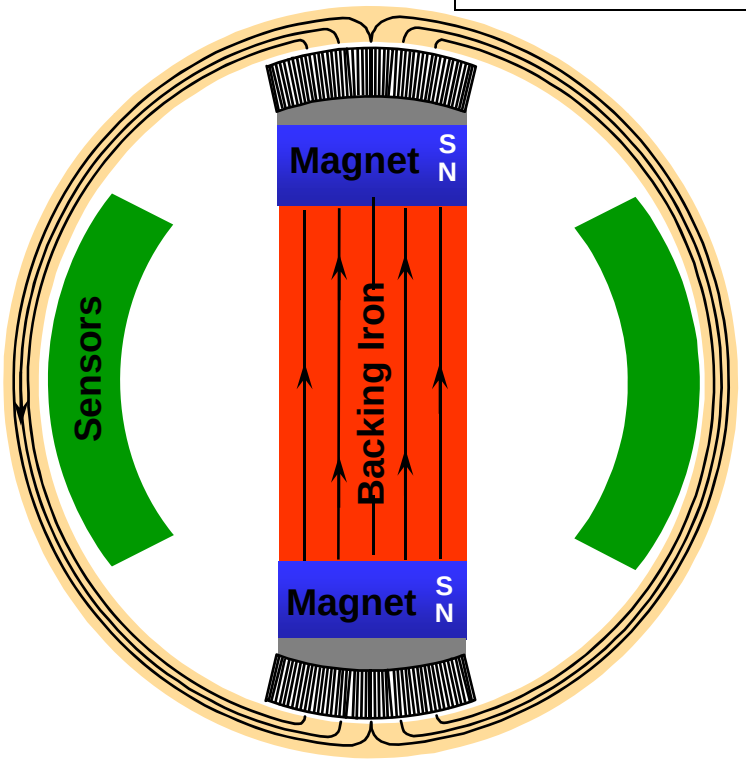


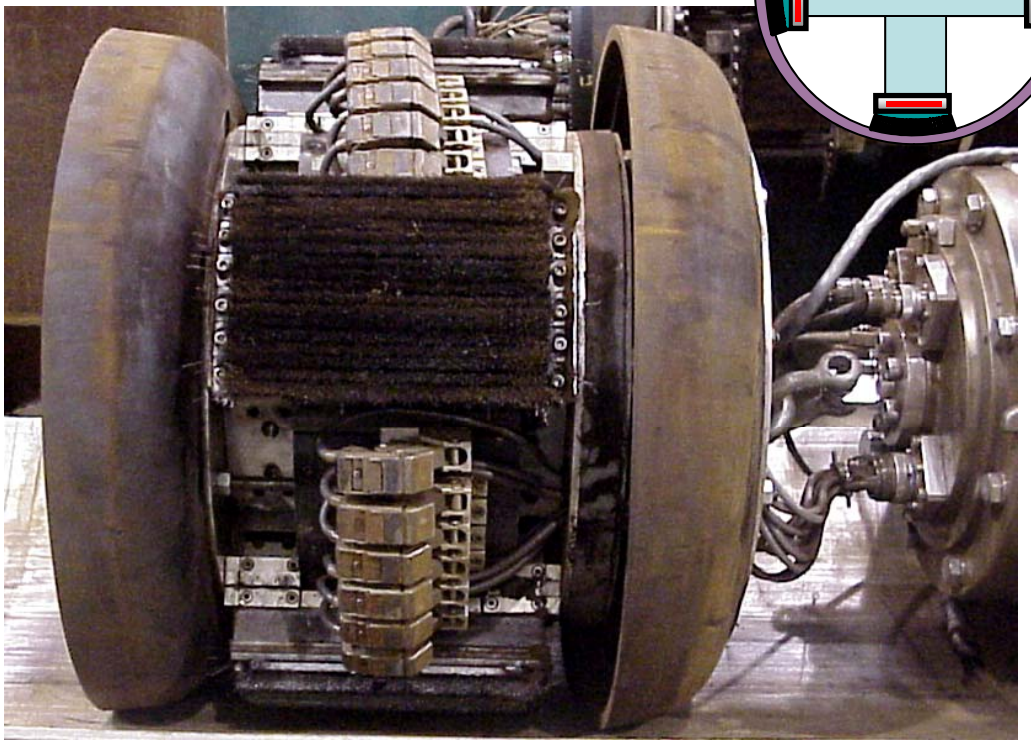
## Current In-Line Inspection (ILI) Technologies

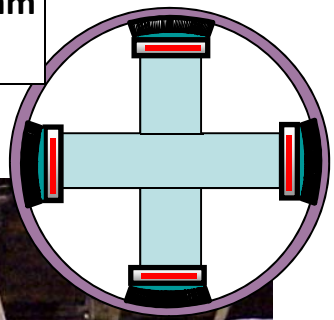
- **MFL – with a the magnetizer putting energy into the hoop direction**
  - Transverse, Circumferential, Spiral
- **Liquid coupled ultrasonic**
  - **Angled transducers putting energy into the hoop direction.**
    - **First UT pigs for corrosion deployed in 1986**
    - **Angle beam UT pigs for crack detection in 1997**
- **E**lectro**m**agnetic **A**coustic **T**ransducer
  - An ultrasonic method that works in gas lines
    - **First commercial deployment in 2004**
- **Phased Array Crack Detection**
  - piezoelectric, liquid coupling

# Circumferential MFL Pig

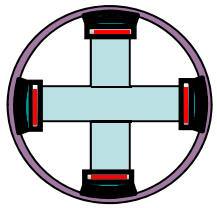
| | Stated Performance | |
|---|---|---|
| | Tech A | Tech B |
| Minimum Flaw Opening | 0.1 mm | 0.2 mm |
| Planar Flaw Depth Limit | 0.5t for 25-50mm length | 0.2t for > 25mm |
| | 0.25t for > 50mm length | |



