“Case Histories for Cased Crossings Using an Integrated Tool Approach with Long Range Guided Wave”

NACE DA Conference
By Joe Pikas
Overview

• Introduction
• Corrosion and Causes
  – Coatings
  – Shielding
  – Metallic Contacts
• Criteria for Casings
• Monitoring
  – Electrical Tests
  – Long Range Guided Wave
  – Other Technologies
• Verification and Prove Up
• Maintenance
• Procedure for Testing Integrity of Carrier Pipe
Introduction

• Common Practice started w/RR X-ings
• End Seals
  – Concrete or Enamel w/Rope (Old Type)
  – Link, Hot Applied Sleeves, etc.
  – None - Concrete coated pipe w/open ends
• Spacers
  – Hemp Rope w/enamel (Old Type)
  – Non metallic
    • Plastics
    • Molded Epoxy Sleeves
  – Concrete coated pipe
Corrosion and Causes

- Coating Deterioration
  - Age
  - Physical Damage to Coating during construction
- Shielding
  - Spacers
  - Insulators
  - Coating
- Metallic Contact (Generally @ End(s))
  - Galvanic
  - Drain on CP outside casing
  - Stress Concentrator
- Atmospheric
  - High Delta $t$ (temperature difference between pipe surface and atmosphere)
  - Humid Environment in Annulus
  - Vent(s) supplying oxygen to the annulus
Criteria for a Short

“A shorted casing may exist if there is a small differential or there is no differential between the pipe to electrolyte and casing electrolyte potential.”

