An Update of ILI Tools & Other Industry Technologies

For the

Oklahoma Gas Association

Lloyd Pirtle
August 27th, 2013
Outline

- Pipeline Preparation
- Regulatory Notes
- Technology Offerings
- Value of Running Multiple Technologies
- Mechanical Damage
- Expanding the Multi-Data Set Value
- Characterization of Materials
- Positive Material Identification
- Questions
Pipeline Piggability

Pipeline Dimensions – Length, wt, pipe ID

Pipeline Materials – Coatings, 70’s ERW, Seamless

Bends – Miters, Long Radius, Factory / Field

Reducers – Concentric/Eccentric

Tees – Position, Diameters, Flows, Barred/Unbarred

Stopple Fittings/Tees – Piggable Plugs installed

Valves – Appropriate design

Launchers/Receivers – design specs

Drips
Pigging Categories

✓ Cleaning
  ✓ Corrosion Control - removal of undesirable corrosive materials
  ✓ Improve operating efficiency - savings in pump or compressor fuel

✓ Batching
  ✓ Product separation – Fuels, crudes, etc
  ✓ Slugging Operations – Cleaning, Biocides, Inhibitors, etc

✓ Displacement
  ✓ Commissioning/Decommissioning
  ✓ Conversions

✓ Inspection Tools
  ✓ Geometry
  ✓ Metal Loss
  ✓ Cracks
  ✓ Mapping
Pipeline Cleaning Choices

- **Dry Mechanical Pigging**
  - Debris can ignite on contact w/ O2 – Black Powder
  - Difficult to remove some debris (especially fine particles)
  - Various pigs, Tubs, Drums, Filters

- **Detergent Enhanced Pigging**
  - More effective at removing solids
  - Water or Diesel as Base solution
  - Wet film left behind

- **On-Line**
  - Convenience of being On-stream
  - In Gas, requires separation
  - Cash Register Running
  - Pig Velocity Control ??

- **Off-Line**
  - Virtually complete control of pig velocity
  - Can make more pig runs
  - Cash Register off
# Technology Strengths & Limitations

Table 1: Types of ILI Tools and Inspection Purposes

<table>
<thead>
<tr>
<th>Anomaly</th>
<th>Imperfection/Defect/Feature</th>
<th>Metal Loss Tools</th>
<th>Crack Detection Tools</th>
<th>Deformation Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Magnetic Flux Leakage (MFL)</td>
<td>Standard Resolution (SR)</td>
<td>High Resolution (HR)</td>
<td>Ultrasonic Compression Wave</td>
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<tr>
<td>Metal Loss</td>
<td></td>
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<tr>
<td>External Corrosion</td>
<td>Detection((^{(A)})) Sizing((^{(B)}))</td>
<td>Detection((^{(A)}))</td>
<td>Detection((^{(A)})) Sizing((^{(B)}))</td>
<td>Detection((^{(A)})) Sizing((^{(B)}))</td>
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<tr>
<td>Internal Corrosion</td>
<td>No ID/outer diameter (OD) discrimination</td>
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<tr>
<td>Gouging</td>
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<tr>
<td>Crack-Like Anomalies</td>
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<tr>
<td>Narrow Axial External Corrosion</td>
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<td>Detection((^{(A)}))</td>
<td>Detection((^{(A)})) Sizing((^{(B)}))</td>
<td>Detection((^{(A)})) Sizing((^{(B)}))</td>
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<tr>
<td>Stress Corrosion Cracking</td>
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<td>No Detection</td>
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<td>Fatigue Cracks</td>
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<td>No Detection</td>
<td>No Detection</td>
<td>Detection((^{(A)})) Sizing((^{(B)}))</td>
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<tr>
<td>Long Seam Cracks, etc. ( toe cracks, hook cracks, incomplete fusion, preferential seam corrosion)</td>
<td>No Detection</td>
<td>No Detection</td>
<td>No Detection</td>
<td>Detection((^{(A)})) Sizing((^{(B)}))</td>
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<td>Circumferential Cracks</td>
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<td>Detection((^{(C)})) Sizing((^{(B)}))</td>
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<td>Hydrogen-Induced Cracking (HIC)</td>
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<td>Detection((^{(A)}))</td>
<td>Limited Detection</td>
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<tr>
<td>Deformation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharp Dents</td>
<td>Detection((^{(E)})) (G)</td>
<td>Detection((^{(E)})) (K)</td>
<td>Detection((^{(E)})) (G)</td>
<td>Detection((^{(E)})) (G)</td>
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</tbody>
</table>