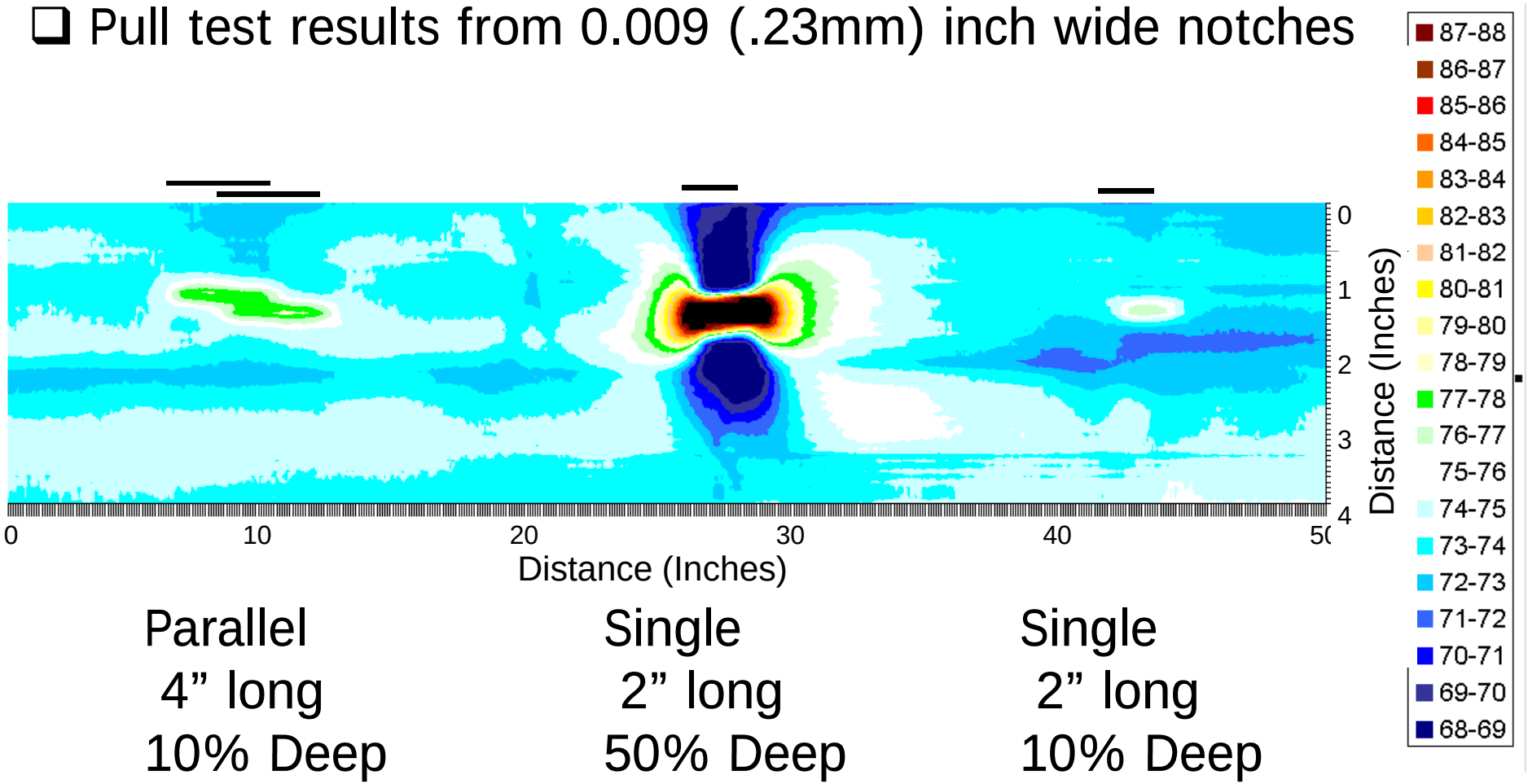





# Test Results on Notches

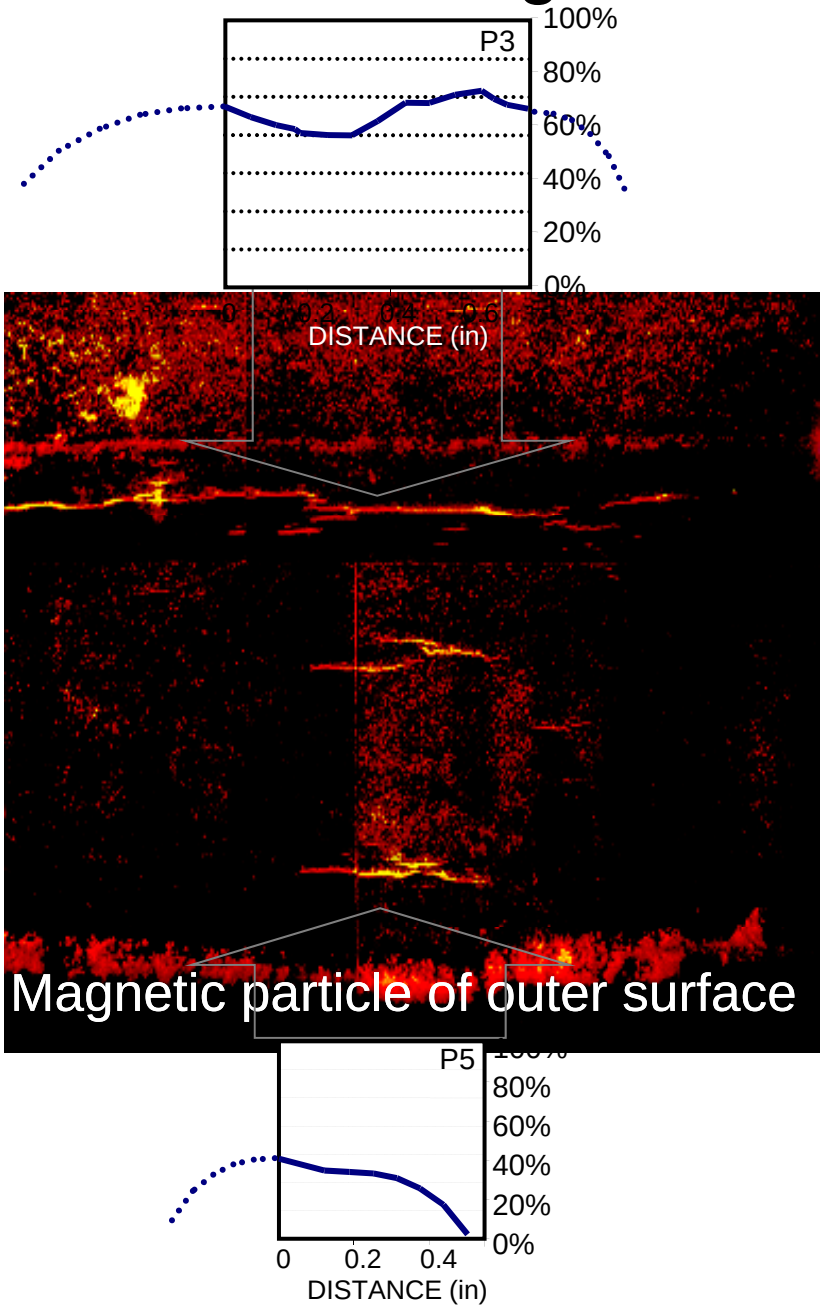


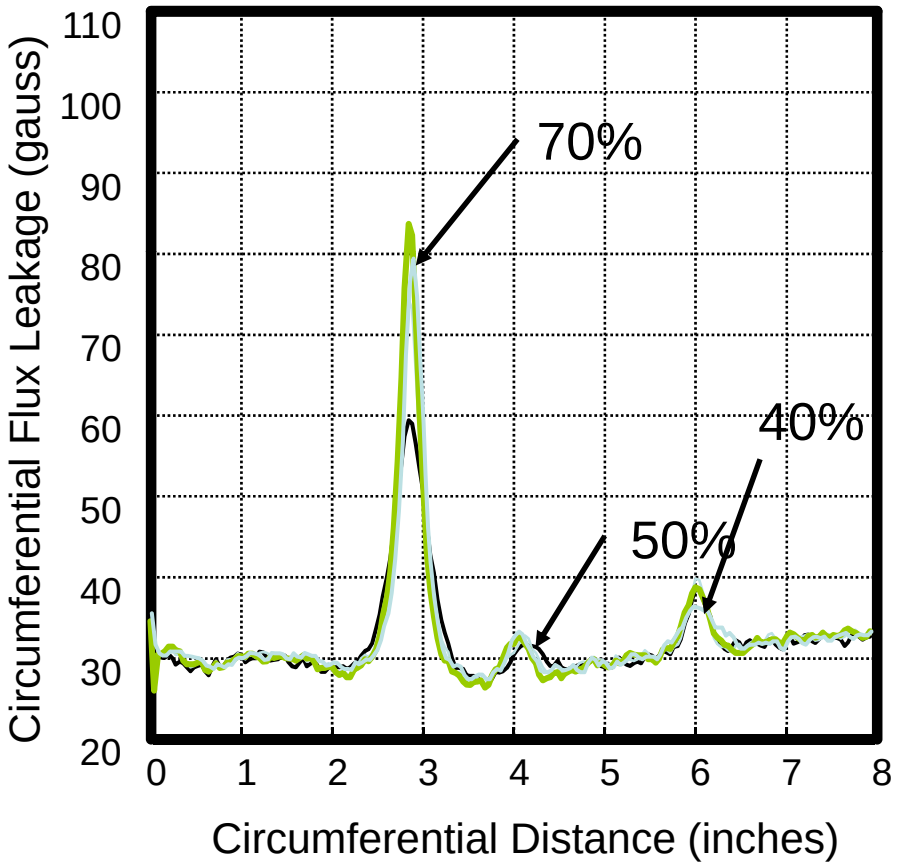
- Pull test results from 0.009 (.23mm) inch wide notches




| Parallel | Single | Single |
|---|---|---|
| 4” long | 2” long | 2” long |
| 10% Deep | 50% Deep | 10% Deep |

