BOARDWALK PIPELINE PARTNERS®

A Case Study on the Reinforcement of Seam Anomalies Using Composite Materials

CRUG Conference
September 25, 2015

Topics

- Background
- Historical use of composites
- Research and Testing
- Approvals
- Seam repairs and further validation
- Questions

Background

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- 16" diameter, X-52 grade, 0.312" wall thickness, low frequency ERW seam pipeline, manufactured by Youngstown. Pipeline built in 1954.
- MOP = 1,336 psi.
- Pipeline hydrostatically tested in 2001 to validate MOP (1.25xMOP for 8 hours). No hydro failures.
- Magnetic Flux Leakage (MFL) tool run in 2007.
- A second MFL tool run in 2011.
- Pipeline hydrostatically tested a second time in 2013, with a 1.39xMOP spike test for 30 minutes, then held at 1.25xMOP for 8 hours. Two hydro failures found and repaired.
- In 2014, a leak was found by patrol. The leak was in the ERW seam.

Background – 2014 Original Seam Leak

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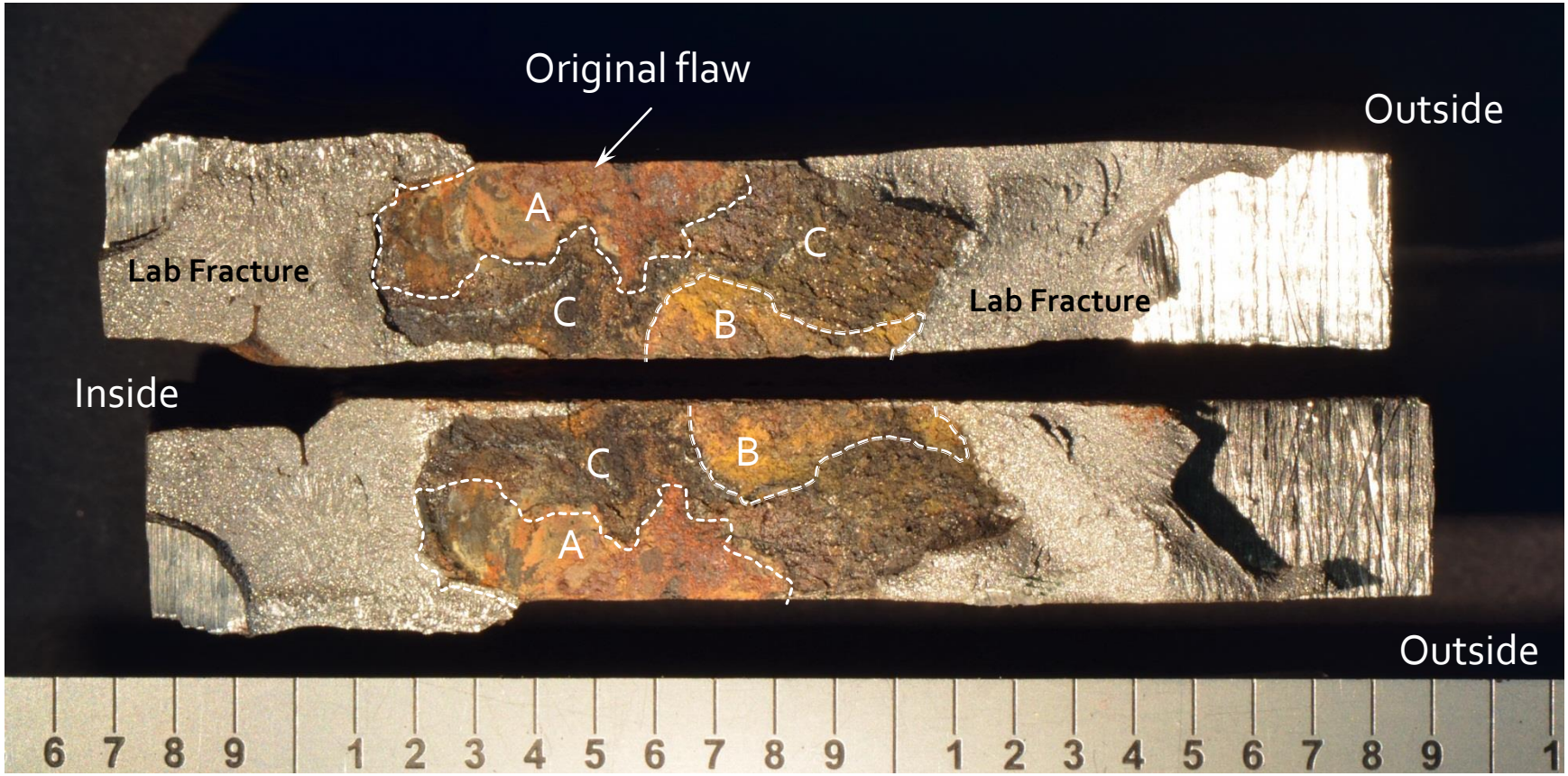
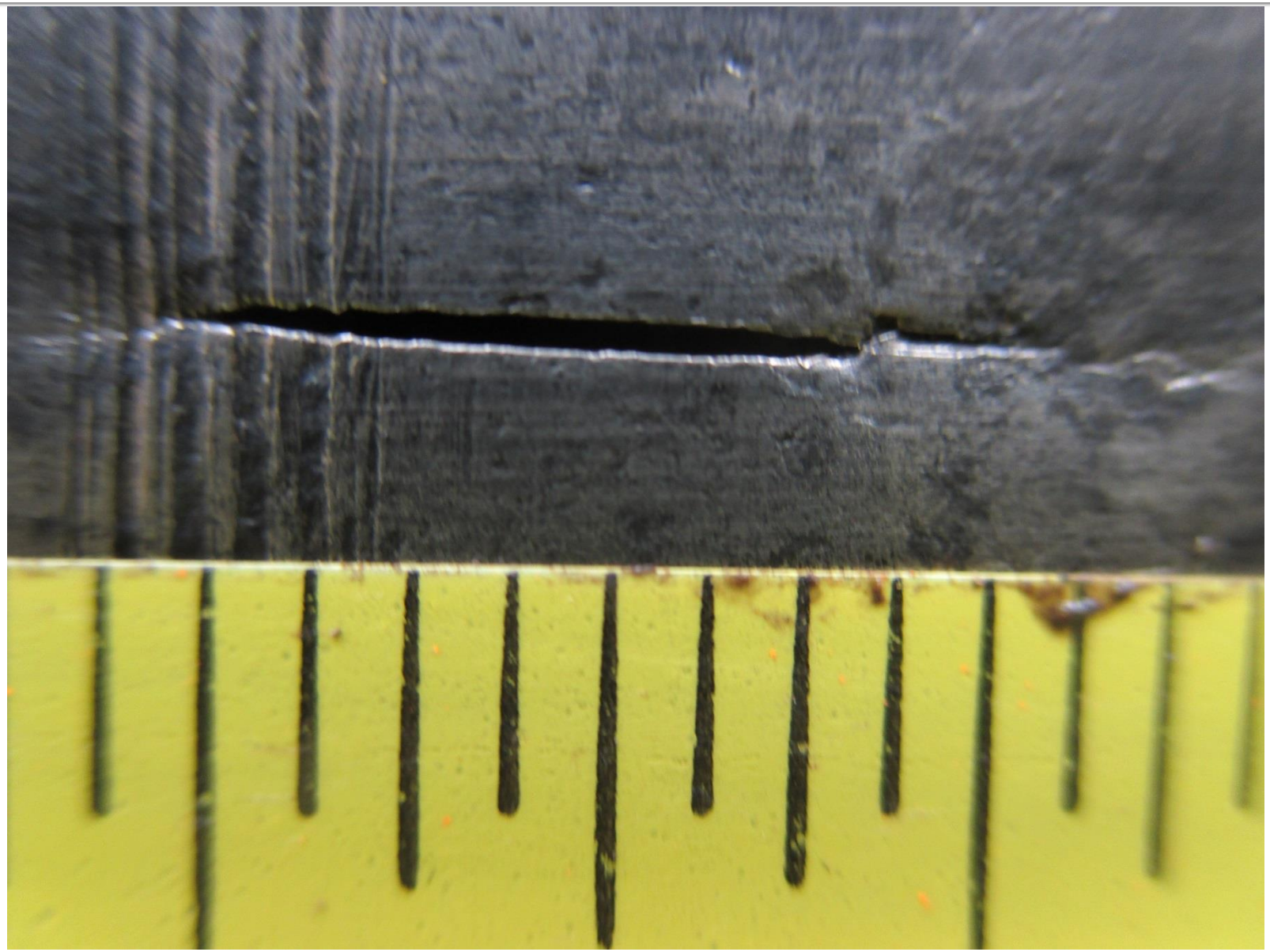


