Case Studies of ILI Crack Detection Inspections of ERW Seams

PHMSA Workshop

Managing Pipeline Crack Challenges

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Reasons for the Case Studies

- Primary reason – Recommendation to PHMSA from the NTSB to perform a "comprehensive study" of ERW seam failure issues including the capabilities for detecting seam defects by ILI and hydrostatic testing. The NTSB recommendation was issued in response to their investigation of the "Carmichael incident" in which an ERW seam failed in service after having been inspected for seam anomalies by an ILI crack-detection tool 2 years prior to the incident.
- Other cases where in-service failures occurred shortly after ILI crack-detection tools had been used to assess seam integrity

The Carmichael Incident

- ERW seam in 12.75-inch-OD propane pipeline failed at a hoop stress level of 71% of SMYS two years after a UCD tool had been used to inspect the integrity of the seam.
- The anomaly believed to have initiated the failure was a 2.4-inch-long, 27%-through-the-wall, ID-connected hook crack.
- The UCD tool results indicated no anomaly at the location of this defect.
- Twenty-three years prior to the failure the pipe had survived a hydrostatic test to a hoop stress level of 89% of SMYS.

Other In-Service Failures Shortly After ILI Seam Inspections

- ERW seam in 12.75-inch-OD petroleum products pipe failed at a hoop stress level of 60% of SMYS one year after both a UCD tool and a CMFL tool had been used to inspect the integrity of the seam.
- The anomaly that initiated the failure was a 9.5-inch-long, 45%-through-the-wall, ID-connected hook crack that had been extended by fatigue to a depth of 80% through the wall.
- Both tools indicated an anomaly at the location of this defect, but in both cases the anomaly was judged to be non-injurious.

Other In-Service Failures Shortly After ILI Seam Inspections

- ERW seam in 18-inch-OD petroleum products pipe failed at a hoop stress level of 61% of SMYS one year after a UCD tool and two years after a CMFL tool had been used to inspect the integrity of the seam.
- The anomaly that initiated the failure was a 27-inch-long, 46%-through-the-wall, damaged skelp edge at the ID surface that had been extended by fatigue to a depth of 86% through the wall.
- The UCD tool indicated no crack-like anomaly at the location of this defect, and the CMFL tool result was interpreted as metal gain.

Scope of the Study

- 13 cases representing 741 miles of pipe inspected between 1999 and 2009
- Pipelines comprised of low-frequency-welded ERW Pipe
- Diameters ranged from 12.75 inches to 20 inches
- 9 of the cases involved ultrasonic crack-detection tools
- 3 of the cases involved circumferential magnetic-flux leakage tools
- 1 of the cases involved an EMAT tool

