IPC 2014

Overview of a Comprehensive Study to Understand Longitudinal ERW Seam Failures

Bruce Young

Jennifer Smith

Steve Nanney

Brian Leis

Battelle

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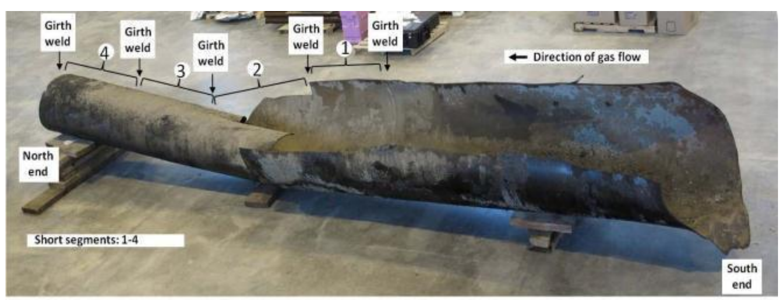
ERW Seam Weld Issues

Electric resistance welded (ERW) pipe is longitudinally welded pipe. A failure in the weld seam of this type of pipe can propagate for a distance along the pipe and can quickly release large quantities of product to the environment. Low-frequency (LF) ERW pipe installed prior to 1970 in particular can be susceptible to such failures. Reference

Carmichael, MS - 2007

San Bruno, CA - 2010



Photograph of the 28-foot-long ruptured section of pipeline

Mayflower, AR - 2013

Project & NTSB Driver

- Stemmed from the Carmichael MS rupture in 2007
- NTSB P-09-01 Recommended Comprehensive Study
  - ERW pipe properties
  - Assess the means to assure the integrity of seam welds so they do not fail in service.
- Battelle, Kiefner and Associates and Det Norske Veritas – Columbus,OH teamed to conduct a comprehensive study to understand longitudinal seam failures in electric resistance welded (ERW) and flash-welded pipes.
- Project started in August 2011
- Phase I completed in January 2014

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Project Objectives

- Assist the PHMSA in favorably closing NTSB Recommendation P-09-1
  - "comprehensive study to identify actions that can be implemented by pipeline operators to eliminate catastrophic longitudinal seam failures in ERW pipe"
  - Include at a minimum,
    - assessments of the effectiveness & effects of in-line inspection tools, hydrostatic pressure tests, and spike pressure tests;
    - pipe material strength characteristics and failure mechanisms;
    - the effects of aging on ERW pipelines;
    - operational factors; and
    - data collection and predictive analysis

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Phase I Organization

Task 1 History and current practice

- failure history of ERW and FW seams,
- the effectiveness of ILI and hydrotesting, and
- experience with predictive modeling

Task 2 Experiments designed to better characterize and quantify the resistance of such seams and their response to pressure.

- the validity of predictive models of pipeline failure and
- the viability of ILI and ITD inspection tools.

Task 3 Focused on selective seam weld corrosion (SSWC).

- literature review and analysis of the results,
- field-deployable method to quantify the susceptibility of a seam to this failure mechanism
- guidelines were also developed to mitigate this mechanism

Task 4 Summary and Recommendations

Phase I Results

- 17 Public Reports in Phase I (https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=390)
- 11 Specific Recommendations provided in the Phase I final report (Task 4.5)
  - Six (6) on Condition Assessment via ILI or Hydrotesting
  - Three (3) on Predictive Models
  - One (1) on Local Mechanical and Fracture Properties
  - One (1) on Aging Pipelines
- 2 presentations at the PRCI Research Exchange Meeting
- 5 presentations scheduled at the ASME IPC