Fractograph showing different colors of deposits on fracture. Scale in inches.
"A" is original flaw.
"B" is crack extension.
"C" is final fracture

Background – 2015 Second Seam Leak



Background – CAO and IVP

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- The original seam leak prompted PHMSA to issue a Corrective Action Order with a pressure restriction.
- An Integrity Verification Plan (IVP) was submitted and was approved.
- IVP included running CMFL or TFI tools in the pipeline to find seam anomalies. A third hydrotest was not considered to be the best course of action. The line had previously been subjected to two hydrotests.
- IVP also included processes and procedures for repair and threat mitigation.
- Boardwalk started to look for alternative repair methods to taking the line down for repairs. This is a liquid line, and very costly to evacuate and purge.

Historical Use of Composites

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- Composites were mostly used to address corrosion anomalies.
- Composites had been used to reinforce dents.
- Composites were not on the list of the recommended options for repair of seam anomalies (PRCI Pipeline Repair Manual - Table 1).
- To determine if composites can be used to repair seam anomalies, significant research and testing was needed.
- Boardwalk Pipeline invested heavily in this testing effort. Boardwalk operates liquid pipelines with low frequency ERW pipe, and such testing can provide an economical alternative to pipe replacement.

Research and Testing

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- Three repair options were selected for testing. Two high modulus composites and one bolt-on clamp.
- Stress Engineering developed the testing protocols using 8" LF ERW pipe samples, as well as actual 16" pipe segments from the subject pipeline.
- EDM Notches were introduced *in the seam* to simulate a significant anomaly.
- Strain gauges were installed across the EDM notches.
- An unrepaired sample was also burst tested as a baseline.
- Samples were wrapped using the two composite repairs. A carbon fiber system and a carbon steel/E-glass composite system. One sample was repaired using a bolt-on clamp.
- Samples were then burst tested.

Research and Testing – Sample Prep.

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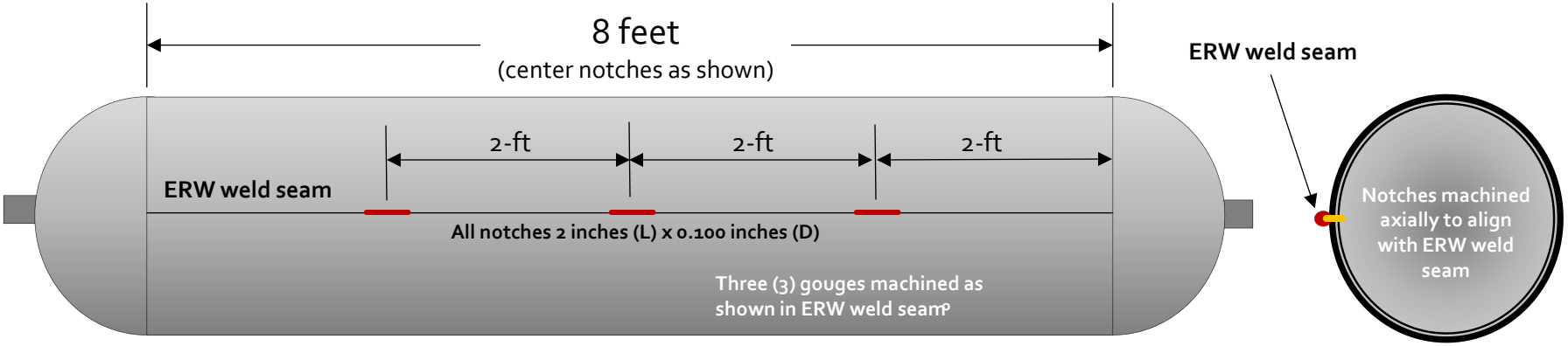
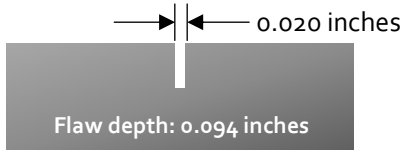