Work was done for PHMSA via a subcontract from Battelle

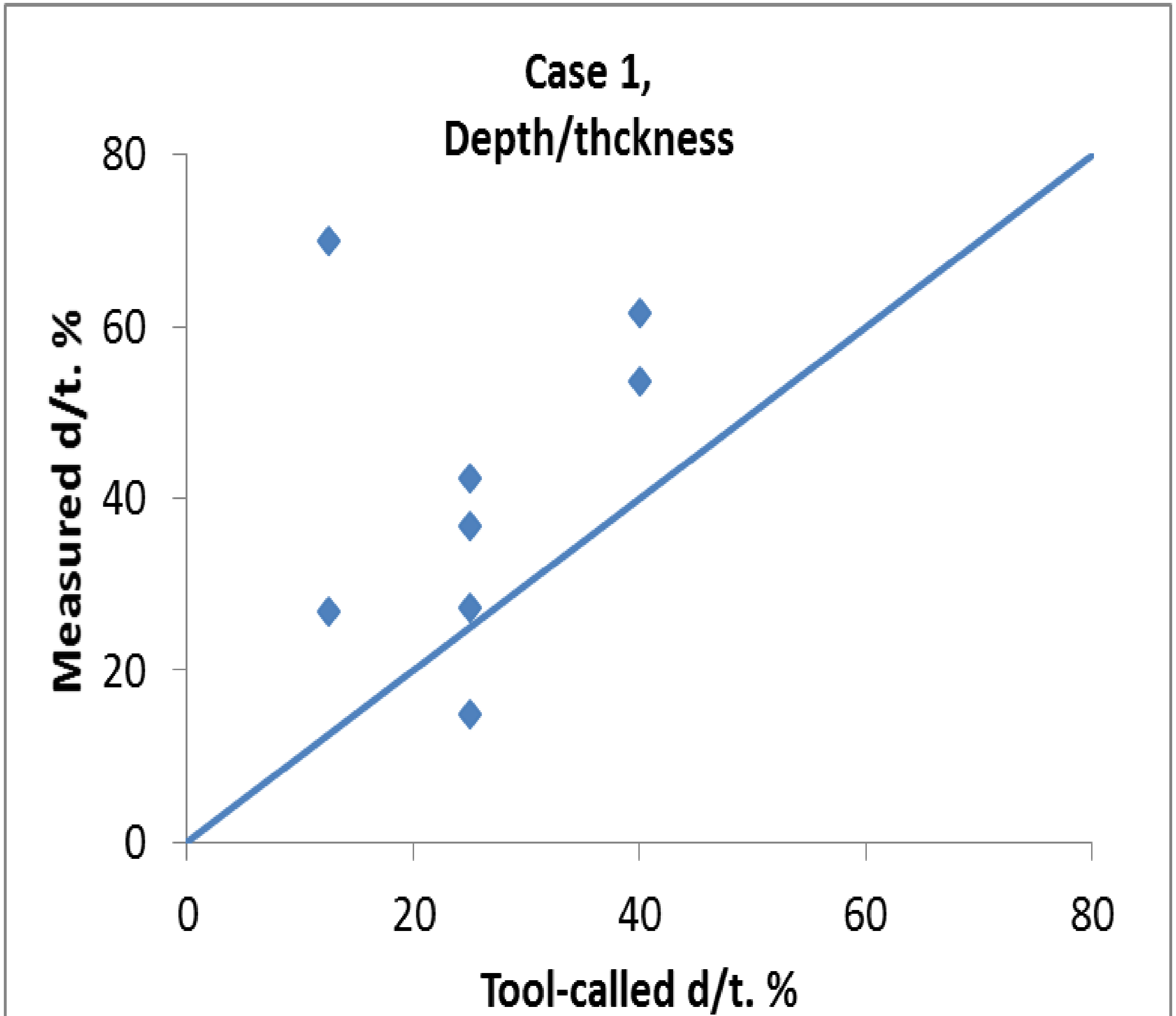
Contract No. **DTPH56-11-T-000003**

Comprehensive Study to Understand Longitudinal ERW Seam Failures

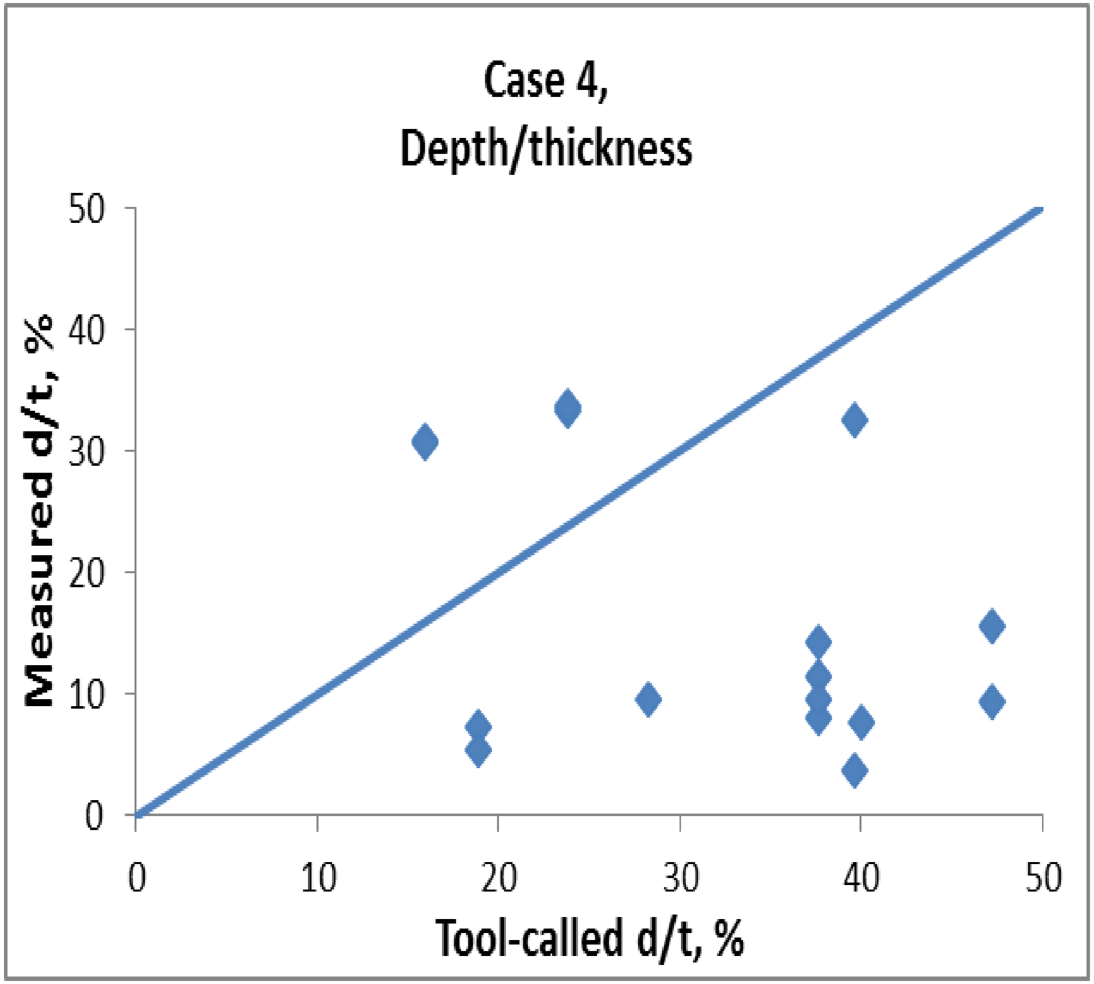
Summary of the Findings

- In every case crack-like defects were found.
- Discrimination as to the type of defect was not good.
- Sizing accuracy was fair to poor.
- In some cases, anomalies with sizes exceeding the stated detection threshold were found upon excavation that had not been detected by the ILI tool.
- Field NDE sizing did not compare well with ILI sizing.
- Field NDE is at least as unreliable as ILI in terms of sizing.
- The EMAT tool found anomalies in the seams but the vendor declined to provide sizing data.