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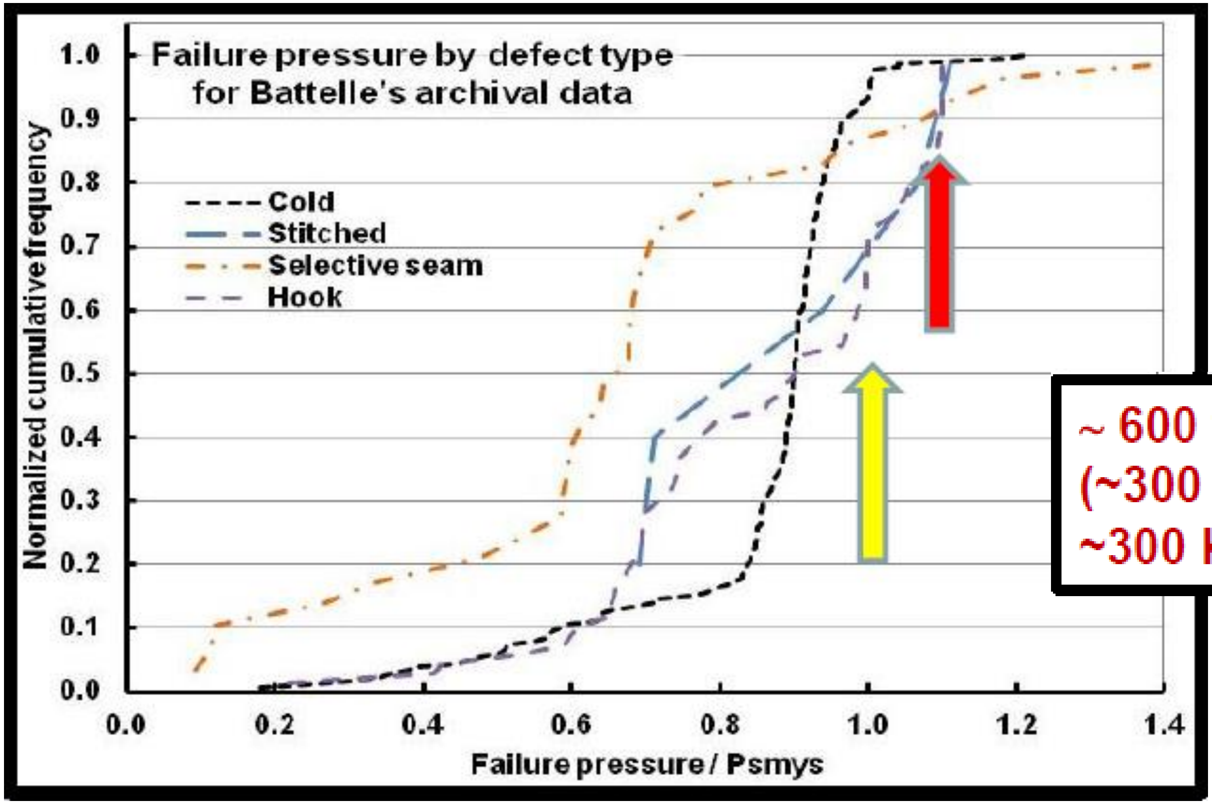
2 Examples of Key Findings (1 of 2)

Hydrotesting: High pressures are required to be effective.
Need to consider: Operating History, incident / test experience, implications of seam quality, potential for defect growth & pressure reversals.



~ 600 failures
(~300 Battelle /
~300 KAI/DNV)

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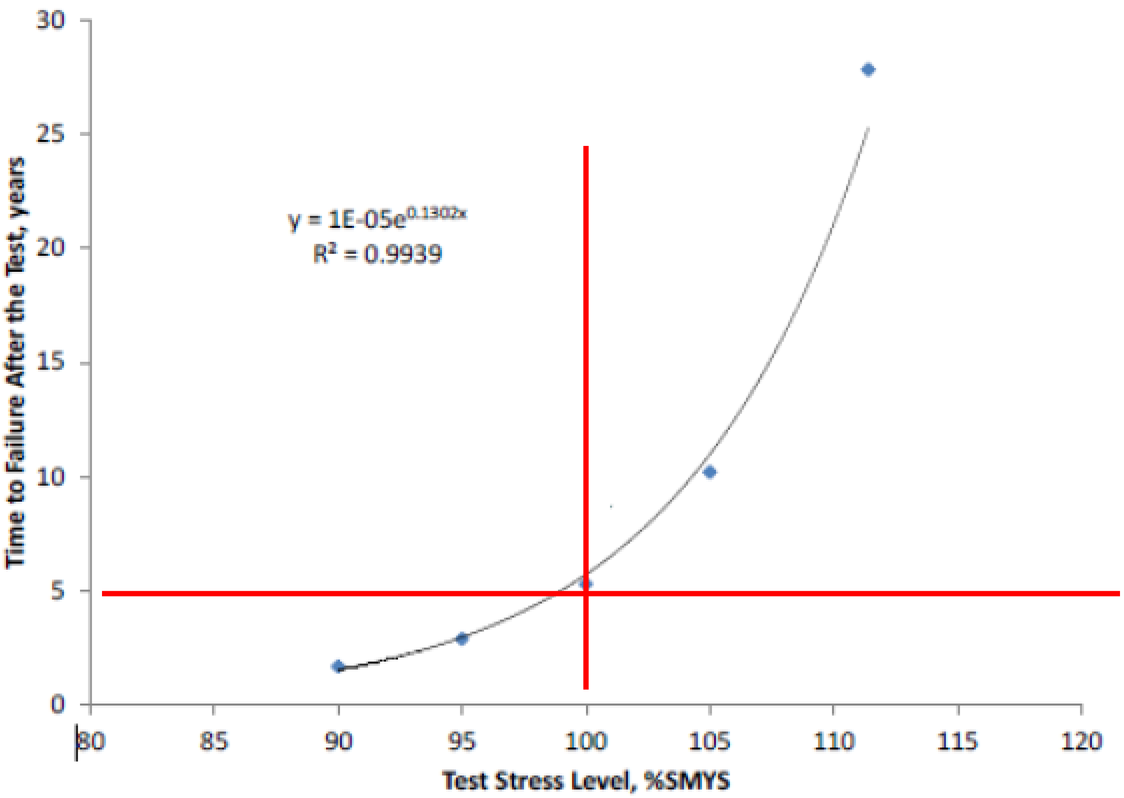
2 Examples of Key Findings (1 of 2)