\(^{(B)}\) For additional information, refer to API 1183.³

NACE International
TDW ILI Technology Offering

- LGT (GEO)
- KALIPER® 360 Deformation
- MFL (SM)
- GMFL (FM)
- XYZ
- SpirALL
- RMFL / LFMFL
- MDS (Multi-Data Set)
- SPC
- LD GMFL
- EMAT (Newest)

(Light Geometry Tool) 6 - 14”
(Geometry Inspection - NC) 16 - 48”
(Hi Res Geometry Inspection) 4 - 48”
(Axial Magnetic Flux Leakage) 4 - 20”
(Gas Magnetic Flux Leakage) 6 - 48”
(IMU – GPS Mapping) 6 - 48”
(Spiral Magnetic Flux Leakage) 6 - 24”
(Residual / Low Field MFL) 8 - 24”
(DEF/GMFL/SMFL/RMFL/IMU) 8 - 24”
Speed Control (24,26,36,42,48”)
Low Drag Air-coupled Axial MFL
Electro-Magnetic Acoustic Transducer 12/16”
Geometry Inspection
**KALIPER® 360 ILI Tool**

Performance Specs
- Provides Clock orientation & distance for locating
- 2% depth sizing accuracy
  - 12” & below is 1/4” dent minimum
- Low drag can be run in low pressure, low flow applications.
- Great tool for new build geometry inspection baselines.

Pipeline Features Detected:
- Bends and elbows
- Girth welds
- ID changes

Pipe Anomalies Identified:
- Misalignment
- Ovality
- Buckles
- Dents
- Wrinkles
K360 – Inside Dent View
Light Geometry Tool

Features
- Lightweight & compact
- Negotiate bore reductions up to 32%
- 1% depth sizing accuracy
- 1-2% expansion sizing accuracy
- Provides orientation & distance
- Fingers touch the pipe wall

Pipeline Features Detected:
- Bends and elbows
- Girth welds
- ID changes

Pipe Anomalies Identified:
- Misalignment
- Expansions
- Weld variations
- Ovality
- Buckles & Wrinkles
- Dents
Deformation Inspection Tool

Performance Features
• High circumferential resolution
• Negotiate bore reductions up to 25%
• \textbf{0.72\% depth sizing accuracy on dents}
• \textbf{0.25\% depth sizing on expansions}
• Provides orientation and distance
• Provides highest level of confidence for characterizing geometric features

Pipeline Features Detected:
• Bends and elbows
• Girth welds
• ID changes

Pipe Anomalies Identified:
• Dents
• Misalignment
• Expansions
• \textbf{Weld variations}
• Ovality
• Buckles & Wrinkles
Expansion

Cross Section at Nominal

The orange circle in this view represents the nominal ID of the pipe. The Blue circle represents the maximum ID at the specific location.

Cross Section at Increased ID
The Real Thing
Deformation – How sensitive is it?

SLIGHT INDICATIONS IN DEFORMATION DATA
Deformation

SAME LOCATION IN MFL
Axial MFL Inspection Tools
Axial MFL - Principle

Pipe Wall Section
Brushes
Magnet

Metal Loss Defect
Pipe Wall Section
Brushes
Magnet

Magnet Flux Leakage
Typical SM Axial MFL – Brush Tool

Magnetism running through pipe from pole North to South Pole

Sensors taking measurements of Magnetic Flux Leakage & collecting data
Axial MFL Technology

Pipeline Features Detected:
- Valves, flanges, fittings
- Bends and elbows
- Girth welds
- Long Seam welds (HD)
- Spiral welds
- Wall Thickness change

Pipe Anomalies Identified:
- General metal loss due to corrosion
- Gouges
- Internal/External metal loss
Value of Axial Datasets

MFL w/IDOD
- Volumetric Anomalies
- Mill Anomalies
- Extra Metal
- Internal/External Classification
- Dents
Combo Tools