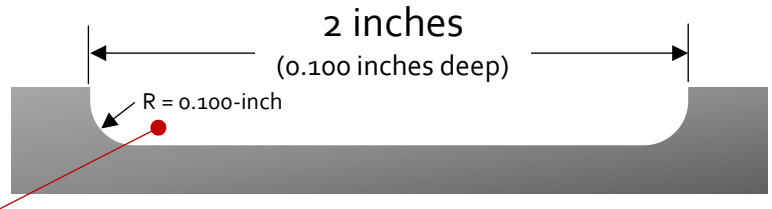
16-inch x 0.312-inch, Grade X52 pipe material



Cross-sectional profile

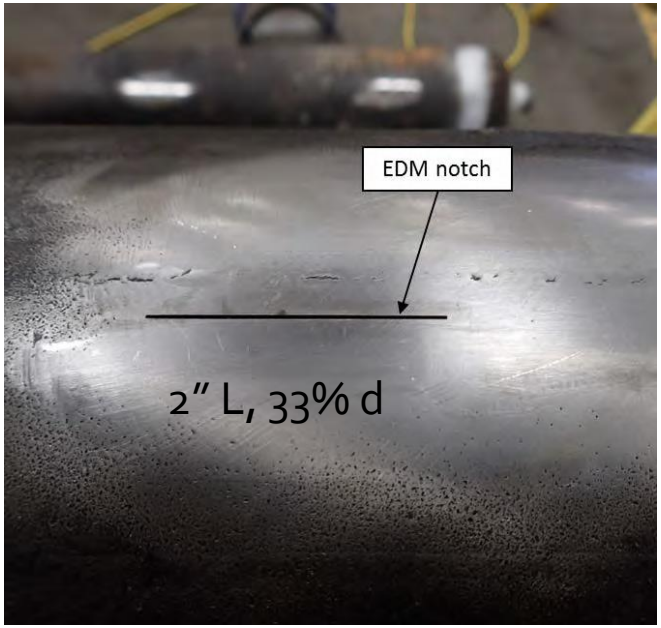
Notes:

1. Install three (3) axially-oriented EDM notches (2 inches long x 0.100 inches deep).
2. **ALL notches** interact with ERW weld seam.
3. SES will mark the ERW seam.
4. The PLIDCO sample only had 1 notch. (centered axially).