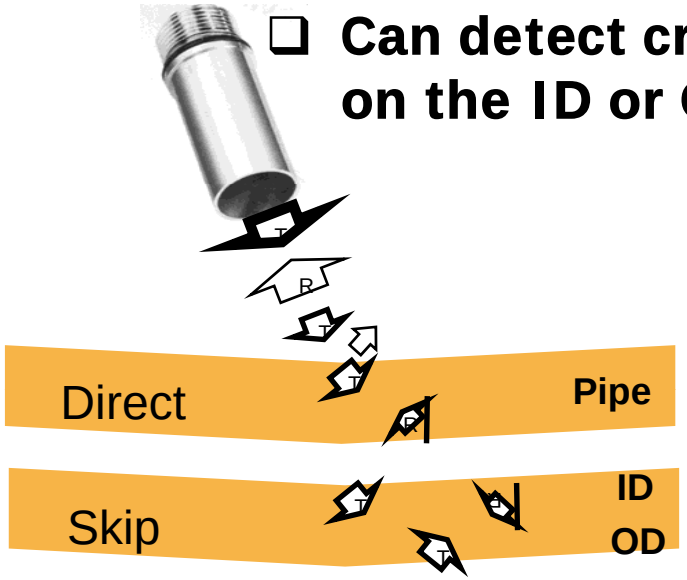
# Detection of Tight anomalies such as SCC

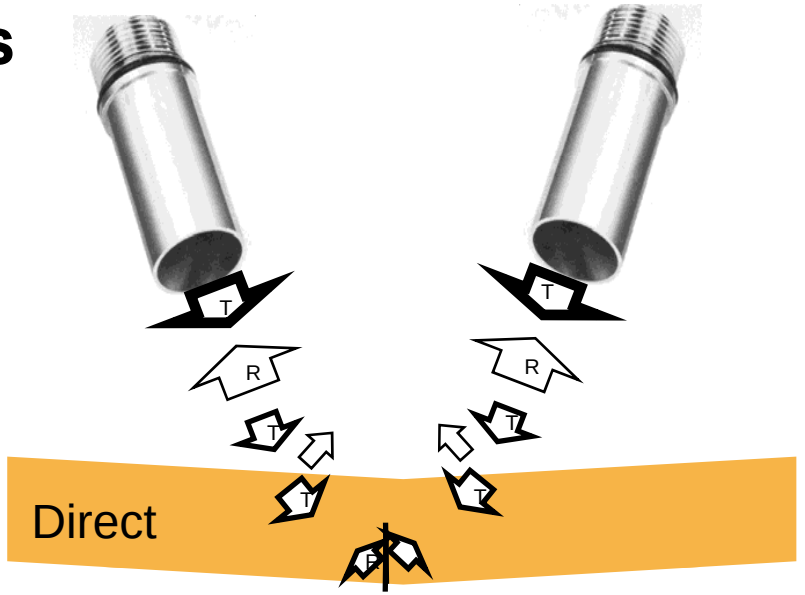


# Liquid Coupled Ultrasonic Basics

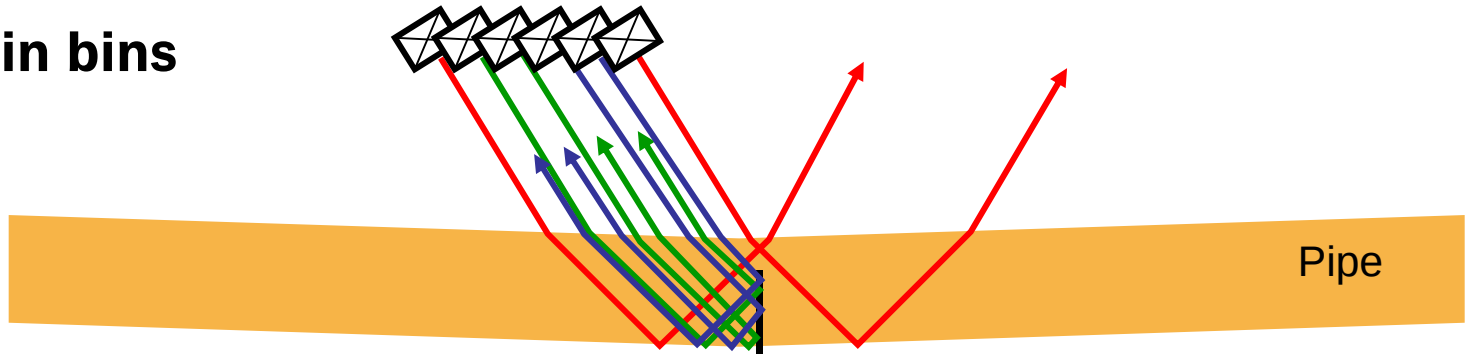
- Can detect cracks on the ID or OD



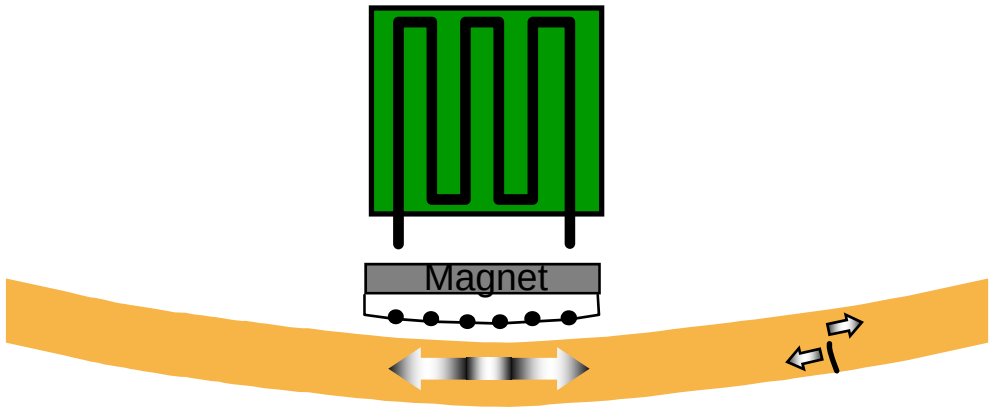

- Detection from both sides reduces false calls
  - But both sides can give different signals

- Amplitude good for detection
- Lots of sensors improve with sizing
- Sizes in bins