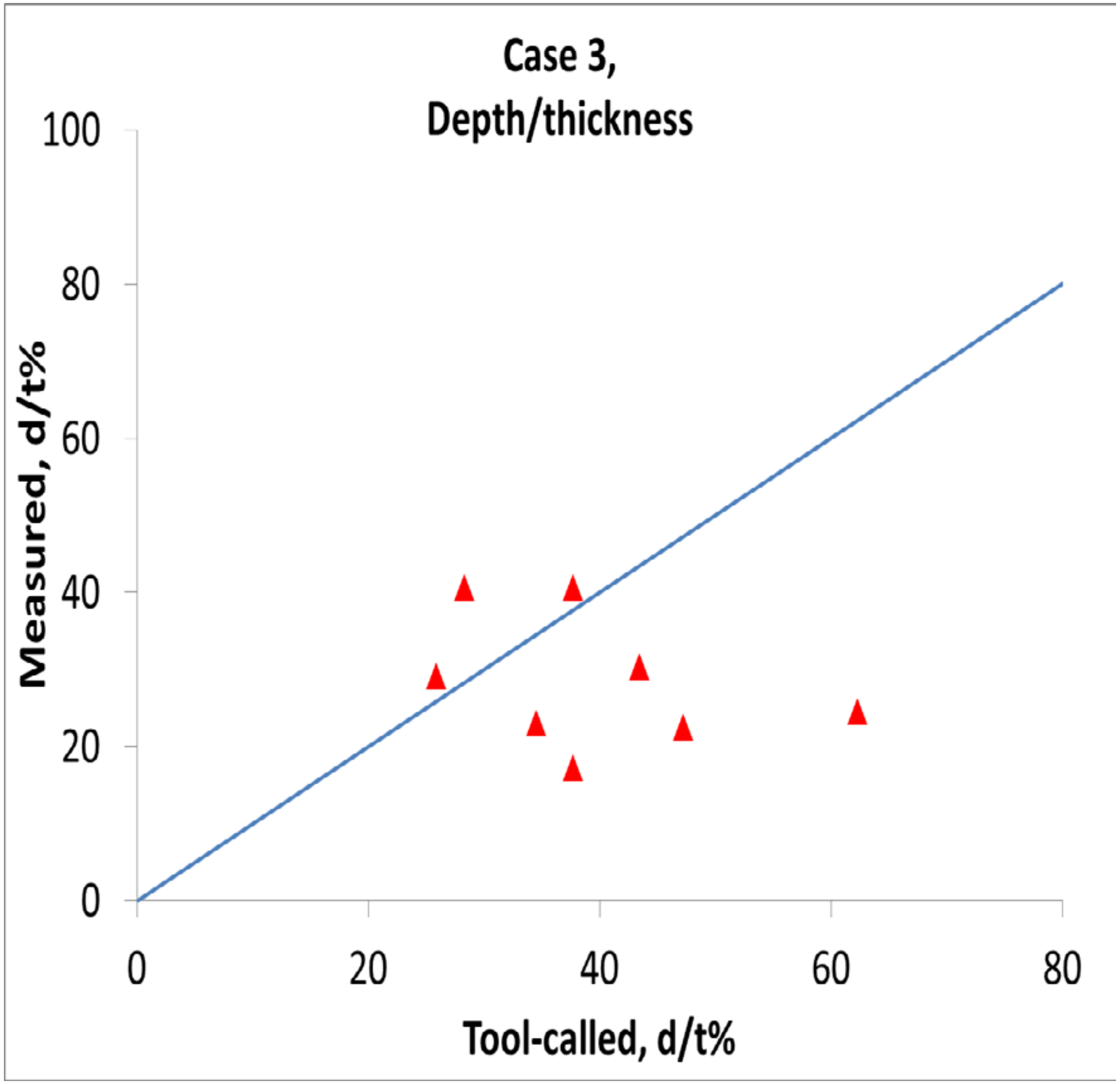
CASE 1 UCD Tool – Depth Accuracy Compared to Field NDE