- DEF + XYZ
- MFL + XYZ
- GMFL + XYZ
- MFL + DEF + XYZ
- GMFL + DEF + XYZ
- Many Additional Configurations
Value of Combination Datasets

MFL w/IDOD
- Volumetric Anomalies
- Mill Anomalies
- Extra Metal
- Internal/External Classification
- Dents

DEF
- Ovalities
- Dents
- Misalignments
- Other bore changes

Dent with Volumetric Metal Loss
AGM’s
“aka” Above Ground Markers

NOTE:
If you’re interested in finding anomalies / defects… this is important

- Centerline
- Depth of Cover
- AGM Selection
- Anomaly
- Mapping
## AGM Survey

**TDW AGM Report**

<table>
<thead>
<tr>
<th>Job Number:</th>
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<tbody>
<tr>
<td>Line Name:</td>
<td>Station 1 to Station 6</td>
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<td>Customer Name:</td>
<td>AAA pipelines</td>
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<td>Contact Phone:</td>
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<td>Land Owner:</td>
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<tr>
<td>Owner Phone:</td>
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<td>Survey Method:</td>
<td>Standard Static</td>
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<td>370-0000</td>
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<td>Survey Date:</td>
<td>30-Aug-06</td>
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<tr>
<td>Survey Technician:</td>
<td>Nick Landon</td>
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<table>
<thead>
<tr>
<th>Point ID:</th>
<th>AGM 1</th>
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<tbody>
<tr>
<td>Chainage:</td>
<td>441+46</td>
</tr>
<tr>
<td>Milepost:</td>
<td>5.36</td>
</tr>
<tr>
<td>Ground Elevation:</td>
<td>495.6</td>
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<tr>
<td>Reference Chainage:</td>
<td>441+46</td>
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<tr>
<td>Depth of Cover:</td>
<td>48&quot;</td>
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<tr>
<td>Chainage Source:</td>
<td>Ref Fence</td>
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<tr>
<td>County Parish:</td>
<td>Limestone County</td>
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</tbody>
</table>

**Site Description:**
- AGM sits Fence line and P/L, next to MP 120
- Nearest US Station: Station 1
- Nearest DS Station: Station 6

*Not For Excavation Purposes*

**Site Photo**
- Photo is Looking: Upstream [ ] Downstream [x]

*Site Drawing: (Not To Scale)*

- Railroad Tracks
- P/L
- Fence

*Key Required:* Enter just South of Railroad Tracks by AGM 8 and follow dirt road to fence and turn right down fence.
Mapping Overview

- Accelerometers measure linear movement
- Gyroscopes measure rotational movement
- If a known initial position and speed is given, the current position and speed can be calculated
Run Requirements

- Initial and Final alignment locations are crucial for IMU processing
  - Questionnaire lists 14’ oversize at receive site
  - Survey places the Door to Reducer at 2’
Road crossing at receive
Location Accuracy
Run Requirements

Pipeline Operation

• Mapping and/or chaining will be required to locate defects
• Pipeline cleanliness is a key factor, minimal vibration is a key element to successful mapping runs
• Optimal tool speed of 1 - 3 m/s (3.3 ft/s - 9.8 ft/s)
• Above ground reference points every 2km (1.24 miles) or 25 minutes
  - Stop points longer than the 5 minutes need to be surveyed
• A 15 minute alignment time at the launcher and receiver locations
  - The tool must remain motionless during this time
Speed Control

- 24” SC+GMFL+XYZ+DEF
- 26” SC+GMFL+XYZ+DEF
- 36” SC+GMFL+XYZ+DEF
- 42” SC+GMFL+XYZ+DEF
- 48” SC+GMFL+XYZ+DEF
Multiple DataSets with SpirALL® MFL Technology
Seam Assessment Technology

Axial versus Circumferential MFL

Axial MFL

Circumferential MFL

Not Detected

Detected
Oblique Concept

Traditional MFL

Oblique MFL

Oblique field illustration
Multiple Datasets
SMFL+DEF+MFL (IDOD)+RES+XYZ
Multiple Data Set Identification