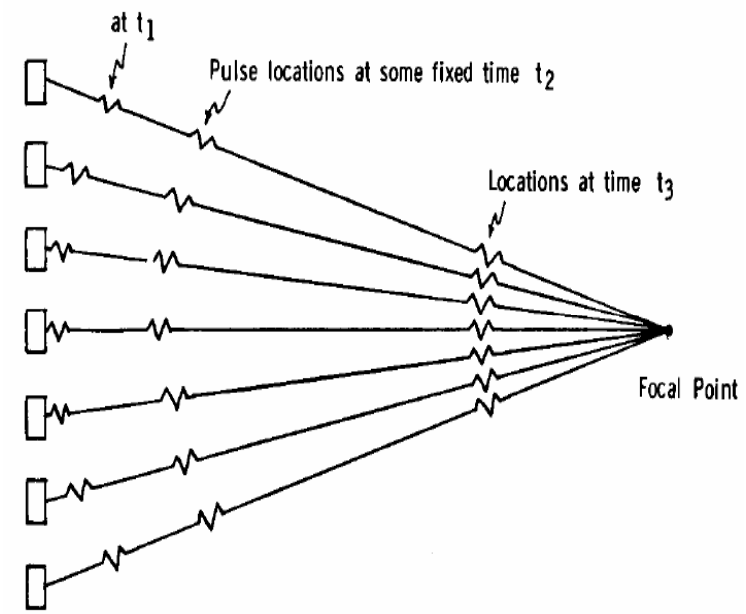
## Emerging EMAT

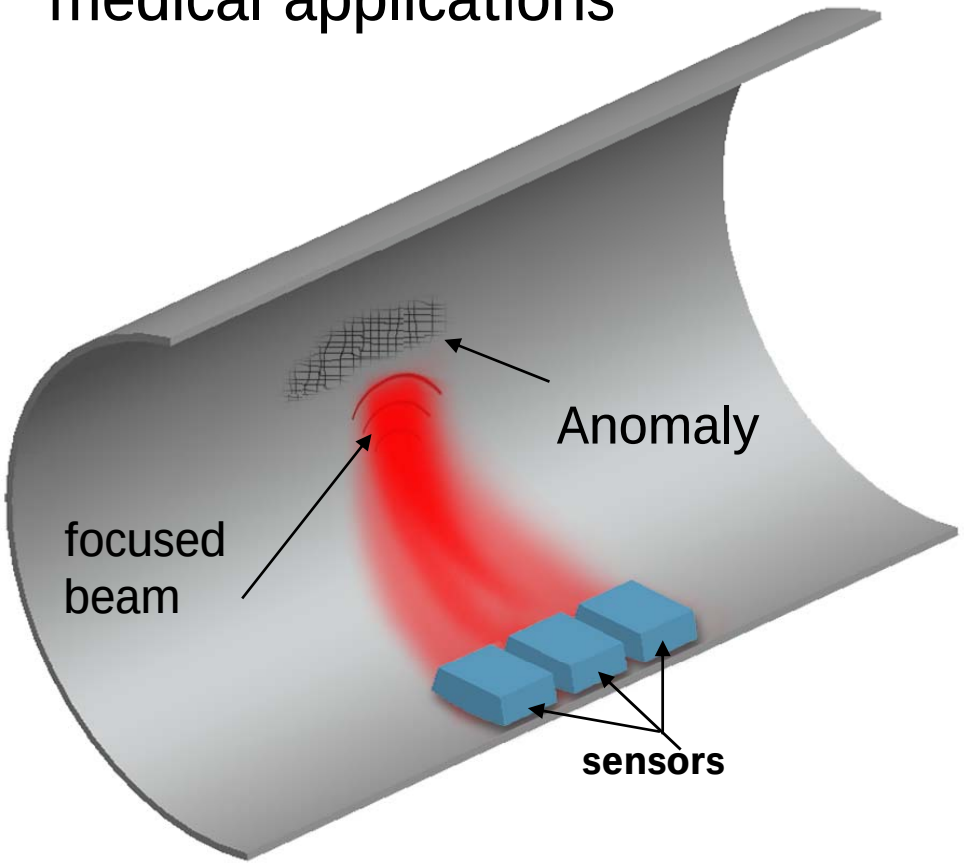
- **E**lectro**m**agnetic **A**coustic **T**ransducer
  - An ultrasonic method that works in all lines, gas included
  - Typically work lower 10x lower frequency than conventional ultrasonic. Higher frequency means better resolution.
- Initial discovery and fundamental research by Rockwell Science Center in the 1960's
  - The challenge is to make EMAT Sensors small and rugged
- Many configurations possible



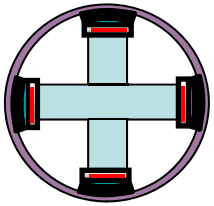
# Phased Array

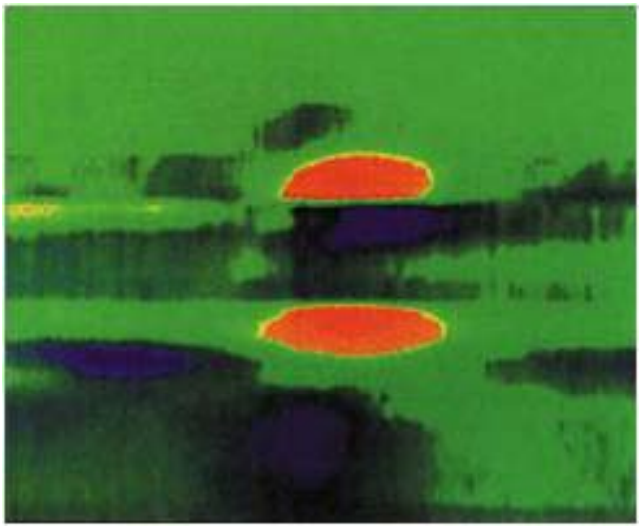
- Many ultrasonic transducers
- Needs liquid coupling
- Excellent diagnostic capability in medical applications



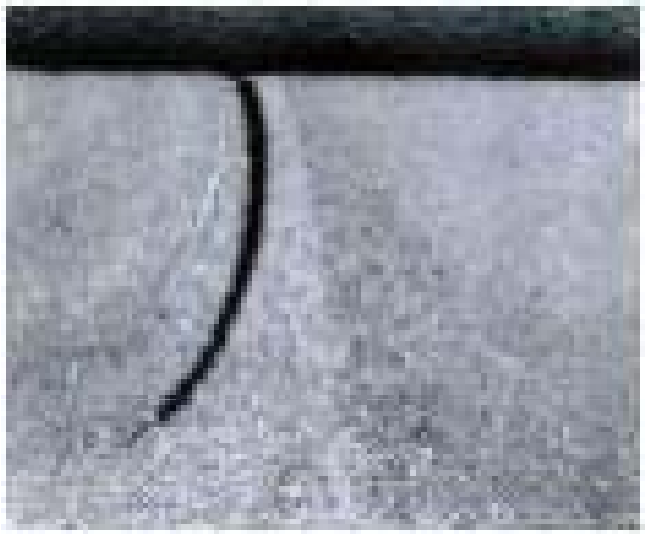




# Field Results using Circ MFL





ILI Signal



Actual Hook Crack

**Wide mouth cracks and Narrow Axial Corrosion**

Not really an issue for ILI or Field NDE

**Integrity Management Challenge**

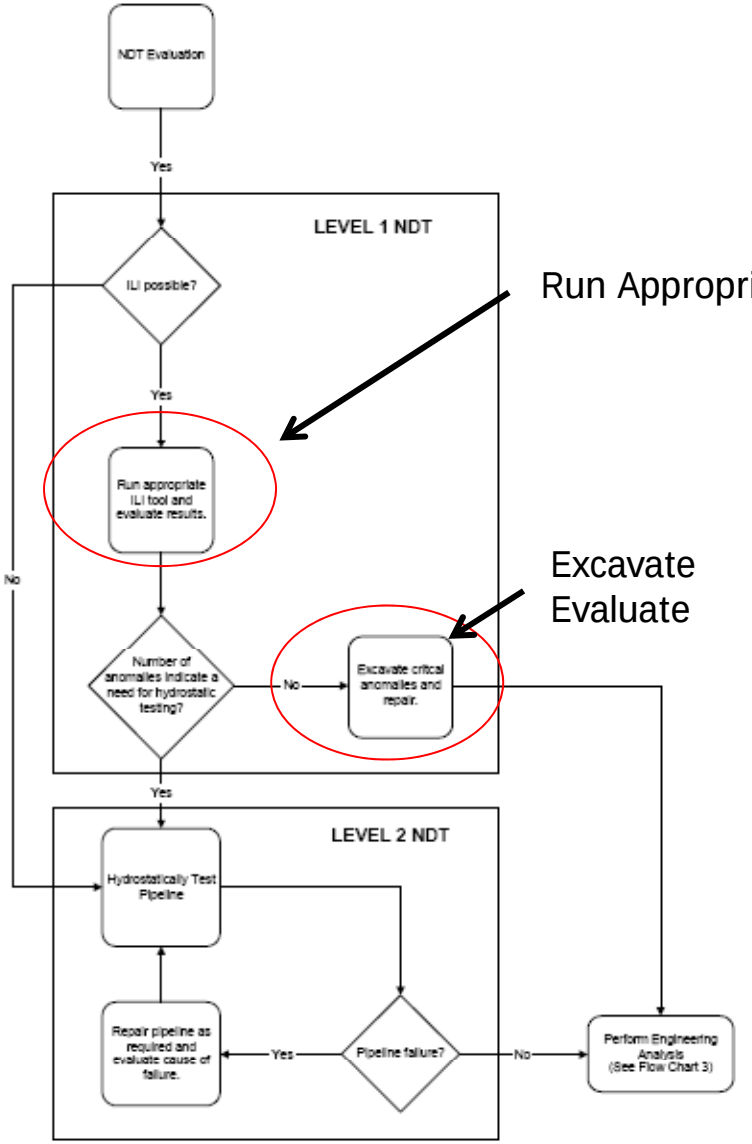
- ILI also detects cold welds and geometries
  - > Not cracks, discrimination issue
- Limited performance specification
  - > Limits of detection based on crack width < spec ?
- Assessment models
  - > Weld fracture toughness
  - > Feature Interaction