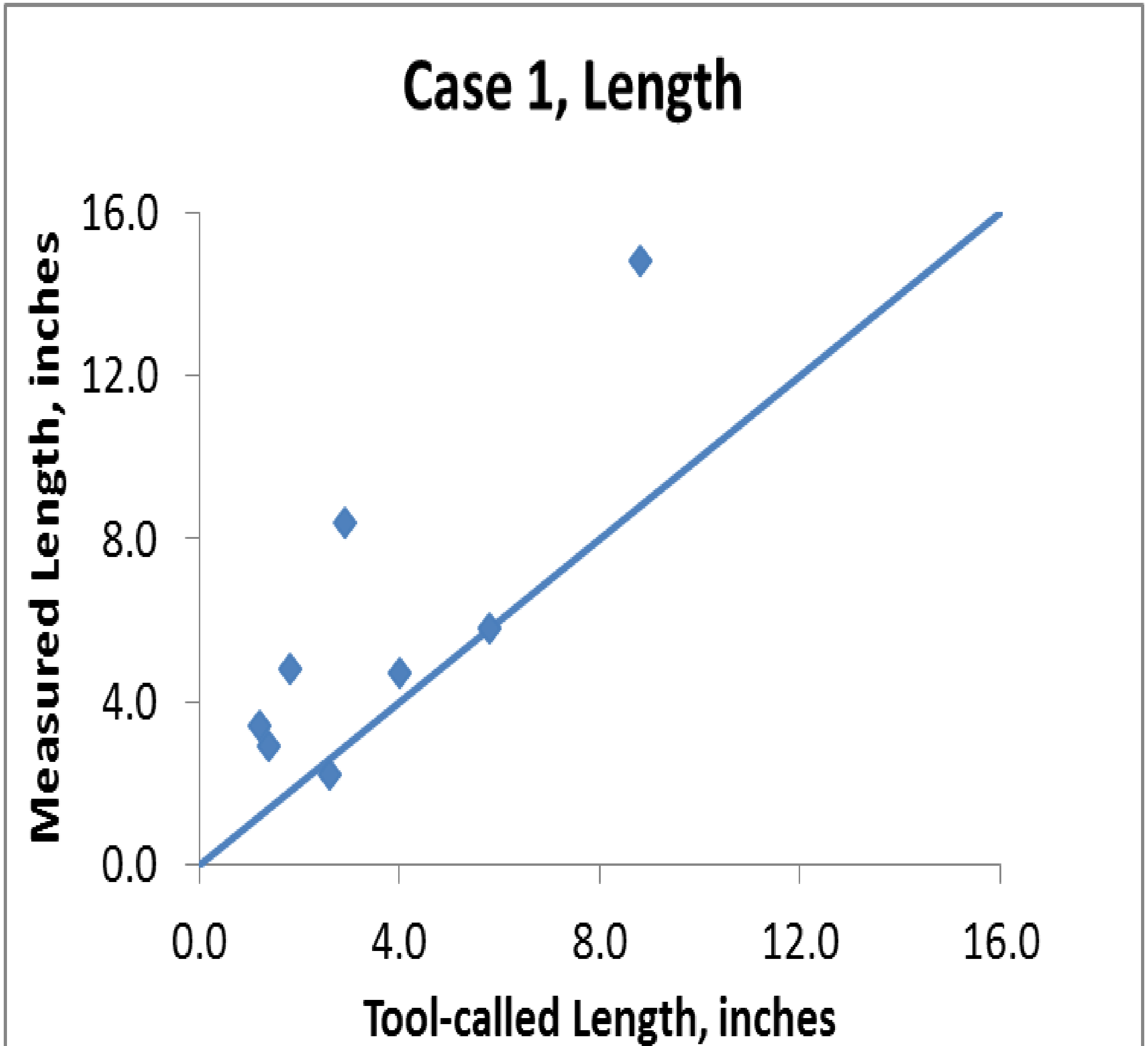
Case 4 UCD Tool – Depth Accuracy Compared to Field NDE