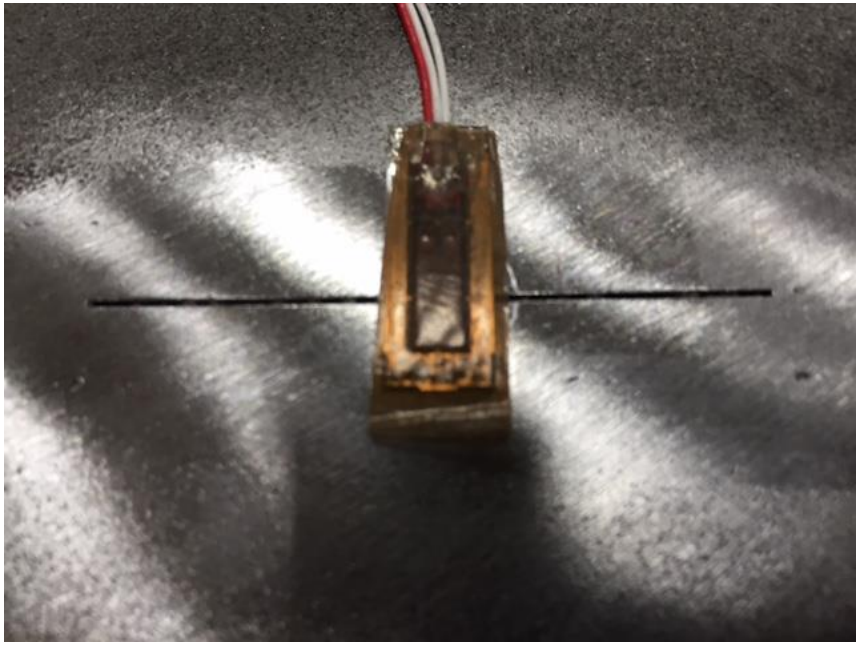


Axial view of pipe cross section

0.100 inches deep (32% w.t.)



Strain gauge across EDM notch



Research and Testing – Sample Prep.

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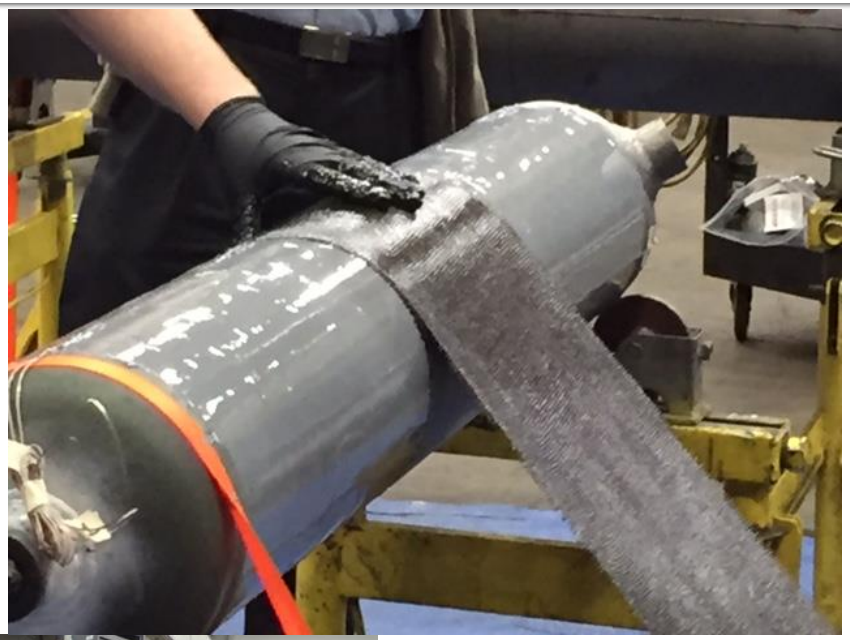
ComposiSleeve



Atlas Wrap

Plidco Clamp

Research and Testing - Results

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Unreinforced Sample


Wrap 2 – Atlas Wrap


Wrap 1 – Composi Sleeve


Bolt-on Clamp

Research and Testing - Results

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Repair Type	Pipe Diameter (in)	Sample #	Burst Pressure (psi)	% SMYS
Unreinforced	8	2	2,105	79
Unreinforced	8	3	2,751	103
Unreinforced	16	16	2,304	114
Pipe Wrap - Atlas	8	12	9,096	341
Pipe Wrap - Atlas	8	13	9,387	352
Pipe Wrap - Atlas	8	14	9,367	351
Pipe Wrap - Atlas	16	15	6,440	318
Western Specialties - ComposiSleeve	8	5	4,995	187
Western Specialties - ComposiSleeve	8	8	3,979	149
Western Specialties - ComposiSleeve	8	9	3,084	116
Western Specialties - ComposiSleeve	16	11	3,478	171
PLIDCO Clamp	16	-	3,092	152