# Summary of ILI

- Seam weld inspection more challenging than corrosion
  - A seam weld - good, bad, deteriorating - provides a signal
  - More variability in the in-the-ditch answers
- Magnetic and ultrasonic methods had different strengths and weaknesses
  - One key factor to magnetic methods is the opening
  - One key factor ultrasonic methods is angle
  - If you have multiple seam issues, multiple technologies may be needed.
- Proving performance is difficult
  - Many variables to characterize
  - Terminology, yardsticks can be different
  - Pipeline to vendor feedback needed
- Solutions exist but performance unknown
  - Pipeline owners ask pigging companies “what can you find?”
  - Pigging companies ask pipeline owners “what the smallest  I need to find?”
  - Representative, well characterized samples needed for development and performance asessment

# TTO5 ERW Process

- Process Established
  - Process Issues
    - Appropriate ILI?
    - Actual or True ILI Performance Considerations
- Two Roles for NDE
  - Repair vs Recoat
    - Relies on Detection
    - Current NDE Practice
      - Adequate
  - Accept based on ILI log
    - True ILI performance
      - Detection & Discrimination
      - Sizing Accuracy
    - Requires
      - Known NDE Accuracy
      - As good as the ILI tool
    - Feedback to ILI vendor
      - Process Improvement



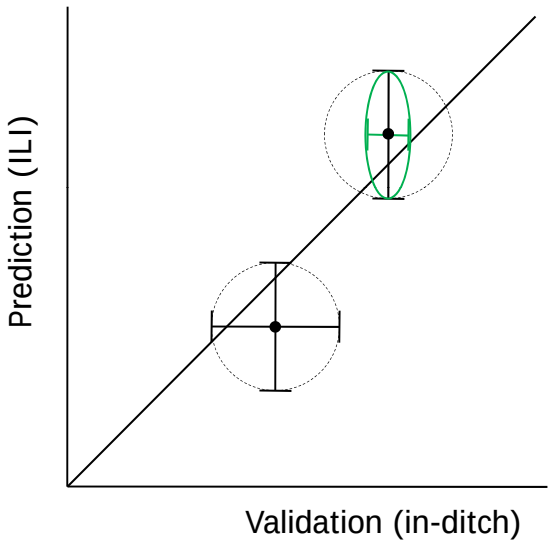
## TRUE ILI Performance

Assume the ILI and Field measurements are independent.

$$\sigma_Z = \sqrt{\sigma_{ILI}^2 + \sigma_{Field}^2}$$

Equivalently,

$$\sigma_{ILI} = \sqrt{\sigma_Z^2 - \sigma_{Field}^2}$$

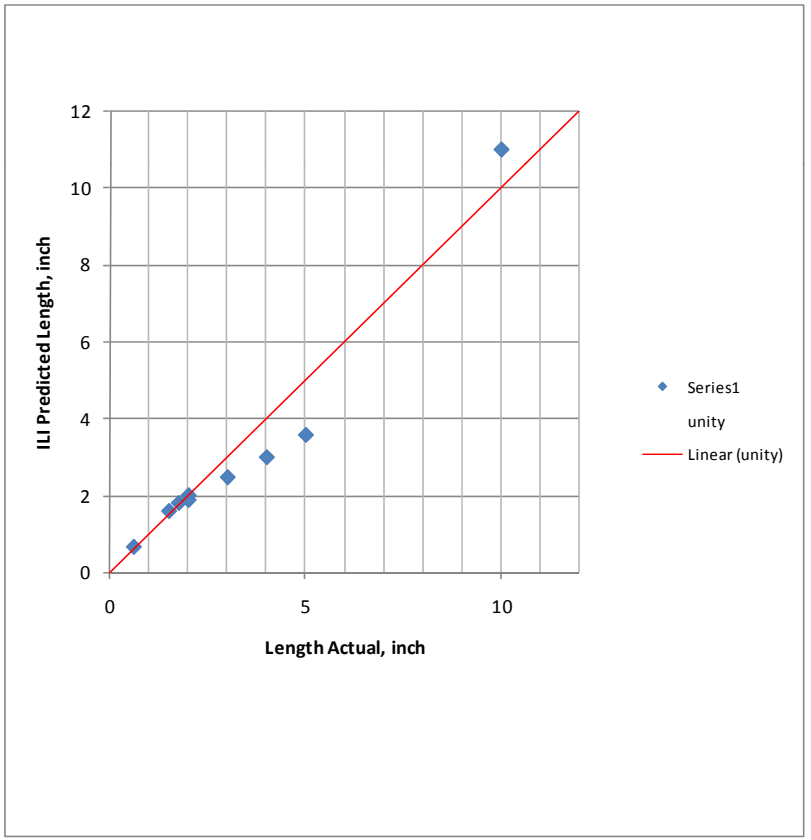



Challenge:

- To Get True ILI Error: Must Consider Field NDE Error
  - Or minimize NDE error to avoid need for correction
- At some point you need to know the ACTUAL dimensions

# Circumferential MFL Length Data Performance

- Experience
- Assessment Providing Reliable Length Predictions
- Depth Correlation IAW MFL Capability
  - MFL is not a crack tool
    - Often prioritized response
      - Based on categories
      - More complete ILI performance specs ?
  - But burst validations demonstrate safety for current anomaly classifications

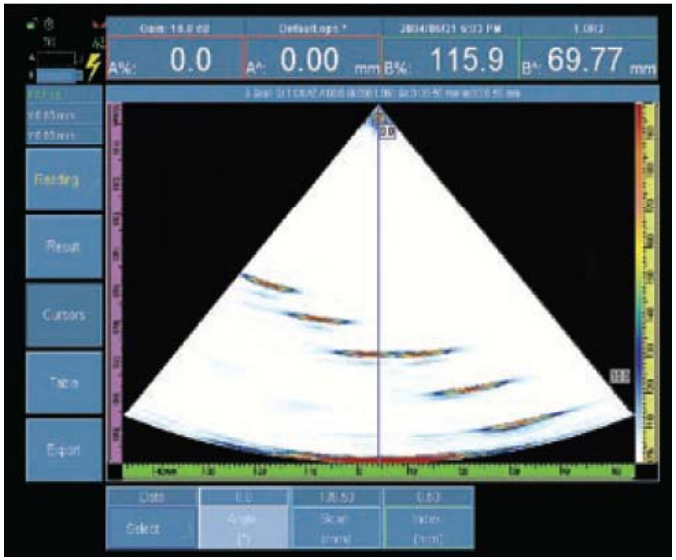


# Depth Challenge for NDE

- Similar considerations as for ILI
  - Good performance for single cracks for Phased Array or TOFD
  - However, not all ILI features are cracks
- Circ MFL Type A seam feature example
- 95%wt x 1.75 inch
  - Not a “crack”- cold weld, not covered by ILI spec but still reported
- Actual Pburst = 1360 psi
  - Pb(95%wt)= 586 psi pred
  - Pb(80%wt)= 1304 psi pred
- No evidence of fatigue
- UT reflector
  - What is sizing reliability?
    - TOFD UT
    - Phase Array UT

# NDE Crack Depth by Ultrasonic Testing

- Issue is Weld and Defect Geometries
  - ToFD very accurate for single cracks
    - +/-0.1 mm possible
  - Phased Array in Practice
    - +/- 1.0 mm depth
  - A gap is to understand performance for;
    - Hook cracks, profiles
    - Translucent Cold Bond Features