- **Severe Indication** - Pipe to Electrolyte "ON" Potentials are less than -850 mV and the difference in the Pipe and Casing Potential is less than 10 mV.
- **Moderate Indication** - Pipe to Electrolyte “ON” Potentials are borderline -850 mV and the difference in the P/S & C/S potentials is greater than 10 mV and less than or equal to 100 mV.
- **Minor Indication** - Pipe to Electrolyte “ON” Potentials are greater than -850 mV and the difference in the P/S & C/S potentials is greater than 10 mV and less than or equal to 100 mV.
- **Electrically Clear** – Pipe to Electrolyte “ON” Potentials are greater than 1000 mV and the difference P/S & C/S potentials is greater than 150 mV.
<table>
<thead>
<tr>
<th>Test Description</th>
<th>Severe (Metallic Contact)</th>
<th>Moderate (Electrolytic with Coating Holidays)</th>
<th>Minor (Electrolytic Path)</th>
<th>Electrically Clear</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe to Electrolyte Potential (Industry Standard)</td>
<td>Pipe to Electrolyte Potentials are severely depressed and below -850 mV Criterion</td>
<td>Pipe to Electrolyte ON Potentials are borderline near casing</td>
<td>Pipe to Electrolyte ON Potentials are slightly depressed near casing structure and are above -850 mV criterion</td>
<td>Pipe to Electrolyte ON Potentials show no or little influence from casing proximity</td>
<td>Pipe, Casing and OCP Potential Tests Should Always be Run Together</td>
</tr>
<tr>
<td>Casing-to-Electrolyte Potential (Industry Standard)</td>
<td>Casing to Electrolyte ON Potentials partially track Pipe Potentials and the difference in the Pipe and Casing &quot;ON&quot; Potentials &lt; than 10 mV.</td>
<td>Casing to Electrolyte ON Potentials partially track Pipe Potentials and the difference in the P/S &amp; C/S &quot;ON&quot; potentials is greater than or equal to 10 mV and less than or equal to 100 mV .</td>
<td>Casing to Electrolyte ON Potentials partially track Pipe Potentials and the difference in the P/S &amp; C/S &quot;ON&quot; potentials is greater than100 mV .</td>
<td>Difference in the P/S &amp; C/S &quot;ON&quot; greater than 150 mV and are below bare steel potential for that environment</td>
<td>Pipe, Casing and OCP Potential Tests Should Always be Run Together</td>
</tr>
<tr>
<td>Open Circuit Potential (OCP) between Casing and Pipe (Industry Standard)</td>
<td>Difference in Pipe and Casing Structure Potential &lt; 10 mV</td>
<td>Difference in the P/S &amp; C/S &quot;ON&quot; greater than or equal to 10 mV and less than or equal to 100 mV.</td>
<td>Difference in the P/S &amp; C/S &quot;ON&quot; greater than100 mV .</td>
<td>Difference in the P/S &amp; C/S &quot;ON&quot; greater than 150 mV.</td>
<td>Pipe, Casing and OCP Potential Tests Should Always be Run Together</td>
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<td>Internal Resistance (Industry Standard)</td>
<td>Pipe-to-Casing (P/C) resistance less than or equal to 0.01 Ω</td>
<td>P/C resistance greater than 0.01 Ω and less than or equal to 0.1 Ω.</td>
<td>P/C resistance greater than 0.1 Ω.</td>
<td>P/C resistance greater than 0.15 Ω</td>
<td>Internal Resistance Test will determine metal to metal contacts</td>
</tr>
<tr>
<td>Classification Table</td>
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<td>Cycling the Rectifier (Subjective)</td>
<td>Difference in the P/S &amp; C/S shifts less than 10 mV &quot;OR&quot; C/S shift greater than 75% P/S shift</td>
<td>Difference in the P/S &amp; C/S shifts greater than or equal to 10 mV and less than or equal to 100 mV &quot;OR&quot; C/S shift greater than or equal to 25% P/S shift and less than or equal to 75% P/S shift</td>
<td>Difference in the P/S &amp; C/S shifts greater than 100 mV &quot;AND&quot; C/S shift less than 25% P/S shift</td>
<td>Difference in the P/S &amp; C/S shifts greater than 150 mV &quot;AND&quot; C/S shift less than 10% P/S shift</td>
<td>Subjective</td>
</tr>
<tr>
<td>AC Signal (Subjective)</td>
<td>Near total signal loss from both directions large spike in mb/ft (C-Scan) or &gt; 80 dBmA (PCM)</td>
<td>Moderate Spike mb/ft (C-Scan) or &lt; 80 dBmA (PCM)</td>
<td>Minor spike or signal loss for either C-Scan or PCM</td>
<td>No significant signal loss (Normal Attenuation)</td>
<td>Subjective except for direct metal to metal contact</td>
</tr>
<tr>
<td>Polarization Test (Panhandle Eastern Method) (Subjective)</td>
<td>P/C resistance less than or equal to 0.01 Ω</td>
<td>P/C resistance greater than 0.01 Ω and less than or equal to 0.1 Ω.</td>
<td>P/C resistance greater than 0.1 Ω.</td>
<td>Additional testing required to define</td>
<td>Subjective</td>
</tr>
<tr>
<td>Casing-to-Pipe (C/P) Capacitance</td>
<td>&quot;Shorted&quot; display</td>
<td>Not Defined</td>
<td>None</td>
<td>&quot;Clear&quot; display</td>
<td>Not Proven by Industry</td>
</tr>
</tbody>
</table>

**Note:** Many of these tests were determined subjective because the results have not been proven up empirically or by standards.
Monitoring

• Initial Electrical Field Tests
  – Potential Survey
    • This method is the initial test conducted to identify a shorted casing. A voltmeter and a reference electrode are used to conduct these tests.
    • P/S, C/S, & OCP
  – Internal Resistance
    • This method indicates whether direct metal-to-metal contact exists between a carrier pipe and the casing pipe by measuring electrical resistance.
    • Metal to metal <0.01 ohms)
  – Four Wire IR Drop
    • This method may indicate the existence and location of a short.
Potential Survey