Hydrotesting: High pressures are required to be effective.



- Time to failure increases at an exponential rate to increased test pressure.
- Highest test pressure assures a longer interval before a retest.
- Should not test so high that you get plastic expansion
- Test failures will increase with higher pressure

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2 Examples of Key Findings (1 of 2)

Hydrotesting: High pressures are required to be effective.

Stress Level that Defect Barely Survives, %SMYS	Test-Pressure-to-Operating – Pressure Ratio	Depth of Defect, inch	Years for Defect to Grow to Failure
90	1.25	0.1166	1.6
95	1.32	0.1018	2.9
100	1.39	0.0854	5.3
105	1.46	0.0667	10.2
111.4	1.55	0.0400	27.8

- Fatigue crack growth using “Paris-law”
- Requires relevant data including: pipe geometry, strength level, operating pressure cycle, and test history,
- Need conservative values for material toughness and flow stress

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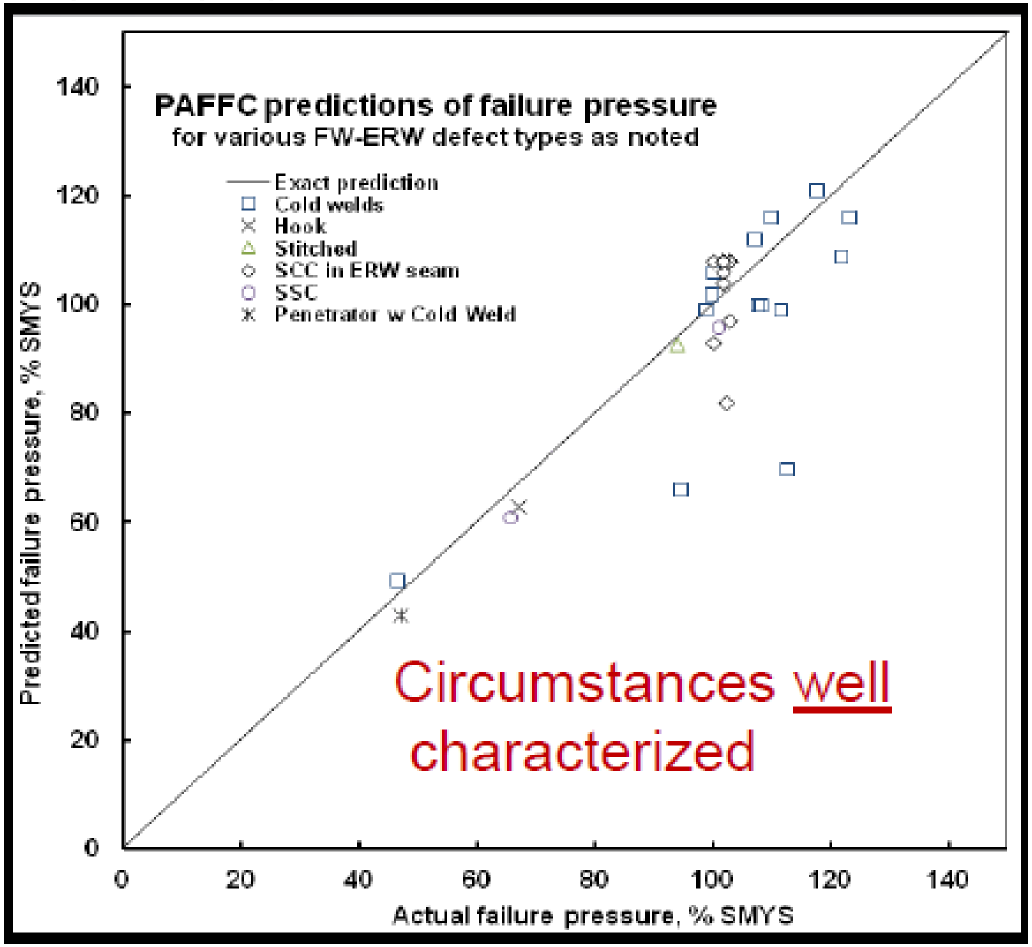
2 Examples of Key Findings (2 of 2)

