Pipeline Research Council International, Inc.

Validation of Material Verification Techniques for Pipeline Integrity Management

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Fundamental Requirement

- **~60% US pipeline infrastructure constructed pre-1970 - prior to formal pipeline regulatory programs**
  - Records can be incomplete or lost for older generation pipelines
  - Material, pressure test or as-built records not available in many cases
  - US regulators are requiring Traceable, Verifiable & Complete (TVC) records (ADB-11-01, ADB-12-06)
  - Proposed requirements testing pipelines without TVC records (192.607)
- **Integrity management requires accurate pipe property information**
  - MAOP / MOP Establishment & Confirmation
  - Flaw and Fitness for Service Evaluation
- **Conventional material sampling and testing would**
  - More Costly
  - Disrupt service
  - Pose safety and in-service welding risks
  - Disrupt or delay maintenance

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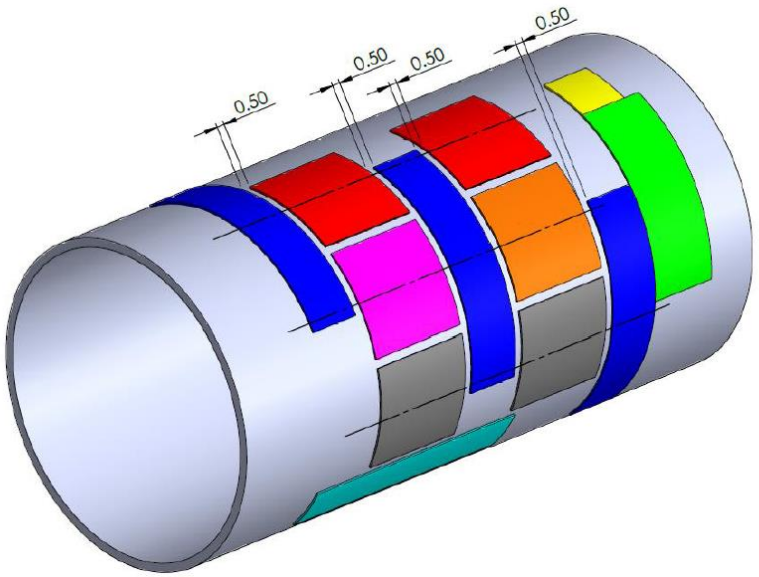
PRCI MV Program

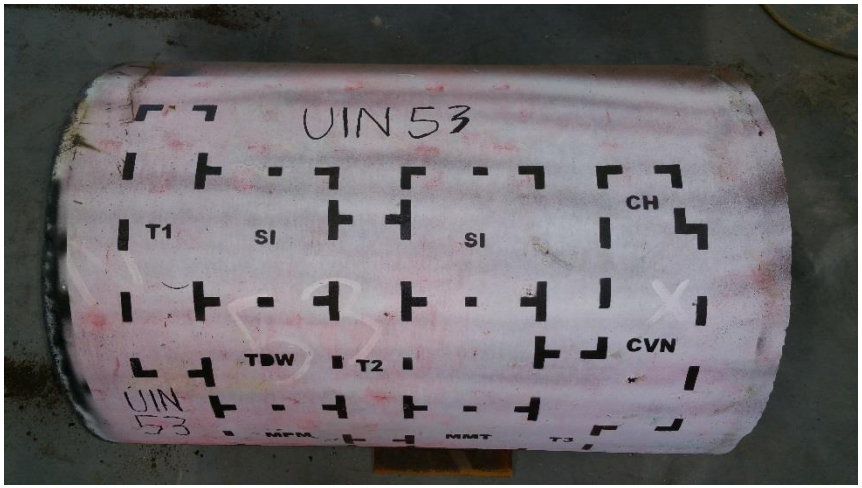
- **In light of this need, PRCI sought tools to support Material Verification (MV)**
- **ILI tools can identify changes in material type or property**
  - Technology being applied for material characterization
- **PRCI initial focus is on *in-situ* NDE material characterization**
  - 1st step in supporting integrity management in the absence of material test data / records
- **PRCI project developed an MV technique and then evaluated with other proprietary in-situ techniques**