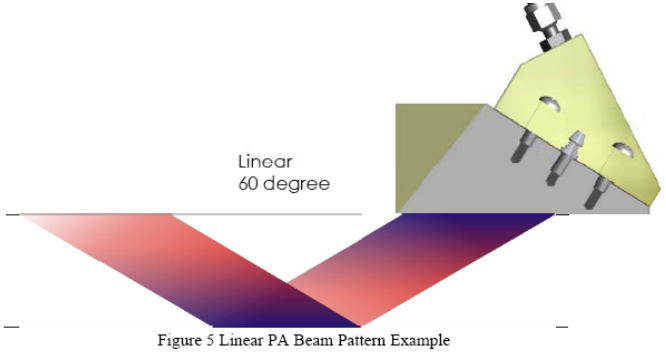




Figure 5 Linear PA Beam Pattern Example

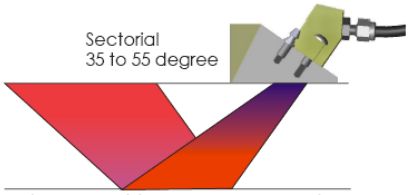
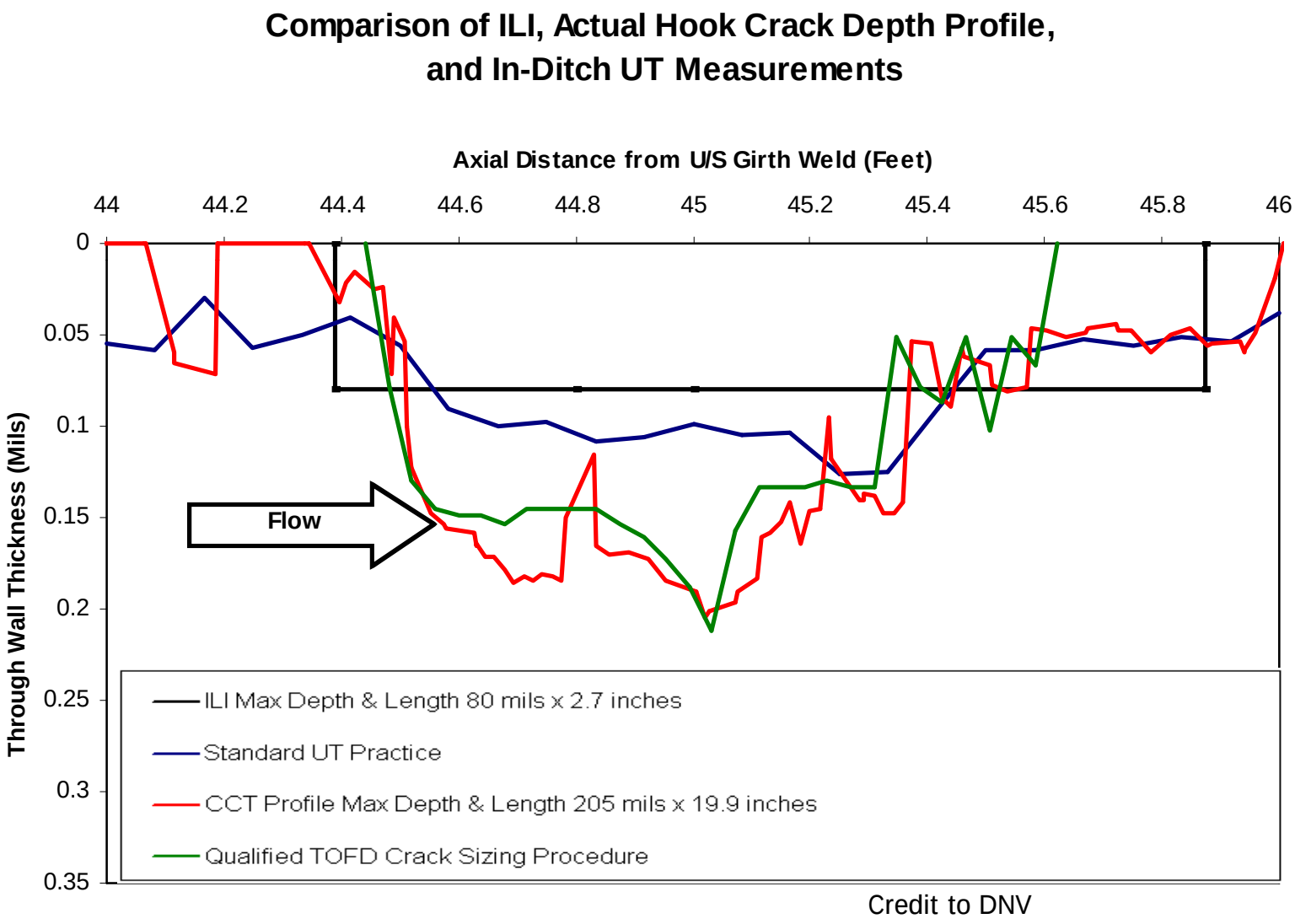