ODO & Drive  SMFL  DEF&IDOD with CPU  MFL  Residual with Battery
Analysis with Multiple Data Sets
Value of Multiple Datasets

- **MFL w/IDOD**
  - Volumetric Anomalies
  - Mill Anomalies
  - Extra Metal
  - Internal/External Classification
  - Dents

- **SMFL**
  - Gouging
  - Narrow Axial Corrosion
  - Selective Seam Corrosion
  - Planar / Crack-like Seam Anomalies
  - Volumetric Anomalies (pipe body or seam)
  - Mill Anomalies

- **DEF**
  - Ovalities
  - Dents
  - Misalignments
  - Other bore changes

- **Residual / Low Field Magnetization**
  - Permeability Anomalies – Hard spots
  - Mechanical Stress
  - Pipe Characteristic Changes

- **Planar versus Volumetric Anomalies**
  - Axially oriented Anomalies

- **Metal Loss in Seamless Pipe**
  - Metal Loss crossing Girth Welds

- **Dents with Metal Loss**
  - Pipe Characteristic Changes
  - Gouging/ML without dent

- **Dent with Volumetric Metal Loss**
  - Dent with residual stress

- **Dent w/IDOD**
  - Volumetric Anomalies
  - Mill Anomalies
  - Extra Metal
  - Internal/External Classification
  - Dents
Axial MFL + SMFL

<table>
<thead>
<tr>
<th>Normalized Defect Width, W/A</th>
<th>Normalized Defect Length, L/A</th>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
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<tr>
<td>2</td>
<td>2</td>
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<tr>
<td>3</td>
<td>3</td>
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<td>4</td>
<td>4</td>
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<td>5</td>
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<td>6</td>
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</tr>
<tr>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

**Overlap = Enhanced Characterization**

- Circumferential Slotting
- Circumferential Grooving
- Axial Slotting
- Axial Grooving
- Pitting
- Pinhole
- SpirALL™ MFL
- Axial MFL
- General
Pull Test Data

Axial MFL

Oblique MFL
Field Results

Dig location “C” Planar Anomaly in seam weld
Characterization

Volumetric versus Planar anomalies

Planar anomaly not visible in MFL

MFL data

SMFL data
Characterization

Low-Level Metal Loss in Seamless Pipe

SMFL eliminates Seamless noise pattern which makes low-level metal loss visible
FOREWORD

Pipeline Operators, Service Providers, and the Regulatory Community continuously strive to improve the safety and integrity of gas and liquid pipelines.

In-line inspection of pipelines is a key technology utilized by the industry to help maintain systems safety and integrity.

This Standard serves as an umbrella document to be used with and complement companion standards. NACE RP 0102-2002, “Standard Recommended Practice, In-Line Inspections of Pipelines”; and ASNT ILI PQ 2003, “In-Line Inspection Personnel Qualification & Certification” all have been developed to enable Service Providers and Pipeline Operators to provide rigorous processes, that will consistently qualify the equipment, people, processes and software utilized in the in-line inspection industry. The teams that have worked so diligently in the development of these three standards expect improvement in the results from in-line inspections with accompanying improvements in the safety and integrity of gas and liquid pipelines.

Appreciation is extended to the Pipeline Operators Forum for the use of their guide for in-line inspections, “Specifications and Requirements for Intelligent Pigging of Pipelines,” Version 2.1, Nov. ‘98. Portions of this guide were incorporated directly into this Standard.
Characterization

Metal Loss Crossing and in Girth Weld

- SMFL greatly minimizes impact of heat-affected zones and can indicate girth weld anomalies
Characterization

Planar/Crack-like anomalies in the Long Seam

<table>
<thead>
<tr>
<th>#</th>
<th>Descr.</th>
<th>ILI %</th>
<th>Field %</th>
<th>ILI Length (in.)</th>
<th>Field Length (in.)</th>
<th>ILI Width (in.)</th>
<th>Field Width (in.)</th>
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<tr>
<td>1</td>
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<td>37</td>
<td>39</td>
<td>2.22</td>
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<td>2</td>
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<td>3</td>
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<td>28</td>
<td>35</td>
<td>1.88</td>
<td>2.00</td>
<td>0.06</td>
<td>0.01</td>
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</table>
Mechanical Damage
Re-rounded versus Cycled Dents