- All wraps provide significant reinforcement to the seam (which included significant anomalies) > 170% SMYS
- Clamp also provided significant reinforcement to the seam >150% SMYS
- Strain gauges did not register significant opening of the seam anomalies under the composite wraps

Research and Testing – Actual Seam Defects

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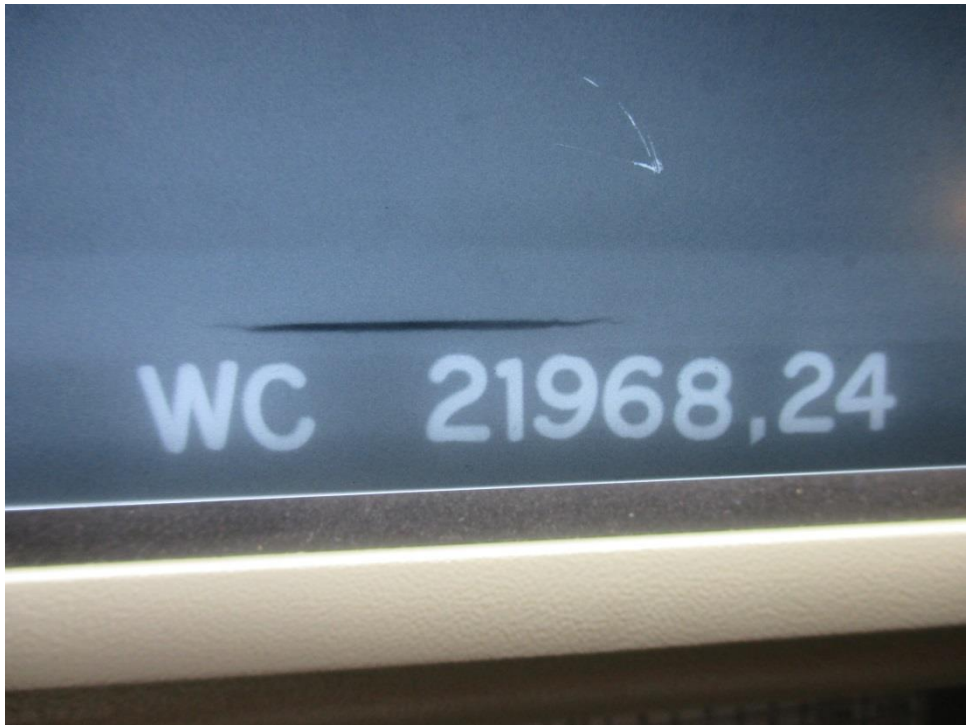
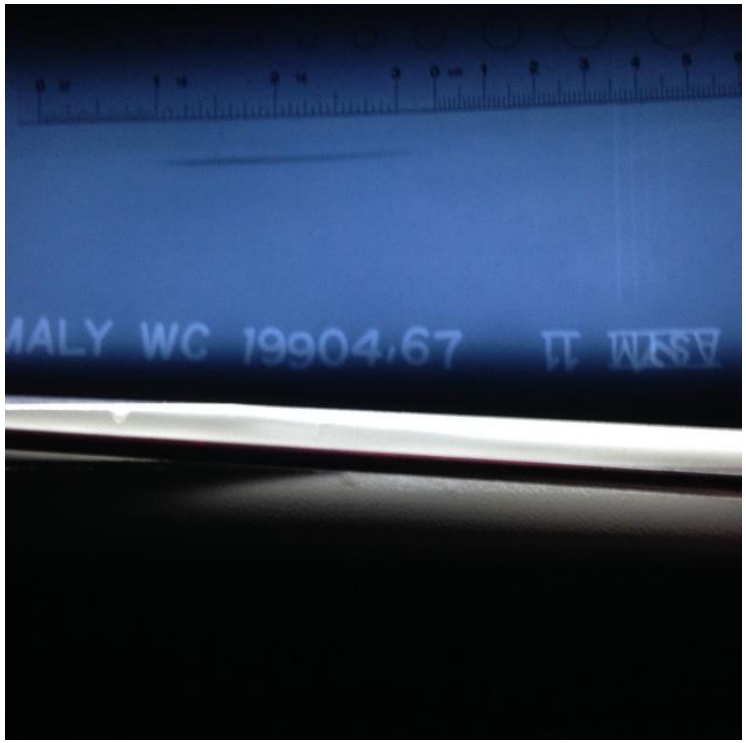
- Boardwalk ran a CMFL tool to inspect the seam.
- The tool identified 84 actionable seam anomalies requiring repair.
- 19 anomalies were cut out. 36 type B pressure sleeves. 29 composite wraps.
- The two most significant anomalies found were selected for further wrap validation testing.