Figure 6 Sectorial PA Beam Pattern Example

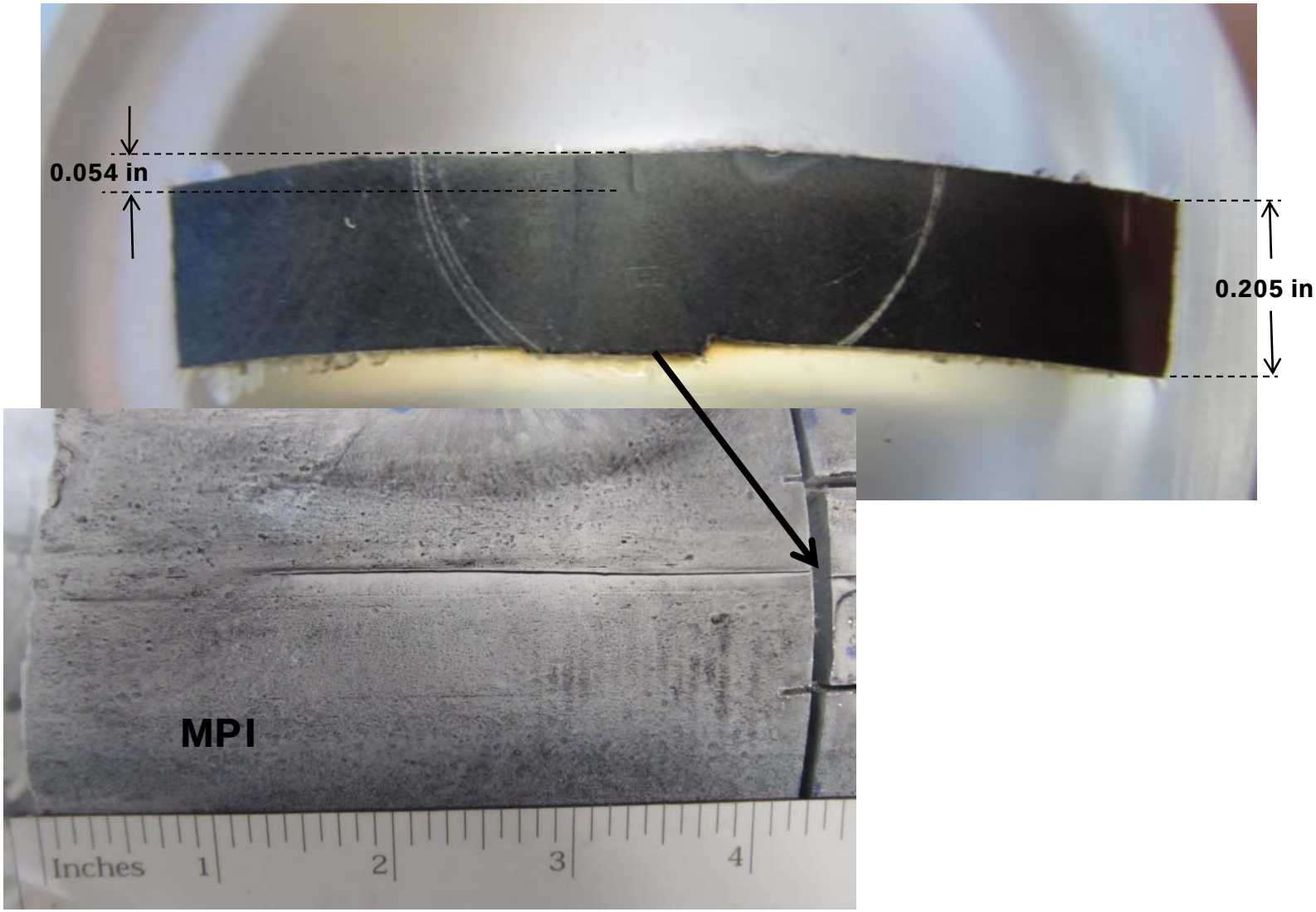
# Early NDE: UT and ILI comparisons

- Actual profile from cross-sectioning



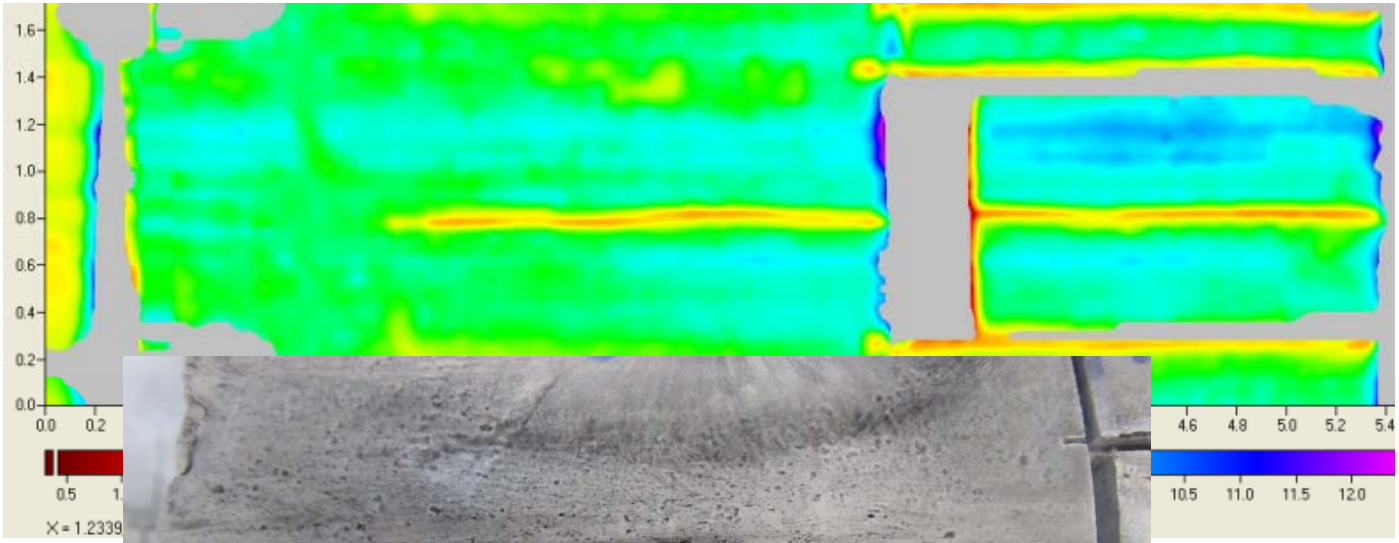
# 6 inch NPS- ERW Crack- Lower Limit for ILI ?

- Detected by MFL, ILI call data unknown
- 26% wall thickness depth actual



# 6 inch NPS- ERW Crack- NDE Reliability

- 26%wt depth x 4 inches long actual (Depth Section, Length by MPI))
- 22% wt x 2.1 inch long by ToFD, 3.42 inches by LToFD
- No ILI data (sample reportedly ID by ILI)




**MWM**


**MPI**

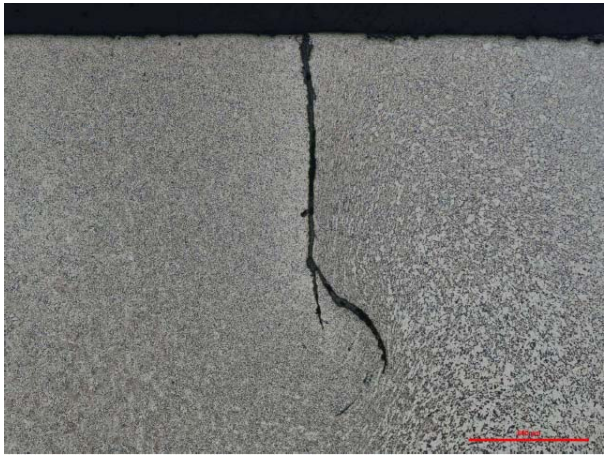
# Sample S3 Pipe Blind Laser ToFD Test

Wall = 0.205” = 5.21 mm

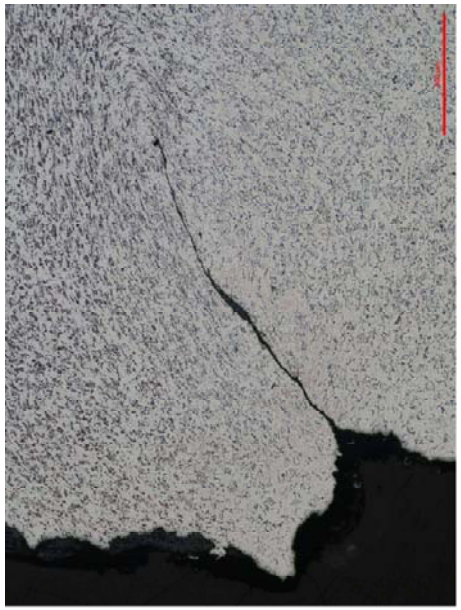

INTELLIGENT OPTICAL SYSTEMS, INC.

# Sample S3 Pipe Laser Ultrasonic  Blind Test

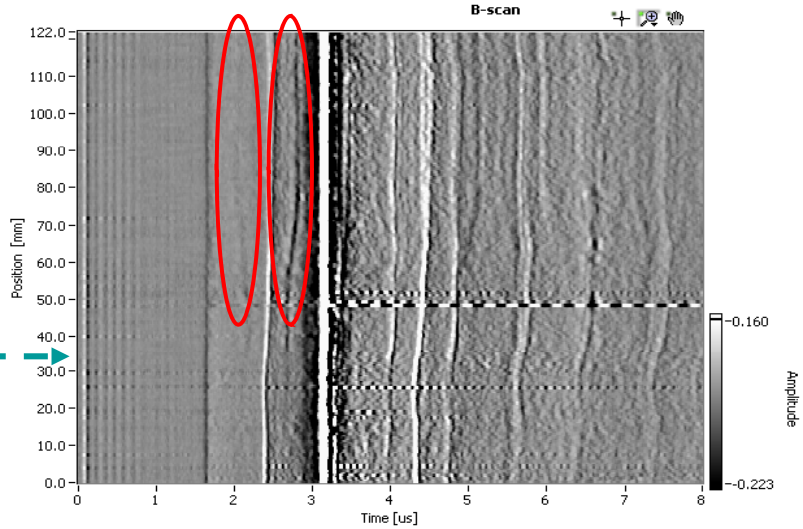
OD

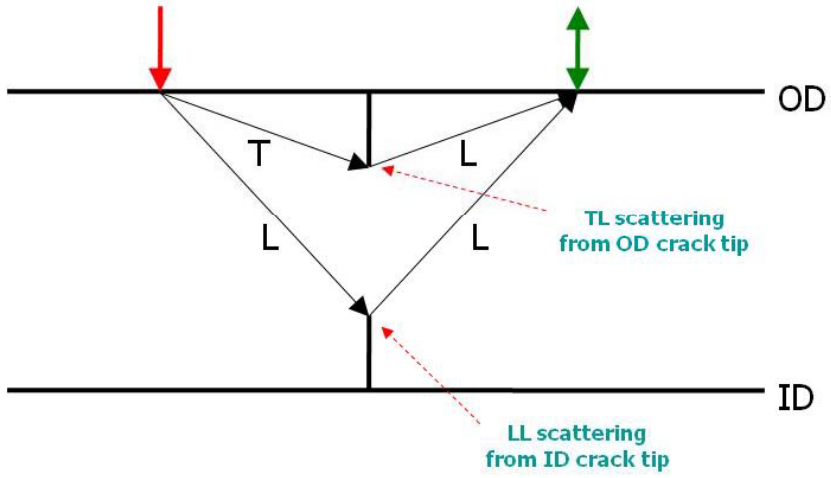


ID



Mark on pipe with pen (defect boundary ?)