Modeling: Requires properties (local) and defects to be well characterized



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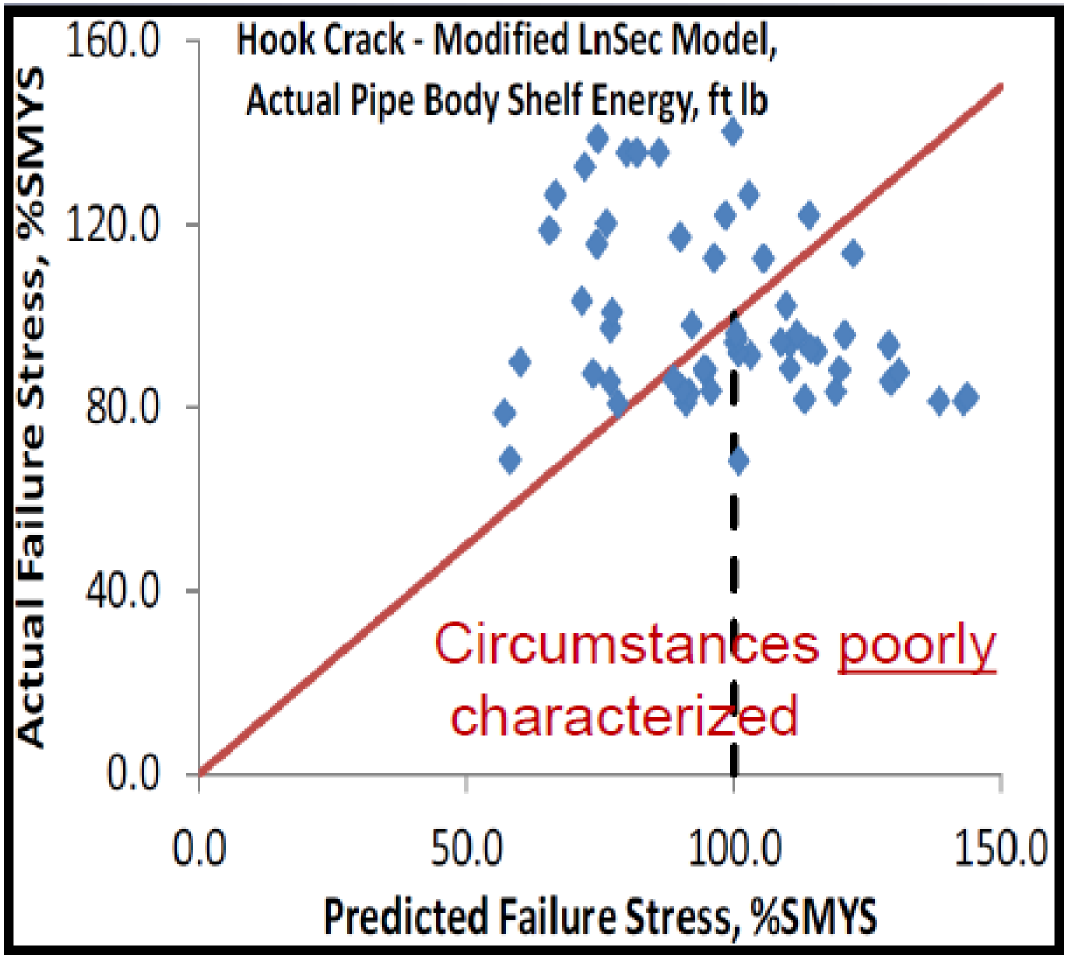
2 Examples of Key Findings (2 of 2)