VENT PIPE

TEST LEAD

VENT PIPE

GROUND LEVEL

VENT PIPE

REFERENCE CELL

TEST LEAD

CARRIER PIPE

CASING

Upstream or Upstation (U/S) End

Downstream or Downstation (D/S) End

VOLT METER
Internal Resistance
Four Wire Calibration

Diagram showing a circuit with a variable resistor, battery, ammeter, volt meter, vent pipe, ground level, carrier pipe, casing, test lead, and U/S End and D/S End.
Four Wire U/S End
Four Wire (D/S End)
Monitoring

• **Initial Electrical Field Tests** (continued)
  – Casing Depolarization
    • Panhandle Eastern Method
  – Cycling the cathodic protection rectifier is another method used to evaluate the electrical isolation between pipe and casing.
  – **AC Signal (Current Attenuation)**
    • This method uses a signal generator and receiver to detect signal loss at a metallic short or a coating defect.
  – Capacitive (Go-no-Go Type Test)
Monitoring

Verification Tests

• Long Range Guided Wave
  – This method uses torsional data as well as compressional wave modes to detect cracks, metal loss and other defects on a carrier pipe inside a casing.

• In Line Inspection or Tethered Pigs
  – ILI is used to determine the presence or absence of pitting-corrosion damage on carrier pipe inside a casing.

• Hydrostatic Test (Go-no-Go Type Test)
Direct Examinations

• Excavate both End(s) of Casing – Prove Up

• Conduct Inspection for:
  – Condition of Carrier Pipe
    • Coating
    • Pipe Surface for defects
  – Condition of Casing & Components
    • Integrity of Casing Pipe, Vent Pipes, Welds, End Seals, Spacers, etc.
  – Electrolyte/Soil/Water Testing for Corrosivity
    • Lab and Field
    • Electrolyte inside casing annulus
    • Electrolyte outside casing
Procedure for Casing Test

• Pre-Assessment
  – Operations
    • Temperature, Stress Levels, Dig Reports, etc.
  – History
    • Year installed, Leaks, Shorts, CP, MIC, etc.
  – Pipe/Casing Attributes
    • Diameter, W.T., SYMS, Welds, etc.
  – Construction Practices
    • End Seals, Spacers, Seam type, Problems, Vents, etc.
  – Soils and Environmental
    • Drainage, Topography, Land Use, etc.
  – Corrosion Control
    • Coating type, Coating Condition, Current Demand, Potentials of Pipe/Casing, Test Stations, etc.
Procedure (Continued)

- Indirect Examinations - Initial Field Tests plus (2 or more tests are recommended)
  - Potential Method
    - Pipe to Electrolyte
    - Casing to Electrolyte
    - Open Circuit Potential (OCP)
  
  Note: If OCP is < 100 mV and P/S below -850 conduct or likelihood of atmospheric may corrosion exist, conduct additional verification tests for corrosion or no corrosion.

  - Resistance Test
    - 0.01 ohms or less Metallic Contact
    - >0.01 and less 0.10 ohms Possible Electrolytic Couple
    - >0.10 ohms - Little or no electrolyte in annulus

  - 4 Wire IR Drop Test – Determine End or Ends for Metallic Short
Procedure for Casing Testing

• Indirect Exams (Verification Field Tests) Determine Likelihood of:
  – Metallic Contact (Stress Riser),
  – Galvanic,
  – MIC,
  – Atmospheric Corrosion,
  – History of Leaks,
  – Any Threats to Cause an Integrity Problems
Procedure for Casing Testing

- Conduct borescope, temperature and humidity tests
- Conduct C-SCAN or PCM Tests
  - Determine if end or ends are metallically shorted
  - Determine coating holidays on carrier pipe where water is present
- Conduct 18 Point Long Range Guided Wave Test
  - Verify the presence or no presence of corrosion
  - Determine depth and length of metal loss
    - B31.G calculations to determine integrity
Procedure for Casing Tests

- Direct Examinations
  - Reason for Inspection (Metallic Short/Atmospheric Corrosion)
    - Location
    - Engineering Station # and GPS
    - Pipe Attributes
  - Coating Type's) and Evaluation
  - Environment (Soil/Water – Field/Lab)
  - Evidence of
    - Corrosion, SCC, Defect, Damage, etc.
  - Repair
    - Recoat, Composite Sleeve, Replace, etc.
  - Type of Tests Performed
    - MIC, UT, Mag. Particle, Dye Penetrant, pH, resistivity, Conformable Array, etc.
New Corrosion Mapping Tool