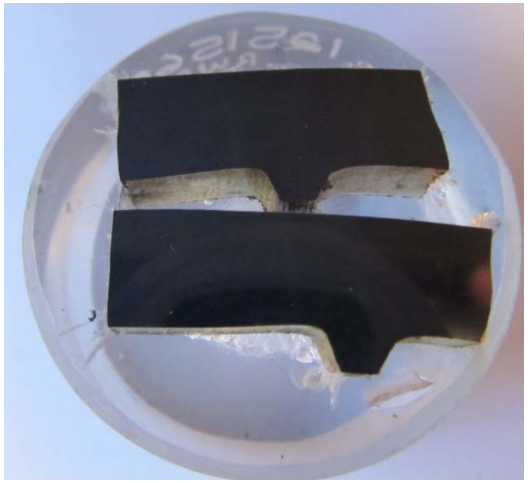


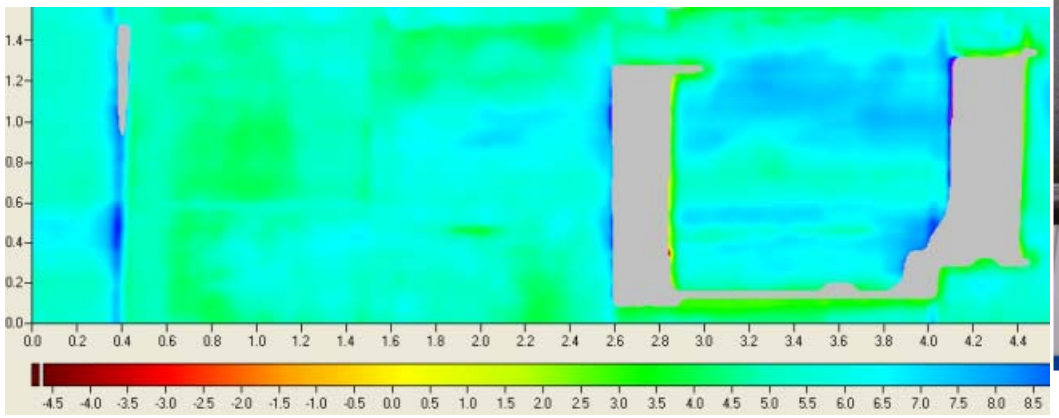

LToFD identified ID and OD crack tips

# Discrimination of Very Small Features in Difficult Geometries

- 0.064 inch depth (20% wt) actual total depth
  - No OD surface length, 0.25 inch ID actual length
- 0.045 inch depth (13%wt) 1.8 inch ToFD length
  - Clear Planar reflector seen by LToFD



S9-1 OD 50x

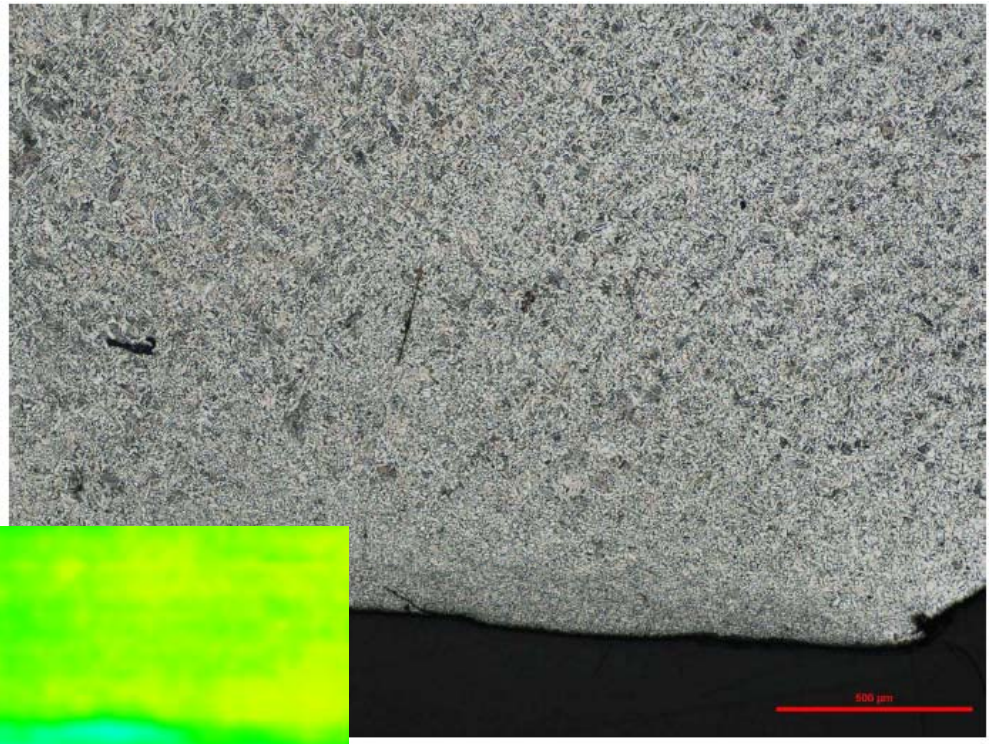


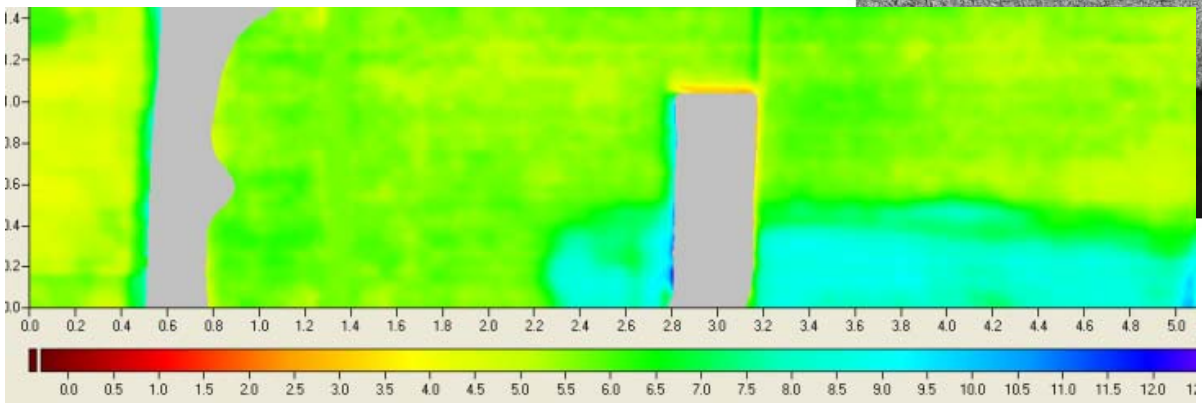


ID Seam Anomaly

# Null Finding- ILI False Call

- Nil Height and Length Actual
- No height, 1.25 inch long TOFD
  - No Indication from LToFD





# Summary

- **Industry could benefit from expanded understanding of true ILI performance for Seam Weld Threat**
  - Probability of Identification
  - Probability of False Calls
  - PRCI Research NDE 1-2: Understanding Current Seam Weld ILI Performance
    - Same approach as successfully applied to
      - External Corrosion (EC-4-2)
      - Mechanical Damage (MD-1-2 and MD-1-4)
      - SCC Crack Tool Technology, CD and EMAT (SCC-3-12 and SCC-3-7)
- **Application of ILI Validation Principles**
  - API 1163
    - Revision committee considering expansion to deformation and crack data
  - NDE Performance
    - Current Technology Available
      - Detects and Discriminates the Big, the Small and the Null
      - Documented performance lacking
      - NDE 2-2 may address together with pipe from PRCI-PHMSA ERW Research
  - ILI Gap: Data
      - MFL and Ultrasonic Pig Dig Data
      - Operator historical dig response data
        - » Likely inadequate to support full ILI tool performance determination
          - » Detection, Sizing, POD, POI
        - » Leverage all programs and fund capture of data
          - » Current digs using consistent protocol, consistent with approach for other threats

## Summary w/ ILI vendor Input

- Comprehensive performance specification for ILI all crack detection
  - Related to what is important to find
- Adaption of a general transparent field protocol for in the ditch measurement
- Adaption of a general transparent field protocol for correlation of in-the ditch data with ILI data
- Development of an inspection process for crack detection
  - Appropriate Technology