- **T_m0**: Pipeline becomes loaded
- **T_1**: Load removed, leaving re-rounding stress, blue, detectable by low-field MFL
- **T_n**: Pipeline may be cycled creating additional residual stresses, green, detectable by low-field MFL
## Prioritization

<table>
<thead>
<tr>
<th>Diet Start</th>
<th>Dent Depth (in)</th>
<th>Orientation (Deg)</th>
<th>Description</th>
<th>Seem or not</th>
<th>Depth %</th>
<th>Dent Length (in)</th>
<th>Severity Number</th>
<th>Final Severity</th>
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<tbody>
<tr>
<td>563805.8560</td>
<td>0.12</td>
<td>146</td>
<td>Dent w/ Metal Loss - Re-rounded (3.01% Strain)</td>
<td>2.0</td>
<td>4.24</td>
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<td>130171.3133</td>
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<td>Dent w/ Metal Loss - Re-rounded (3.37% Strain)</td>
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<tr>
<td>668275.194</td>
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<td>1.40</td>
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<td>1.57</td>
<td>1</td>
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### Table

<table>
<thead>
<tr>
<th>Diet Start</th>
<th>Dent Depth (in)</th>
<th>Orientation (Deg)</th>
<th>Description</th>
<th>Seem or not</th>
<th>Depth %</th>
<th>Dent Length (in)</th>
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<td>563805.8569</td>
<td>0.32</td>
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<td>301</td>
<td>Dent w/ Metal Loss - Re-rounded (3.72% Strain)</td>
<td>1.1</td>
<td>2.36</td>
<td>3</td>
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<tr>
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<td>366755.6328</td>
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<td>288</td>
<td>Dent w/ Metal Loss - Re-rounded (3.37% Strain)</td>
<td>1.0</td>
<td>2.38</td>
<td>3</td>
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<tr>
<td>668275.194</td>
<td>0.15</td>
<td>344</td>
<td>Dent w/ Metal Loss, Found in SpirALL (1.47% Strain) Cycled</td>
<td>0.9</td>
<td>3.30</td>
<td>3</td>
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<td>679495.7892</td>
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<td>352</td>
<td>Dent w/ Metal Loss - Re-rounded, Found in SpirALL (1.67% Strain)</td>
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<td>1.40</td>
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<td>0.8</td>
<td>2.00</td>
<td>3</td>
</tr>
</tbody>
</table>

- **Dent Start**: Date or identifier for the specific condition or issue.
- **Dent Depth (in)**: The depth of the condition in inches.
- **Orientation (Deg)**: The orientation of the condition in degrees.
- **Description**: Description of the condition, including any relevant notes or specifications.
- **Seem or not**: Indicator of whether the condition is visible or not.
- **Depth %**: Percentage of the total depth affected by the condition.
- **Dent Length (in)**: Length of the condition in inches.

---

**Notes**:
- **Severe Number**: A numeric value indicating the severity level.
- **Final Severity**: The final classification based on severity, ranging from High to Low.
Characterization

0.88% ILI depth / 0.62% Field Reported
Ongoing Project and Future work

MDS_EMAT Development
The Next Addition - EMAT

ILI Inspection: Technology vs. Identification

[Diagram showing defect identification through EMAT and other technologies]
How many data sets on your Pig?
Low Field MFL - Steel Microstructure

Weld

Low Carbon

High Carbon

Hard Spot

Figure 11. Photomicrograph of cracking initiating

Pipeline Performance™
Characterization

Pipe Characteristic Changes

Three different types of pipe
6” Low Drag Air-Coupled GMFL Module & Wheeled Geometry Module

- Tool Drive Module
- Wheel Mounted Geo Module
- Air-Coupled Magnetizer

- Centering Brushes
- ODO’s

Short, Compact & Lightweight
Currently acceptable methods MAY include:

- **Hydrotests – w/ specified test pressures**
  1) Where test records are inaccurate or unavailable
  2) Tests require pressure above MAOP – pressures vary with pipeline parameters & conditions
     a) generally not desirable, but may be required to validate a defensible MAOP
  3) Material Documentation can allow for higher yield pipe

- **In-situ methods – may include extracting coupons from the line in questions and offsite lab tests to determine material properties and type**
  1) If MTR’s are unavailable and not secured, Type A material must be assumed which is 24,000 yield strength
PMI is...what?