Conformable Array for Mapping Corrosion Profiles

Pipe Under Inspection

Pipe Corrosion

Conformable Eddy-Current Sensor Array

Corrosion Depth Profile
Example of Metallic Shorted Casing

- **Initial Potential Test (Voltmeter)**
  - P/S -700 mV
  - C/S -698 mV
  - OCP -002 mV

- **Internal Resistance between Casing and Pipe (Resistivity Meter)**
  - Ohms 0.0015

- **Four IR Drop (Shorted on U/S Side)**
- **Electromagnetic – (Coating Holiday U/S Side)**
- **Long Range Guided Wave**
  - 20 to 27 % Metal Loss
Example of Atmospheric Corrosion

- Pre-Assessment – Fluctuating Water Table
  - Temperature/Humidity (90% Relative Humidity and delta $t = 15 F$)
- Initial Potential Test (Voltmeter)
  - P/S - 900 mV
  - C/S - 800 mV
  - OCP - 100 mV
- Internal Resistance between Casing and Pipe (Resistivity Meter)
  - Ohms 0.095
- No Four Wire or Above Ground Tests Conducted
- Electromagnetic Tests Found Possible Defect D/S Side
- Borescope (Possible Atmospheric Corrosion Found)
- Long Range Guided Wave – Verification
  - 10% to 15% D/S - (Corrosion Inside Casing)
GUL – Shorted Casing

Medium Anomaly
Approx wall loss 20% - 27%
Feature -F17
-897" From test location

Minor Anomaly
Approx wall loss 10%
Feature -F5
-275" From test location
GUL Dual Collar, Pitch/Catch

60'

Air to Soil Interface

Minor Anomaly
Approx wall loss 10%-20%
Feature +F6
28'11" From test location

Plan View

Hwy 254

North

Picture of the test location

Hwy 51

Minor Anomaly
Approx wall loss 10%-20%
Feature +F6
28'11" From test location

North
Cased X-ing Mitigation

- Eliminate metal to metal contact
  - Remove casing end if feasible
- Replace carrier pipe
- Provide supplemental cathodic protection to the carrier pipe
- Fill casing with a high dielectric material
- Apply coating or recoat the carrier pipe
- Replace end seals
- Remove, flush electrolyte and debris from inside the casing
- Monitor the condition of the carrier pipe
- Install a new pipe crossing such as using a directional drill
- Inject vapor and or water based type inhibitor in annulus
Conclusions

- **Found Metallic Short - U/S side**
  - Potential, Resistance and 4 Wire Tests showed metallic short
  - Electromagnetic test showed possible short
  - GUL showed 20 to 27% Metal loss
- **Found Atmospheric Corrosion on D/S Side**
  - Pre-assessment showed likelihood of atmospheric corrosion
  - Potential and Resistance tests showed electrolyte in casing
  - Electromagnetic tests showed possible coating indication
  - Borescope showed indication of atmospheric corrosion
  - GUL showed 10 to 20% metal loss
Conclusions

• Indirect Tools Found Problems
  – Potential Surveys, Resistance Tests, etc.
  – Electromagnetic surveys (C-Scan/PCM)
  – Borescope, Temperature, Humidity, etc.

• Tools Confirmed Indications
  – Long Range Guided Wave

• Direct Examination Verified Findings by Indirect Surveys
  – Conformable Array used in inaccessible areas between casing and pipe.
Questions

- Corrosion and Causes
- Criteria for Casings
- Monitoring
  - Borescope, Temperature, Humidity, etc.
- Maintenance/Mitigation
- Procedures for Testing Integrity of Carrier Pipe (Electromagnetic Tools)
- Use of Long Range Guided Wave (GUL)
- Other Technologies