Modeling: Requires properties (local) and defects to be well characterized



A Look Ahead…Phase II Preview

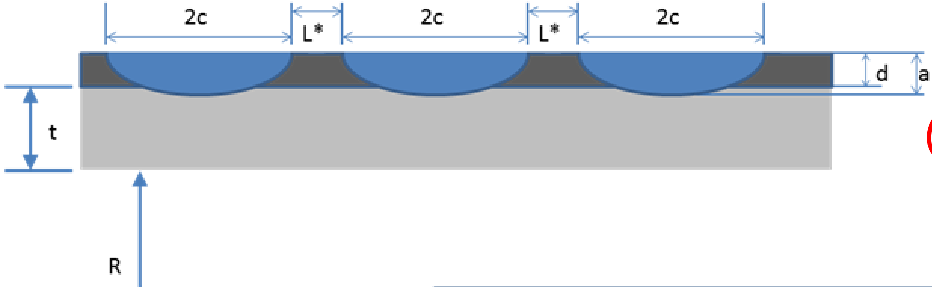
- Identification of Gaps from Phase I
- Five Major Tasks
  - Task 1 – Improve Hydrotesting Protocols for ERW/FW Seams
  - Task 2 – Enhance Defect Detection and Sizing
  - Task 3 – Defect Characterization: Type, Size, Shape
  - Task 4 – Model Refinement
  - Task 5 – Management Tools
- Currently Focused on Tasks 1, 2, and 3
- Task 1 Requires Results from Task 3
- Task 2 Requires Pipe with Specific Defect Types

Phase II, Task 3 Preview

- Modeling requires detailed characterization of flaws
- Defect Characterization: Type, Size, Shape
- Required to complete Tasks 1, 4, and 5
- Currently identified major shape (hook, stitching, SSWC,…etc.)
- Recently characterized shapes for linear elastic stress intensity values (K)

Phase II, Task 3 Preview

- Examples characterizing flaws: *Stitches*



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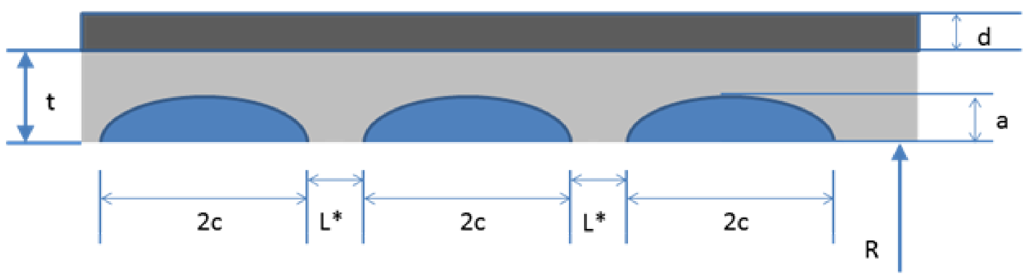