The analysis of a metallic alloy to establish composition by reading the quantities by percentage of its constituent elements as well as mechanical properties.

What is a proven used PMI Method?

Cutting strips or coupons to have them material analyzed in a laboratory environment

Where are we headed with PMI?

OES + ABI = PMI

OES is a method for establishing elemental chemistry is the use of Optical Emission Spectrometry. ABI is a method mechanical properties there are methods for establishing Ultimate tensile strength, ultimate yield strength and fracture toughness.

What other technology can help enhance this Methodology?

ILI tools are capable of establishing material types which can then be positively identified through PMI
Mobile Optical Emission Spectrometer

A field proven technology that analyzes & accurately measures pipe chemistry through the use of air and Argon gas.
NDE In-Ditch Methods
Positive Material Identification

OES – Optical Emissions Spectrometry
The OES provides Non-Destructive Chemical Analysis & Carbon Equivalent determination of unidentified material, categorizing material grade & weldability
NDE In-Ditch Methods
i.e. Positive Material Identification

Automated Ball Indentation

The technique measures load-depth curve during indentation, creates a stress-strain and analyzes the mechanical properties related to deformation such as yield strength, tensile strength, and work-hardening index.
Automated Ball Indentation Systems

- This technique is advantageous for in-field applications:
  - The system is very compact & portable
  - Does not require a large excavation

- This equipment can be secured via chains or magnets
- Results can be provided in a very short time frame in field
  - One to two hours
PMI Methods

PMI Test Results: XYZ Pipeline Co.

OES Results

<table>
<thead>
<tr>
<th>Run 2</th>
<th>Center 1 Burn 1</th>
<th>C: 0.397</th>
<th>Mn: 0.190</th>
<th>V: 0.003</th>
<th>Ti: 0.001</th>
<th>Nb: 0.002</th>
<th>S: 0.017</th>
<th>P: 0.023</th>
<th>CE: 0.705</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Center 1 Burn 2</td>
<td>0.440</td>
<td>0.246</td>
<td>0.003</td>
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<td>0.003</td>
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<td>Center 1 Burn 3</td>
<td>0.347</td>
<td>0.132</td>
<td>0.001</td>
<td>0.001</td>
<td>0.002</td>
<td>0.019</td>
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<td>Center 1 Burn 4</td>
<td>0.022</td>
<td>0.138</td>
<td>0.001</td>
<td>0.001</td>
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<tr>
<td></td>
<td>Center 1 Burn 6</td>
<td>0.261</td>
<td>0.114</td>
<td>0.001</td>
<td>0.001</td>
<td>0.002</td>
<td>0.013</td>
<td>0.019</td>
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<tr>
<td>AVG</td>
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<td>0.139</td>
<td>0.001</td>
<td>0.001</td>
<td>0.002</td>
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<td>0.197</td>
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<td>STD</td>
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<td>0.015</td>
<td>0.001</td>
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OES Results

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<th>Center 2 Burn 1</th>
<th>C: 0.448</th>
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<th>Ti: 0.001</th>
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ABI Results

<table>
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<tr>
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<th>Yield Strength</th>
<th>Run 3</th>
<th>Tensile Strength</th>
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<td>49.40</td>
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<tr>
<td>2</td>
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<tr>
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<tr>
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<td>55.70</td>
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<tr>
<td>5</td>
<td>33.10</td>
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</table>

NOTE: The Information Captured Fundamentally replicates an MTR
Filling Gaps in Documentation

Methods (following) are being considered to fill these gaps:

1. Multiple Data Set / Residual Magnetism Tools
2. PMI (NDE) Methods including the items below:
   
   A. Optical Emission Spectrometer (ARCMET 8000) can provide pipe Chemistry and Carbon Equivalence (OES).

   B. Advanced Ball Indentation (aka: ABI) can provide pipe tensile strength and fracture toughness
Having the RIGHT tool for the RIGHT job is CRITICAL!
TDW Products & Services

Trusted Performance / Innovative Solutions
Questions ?