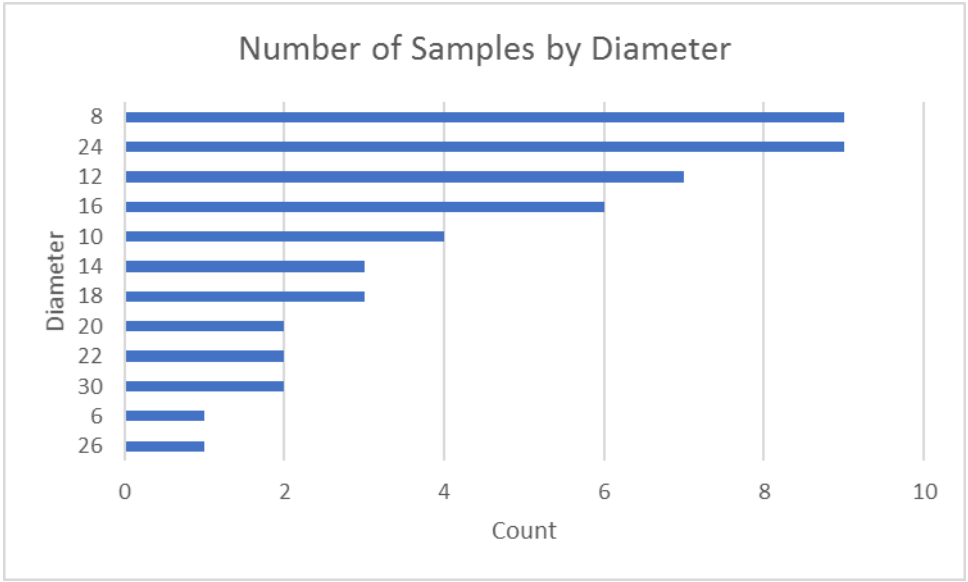
Sample Selection and Layout



Pipe Sample Surface:

- Transverse tensile blank - 3" x 14"
- Longitudinal tensile blank - 14" x 3"
- Area for SI NDE analysis of properties and metallography - 9" x 9" or 2x 6" x 6"
- Sample for chemical analysis - 3" x 3"
- Blank for Charpy impact testing (typically 10 specimens) - 4" x 11"
- TDW NDE analysis - 6" x 6"
- MMT NDE analysis - 6" x 6"
- Optional Additional NDE analysis - 6" x 6"





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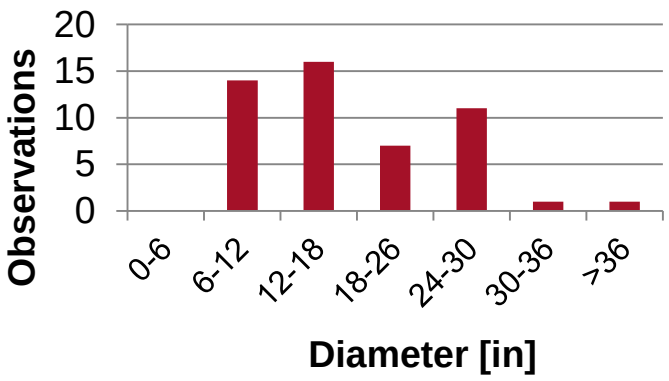
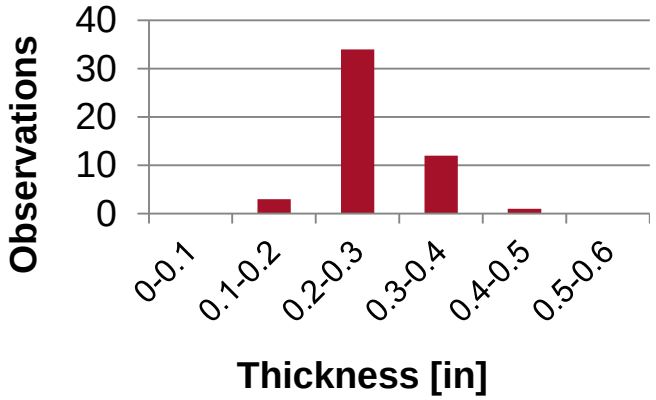
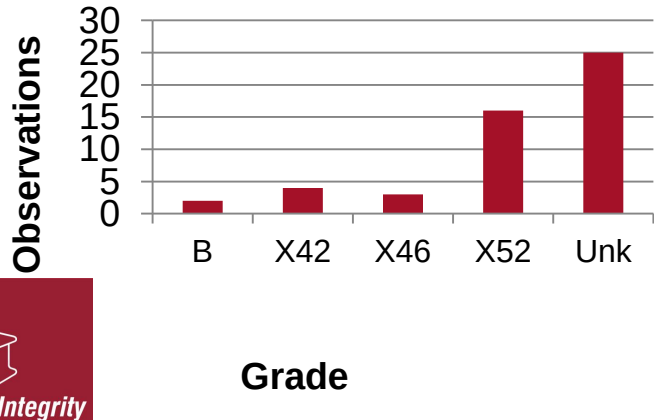
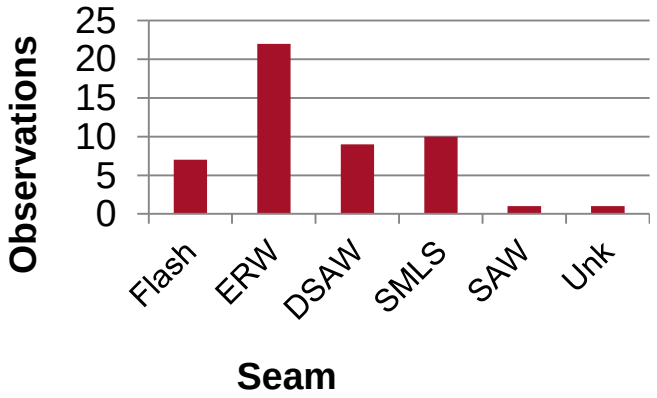
Summary of Sample Variability