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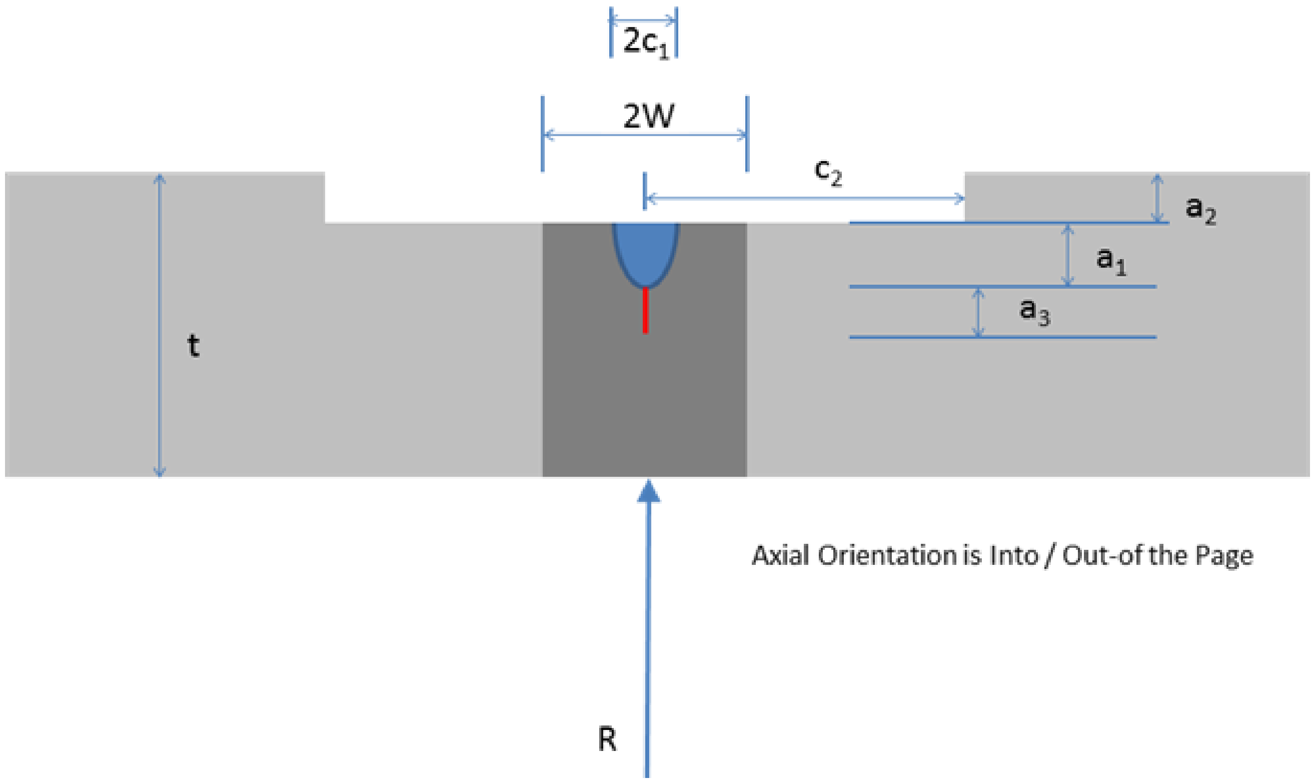
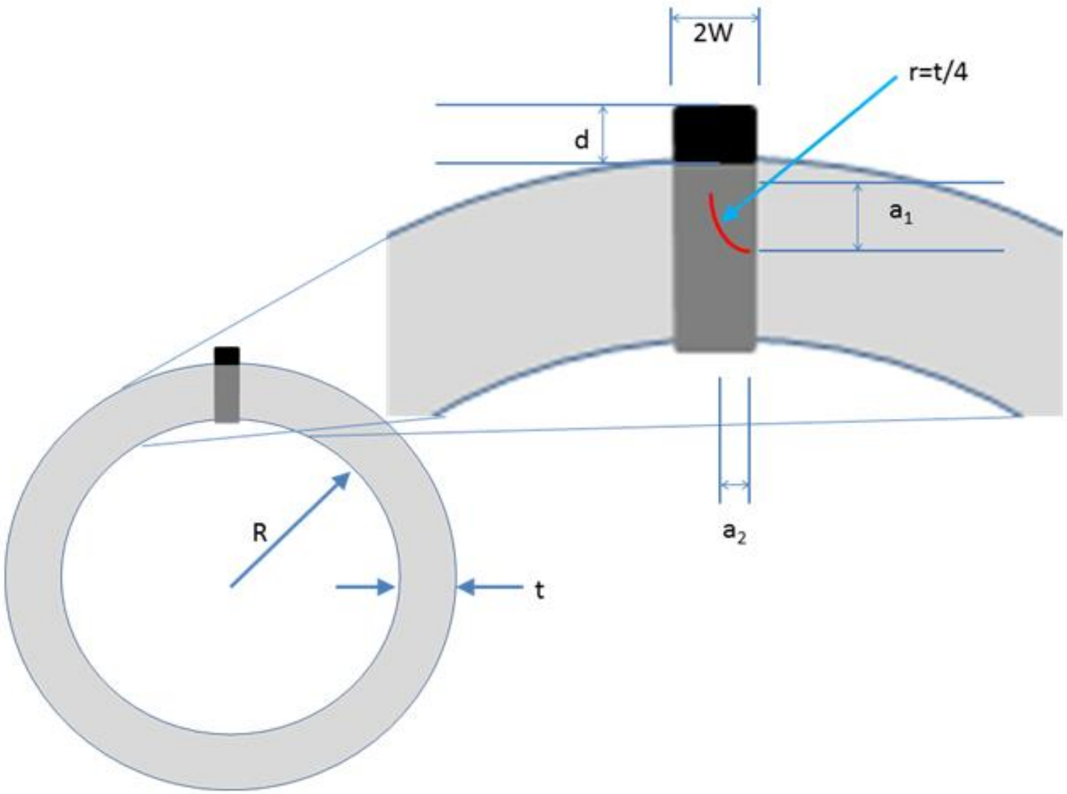
Phase II, Task 3 Preview