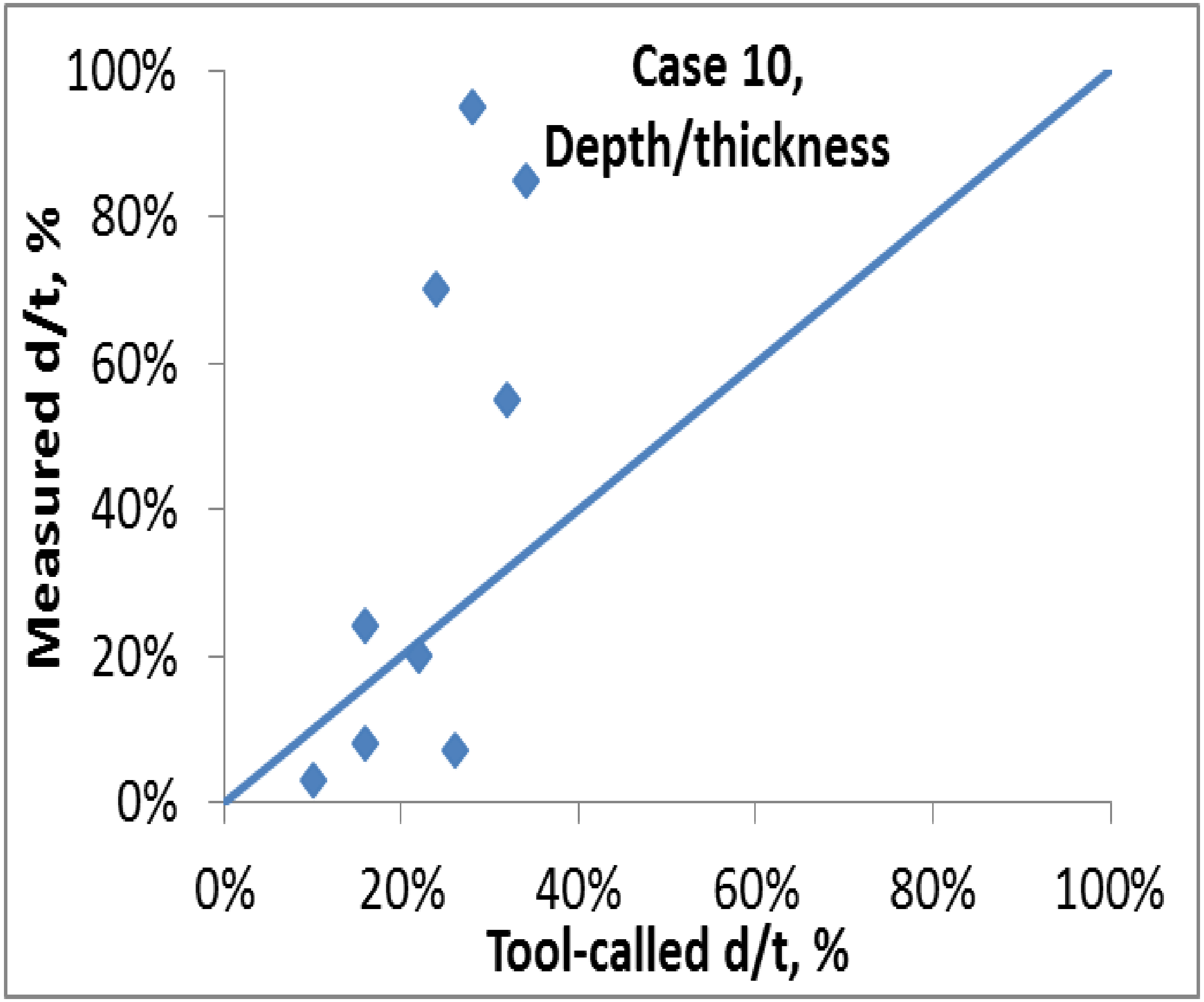
Case 3 UCD Tool – Depth Accuracy Assessed by Met. Section