- **Test Program was developed to consider a range of materials**
  - 50 PRCI materials, augmented with 46 from previous JIP









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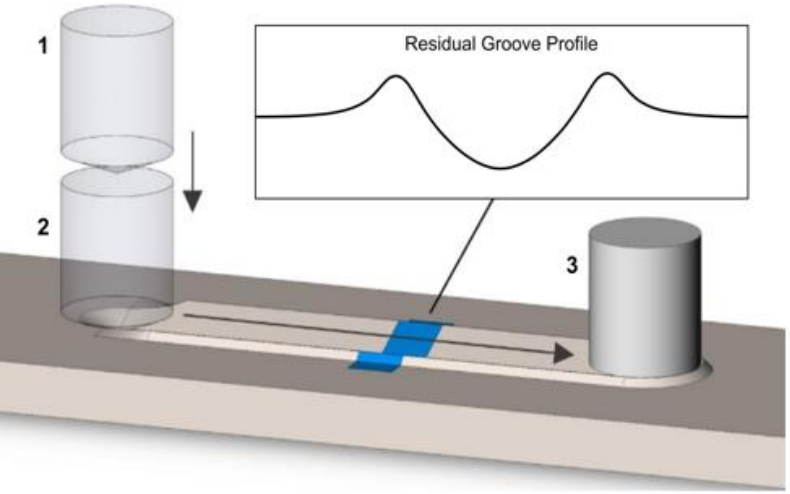
Proprietary Technique 1: Frictional Sliding

NDE for Mechanical Properties via Frictional Sliding

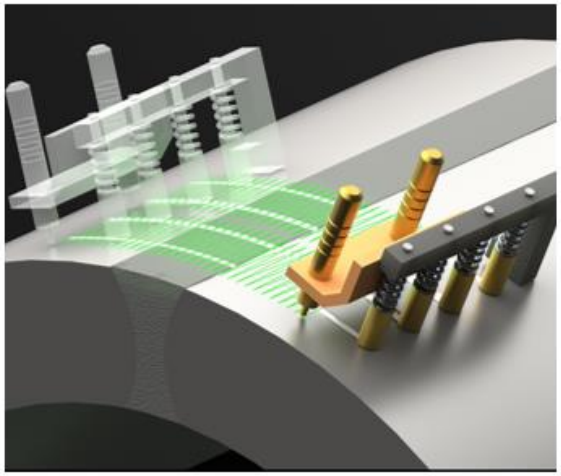
Frictional Sliding Concept

Blunt stylus is pressed on test surface and makes a groove by deforming the steel



NDE Testing in 12 Minutes

4 different shaped styluses make 4 grooves that are simultaneously profiled to obtain 200+ data points



Instant Data Analysis

Built-in algorithms are on-board for instant data verification

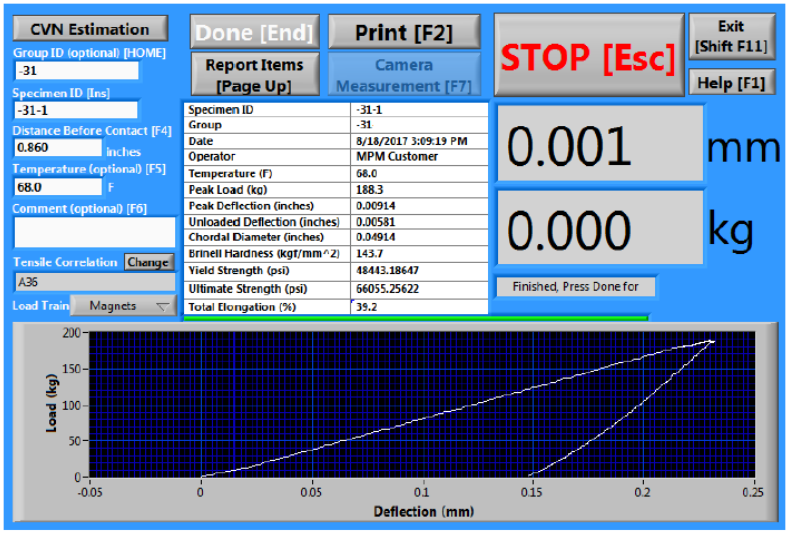
Proprietary Technique: ABI/PMI

Positive Material Identification (PMI)