Called 55% deep, 2.63" long



Called 56% deep, 3.33" long

Research and Testing – Actual Seam Defects

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Called 56% deep, 3.33" long seam anomaly
Burst pressure = 2,787 psi – 2.1xMOP - 138% SMYS

Called 55% deep, 2.63" long seam anomaly
Burst pressure = 3,350 psi – 2.5xMOP - 165% SMYS

Research and Testing – Actual Seam Defects

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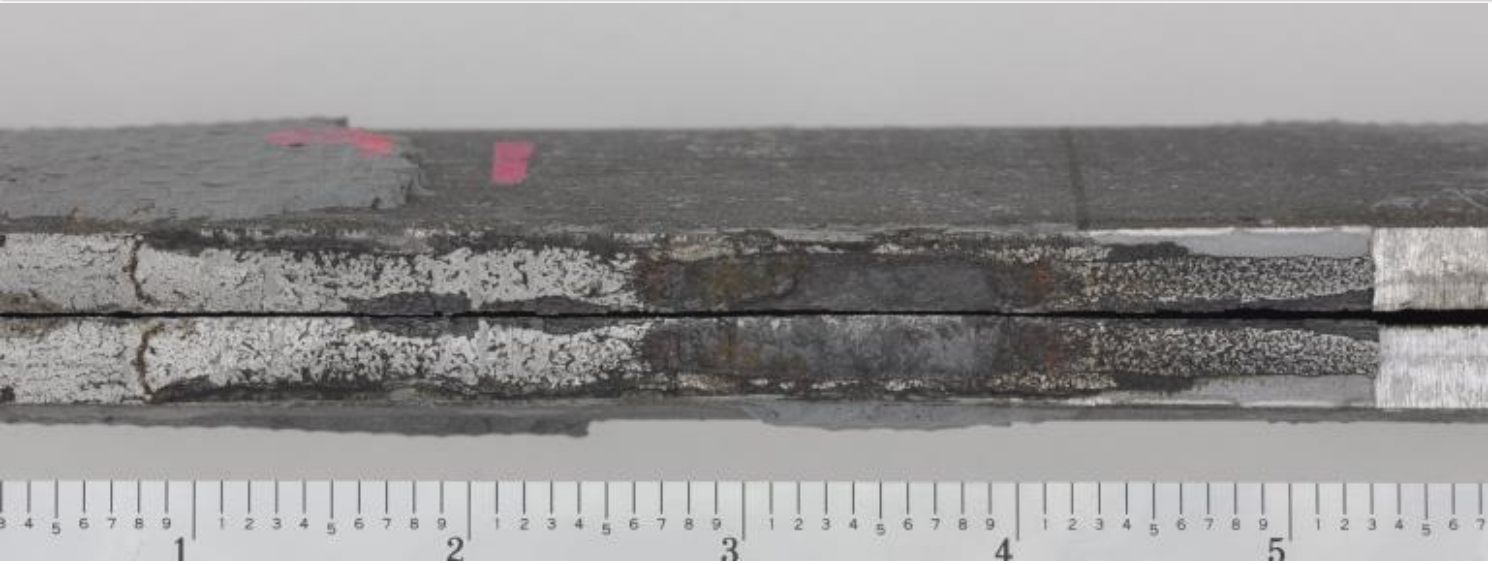
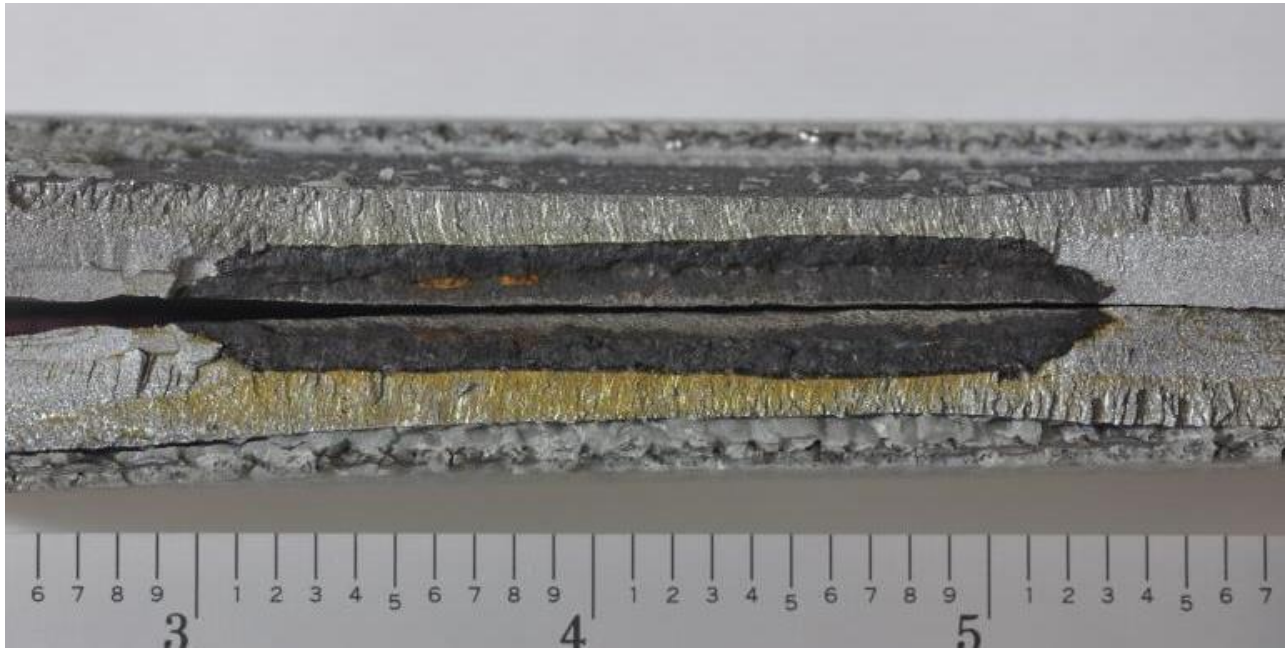


WC 21968.24 Post flaw inspection (reinforced; burst failed outside repair)



WC 19904.67 Post flaw inspection (reinforced; burst failed outside repair)

Approvals – Repairs

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- Data clearly shows that composite repairs are extremely effective in reinforcing LF ERW seam anomalies.
- No failure occurred during testing under the composites. All failures occurred in the seam or the pipe outside the wrapped areas.
- Composites provide significant reinforcement well above 170% SMYS, and above 135% SMYS on the most severe indication found in this pipeline.
- Boardwalk petitioned PHMSA to allow the use of these two composites for the pipeline in question.
- Provided PHMSA with reports and test results. PHMSA approved the use of these two composites for this pipeline.
- All repairs are now completed and the line returned to service.

Thank you

Questions ?