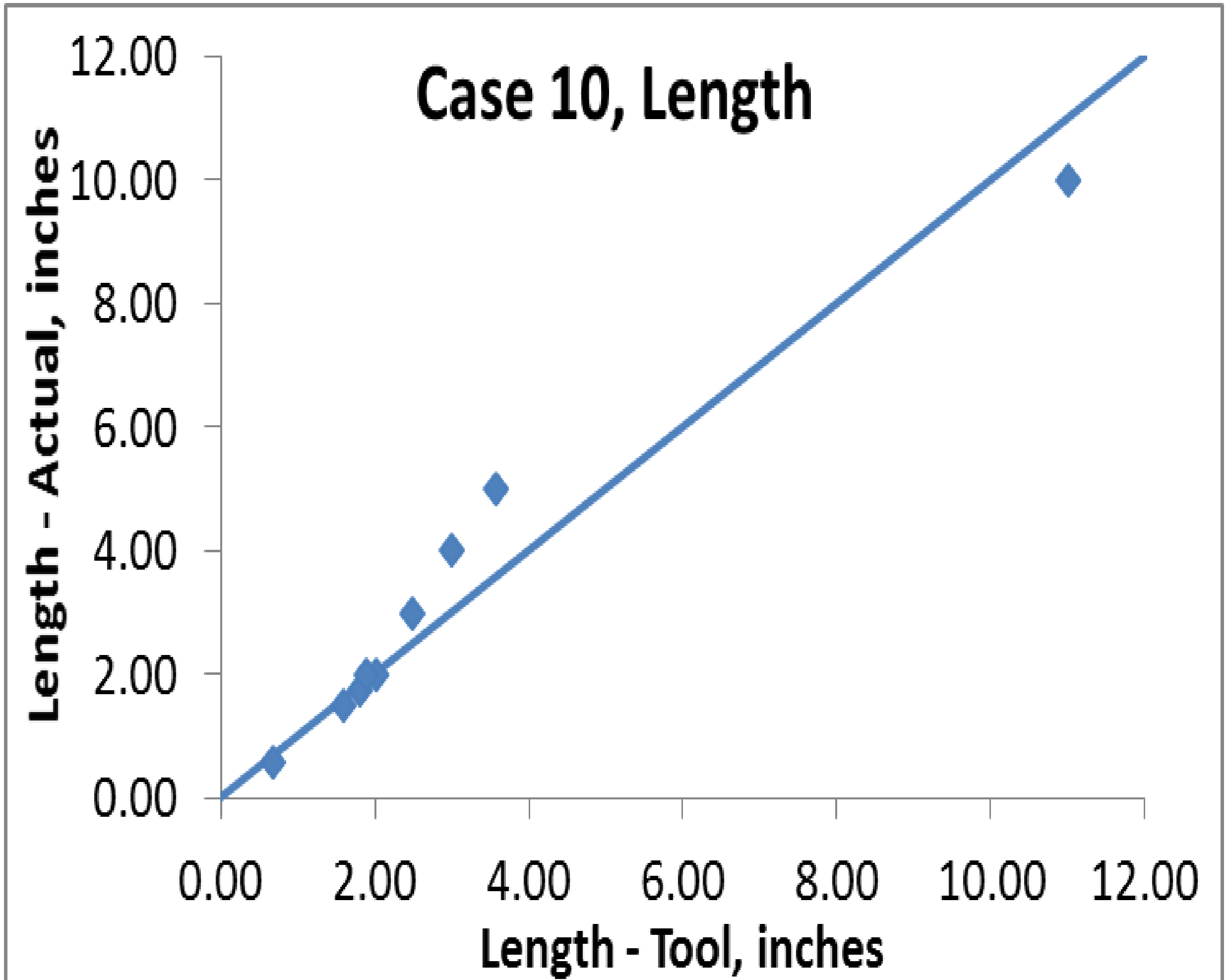
CASE 1 UCD Tool – Length Accuracy Compared to Field NDE



Case 10 CMFL Tool – Depth Accuracy Compared to Field NDE



Case 10 CMFL Tool – Length Accuracy Compared to Field NDE



Toughness and Failure Stress Prediction Issues

- The failure stress level in the case of the “Carmichael” defect would have been greatly over-estimated using a ductile fracture model and value of toughness characteristic of the base metal.
- The bond line toughness must be known for accurate failure stress predictions to be made for bond line defects (i.e., lack of fusion and selective seam weld corrosion)
- In low-frequency-welded ERW and flash-welded seams, it can be expected that the mode of failure of a bond line defect will be brittle fracture.

Conclusions

1. The probabilities of detection and sizing accuracy of the ILI tools were insufficient to provide confidence in the seam integrity in each case.
2. Field NDE was not, by itself, a sufficient means to validate the findings from the ILI crack-tool runs.
3. The tools were not capable of distinguishing defects in the bond line (e.g., lack of fusion) from those in the nearby base metal (e.g., hook cracks and mismatched plate edges).
4. Without some way of knowing the toughness local to the location of a seam anomaly in a low-frequency-welded seam, it was impossible to assess the effects of the anomalies on the pressure-carrying capacity of the pipe.

Path Forward

- Continue to use crack-detection ILI, because improvements can be expected to result in better performance.
- Examine more anomalies in the field with better-calibrated field NDE.
- Cut out and examine at least some anomalies and share the findings with the vendor.
- Conduct hydrostatic tests of at least some segments following a seam integrity assessment via ILI and share the findings with the vendor.
- Pursue development of tools to discriminate between defects in the bond line and those located in the nearby base metal.
- Use brittle fracture failure criteria to assess the failure pressures of defects located in the bond lines of low-frequency-welded ERW and flash-welded seams, and assume a low level of fracture toughness.