- TDW's patented (Patent No.: US 9,880,056) and proprietary technique for material verification identifies both Yield and Tensile Strengths along with Chemical Properties
- To achieve desired results, execution must be within the scope, limitations, and guidelines of the company's procedures
- The process includes but is not limited to:
  - UT – ASTM E1901
  - MPA – ASTM E2546
  - OES –ASTM E415
  - MT-ASTM E709

MP Machinery - I2S

- **Uses an Instrumented Indentation System (IIS) to measure uniaxial YS, ultimate tensile strength (UTS), and Brinell hardness (BHN) from a nondestructive surface indentation.**
- **During the loading and unloading stage, the I2S measures the load and deflection of the indentation.**
  - Correlates to strength for a given material



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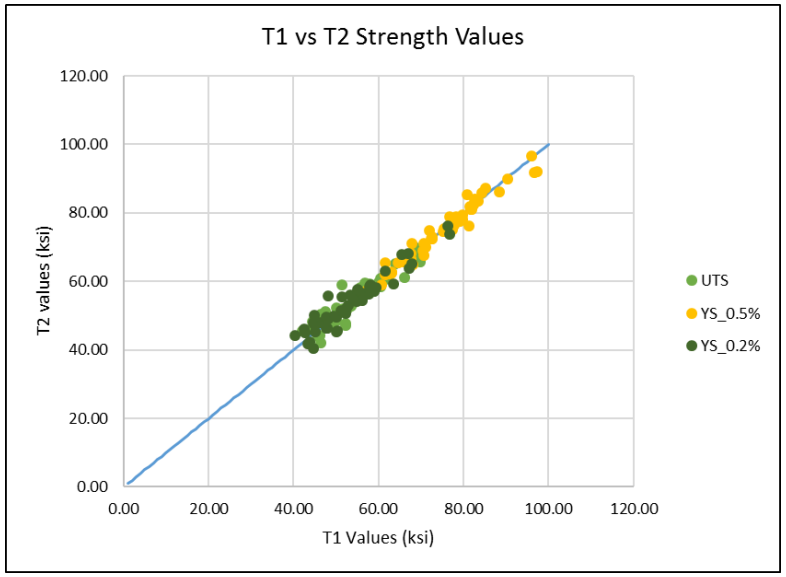
Summary of Lab Testing

- **Tensile Tests**
  - API 5L, ASTM A370, ASTM E8
  - 0.2% Offset and 0.5% Elongation Under Load (EUL), and Ultimate (UTS) Reported
  - 3 Transverse Flattened Straps Per Sample
  - 1 Longitudinal Specimen Per Sample
- **Charpy Tests**
  - ASTM A370 and ASTM E23
  - 10 Temperatures (transition curve)
- **Shavings Chemistry**
  - Bulk Chemistry: ASTM method E1019-11
    - *Combustion Chemical Analysis for C & S, OES For Other Elements*
  - Shavings
    - *Combustion and ICP-AES*
    - ASTM E60. ASTM E1252 and ASTM E1476.



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Summary Scorecard (Yield Strength)

API Selected YS Comparison*

Methodology	Mean Abs Percentage Error (MAPE)	Stdev MAPE	R^2	R	Regression Slope	% Data w/ Err less +/- 10%	% Data w/ Err less +/- 15%	% Data w/ Err less +/- 20%
Technique 1	8.7%	5.9%	0.613	0.783	1.155	66.0%	82.0%	96.0%
Technique 2	8.4%	6.3%	0.579	0.761	1.112	68.0%	80.0%	94.0%
Technique 3	7.6%	7.3%	0.630	0.794	0.822	71.4%	87.8%	93.9%
Technique 4	7.0%	7.3%	0.704	0.839	0.932	78.0%	92.0%	98.0%
Technique 5	12.9%	12.5%	0.160	0.447	0.445	56.0%	62.0%	76.0%

Unity Plot Regression (Lab vs Predicted)

General Measures of Performance:
Mean Absolute Percentage Error (MAPE)
Standard Deviation

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Key Takeaways

- **A number of field deployable techniques exist for predicting material properties**
  - Both proprietary and PRCI developed techniques
  - Relatively good accuracy for NDE performance based on several key performance metrics
- **PRCI techniques show minimal degradation in performance when going from lab to in-situ data collection techniques**
  - Specific to strength properties
- **None of the techniques met the "stringent" NPRM requirements for strength, but need to consider material property / lab testing variation**
  - Requirements of Final Rule are still in development

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