- Examples include characterizing flaws: *SSWC*



Phase II, Task 3 Preview

- Examples include characterizing flaws: *Hook Cracks*



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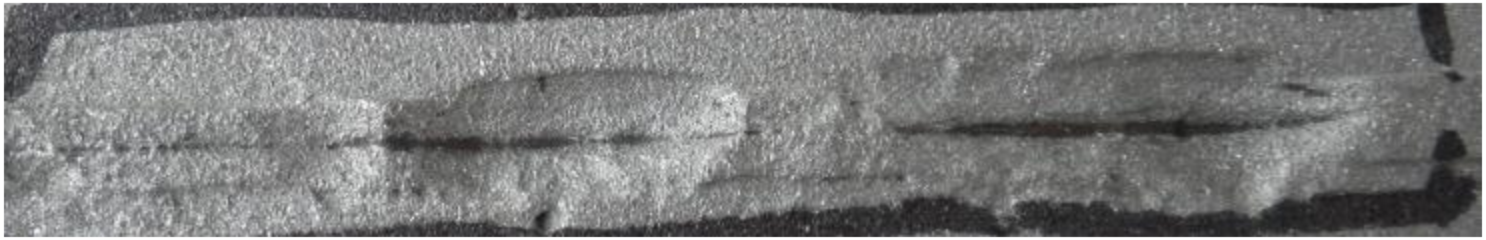
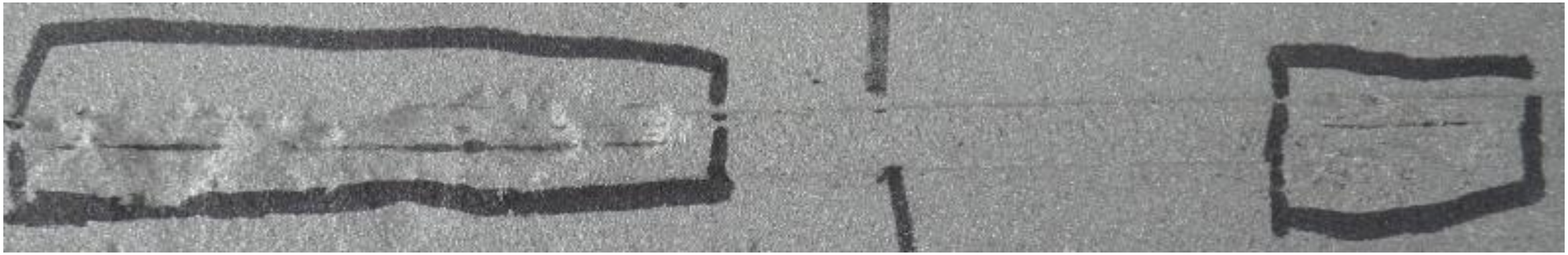
Phase II, Task 2 Preview

- Use of Field Pipe (or mill pipe) for ITDM / ILI Evaluation
- Repository of Pipe from Phase I Insufficient
  - Crack geometries not comprehensive
  - Crack sizes not large enough
  - Burst test results above 120% SYMS
- Repository Growing
  - Large Cracks (%TWC > 50%)
  - Hooks Cracks Promised
  - SSWC – Possible in current repository, more promised
- Longer Time to Obtain than Initially Anticipated

Phase II, Task 2 Preview





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Closing Remarks

- Pipe with useful defects are hard to acquire
- Pipes with defects have been promised to the project (thank you to the companies that have contributed and will be contributing); however, more is better (especially when looking for specific sizes of defects)
- Open Request for Pipe – Contact:
  - Bruce Young at youngba@battelle.org
  - Jennifer Smith at smithjm@battelle.org