Monitoring corrosion protection of pipelines utilizing the main survey techniques

By
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For Corrosion To Take Place You Need The Following ALL Present At Same Time:

- An anode area where corrosion occurs.
- A cathode area for counter electrode reactions.
- A driving force between anode and cathode.
- Anode and cathode area must be electrically interconnected (through the pipe)
- Anode and cathode must be in same electrolyte (moist soil).

Corrosion is Electrochemical by Nature
- REMOVE ANY ONE AND CORROSION STOPS.
Corrosion Mitigation

➢ We use Coatings to separate Pipe Anode and Cathode areas from the moist soil.

➢ We use Coatings to physically isolate Pipe Anode and Cathode areas from each other.

➢ We use CP to change the driving force between Pipe Anode and Cathode areas.
To Mitigate Corrosion and to Maintain Pipeline Integrity You Need to Ensure a Good Coating and Effective CP

But

What Happens if You Don’t get a Good Balance between Good Coating and Effective CP?
Brown/Red Corrosion Product Indicates Poor CP.

Pin Hole Corrosion – Metal Loss

Root Damage to Coating. Root Vegetation Seeks Water in Coating

Blistering - Main Line Flake Shield Coated Pipeline

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Monitoring Pipelines To determine Corrosion Protection
## The Properties of a Coating Fault and their Priority.

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>PRIORITY</th>
<th>METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>1</td>
<td>GPS</td>
</tr>
<tr>
<td>Fault Cathodic Current</td>
<td>2</td>
<td>DCVG</td>
</tr>
<tr>
<td>Fault Anodic Current</td>
<td>3</td>
<td>DCVG</td>
</tr>
<tr>
<td>Net Current Flow</td>
<td>4</td>
<td>DCVG</td>
</tr>
<tr>
<td>DC Interference</td>
<td>5</td>
<td>CIPS / DCVG</td>
</tr>
<tr>
<td>Soil Resistivity</td>
<td>6</td>
<td>EM Technique</td>
</tr>
<tr>
<td>OFF Potential</td>
<td>7</td>
<td>CIPS</td>
</tr>
<tr>
<td>Soil pH</td>
<td>8</td>
<td>pH meter</td>
</tr>
<tr>
<td>Fault Severity</td>
<td>9</td>
<td>DCVG</td>
</tr>
<tr>
<td>AC Interference</td>
<td>10</td>
<td>AC Voltmeter</td>
</tr>
<tr>
<td>ON Potential</td>
<td>11</td>
<td>CIPS</td>
</tr>
<tr>
<td>Type of Soil/Bacteria</td>
<td>12</td>
<td>Analysis</td>
</tr>
<tr>
<td>Fault Size</td>
<td>13</td>
<td>Excavation/Visual</td>
</tr>
<tr>
<td>Origin of Fault</td>
<td>14</td>
<td>Excavation/Visual</td>
</tr>
<tr>
<td>Type of Coating</td>
<td>15</td>
<td>Records</td>
</tr>
<tr>
<td>Field Joint Coating</td>
<td>16</td>
<td>Records</td>
</tr>
<tr>
<td>Overall Density of Faults</td>
<td>17</td>
<td>DCVG/GPS</td>
</tr>
<tr>
<td>Closeness to Another Fault</td>
<td>18</td>
<td>DCVG/GPS</td>
</tr>
<tr>
<td>Age of Coating</td>
<td>19</td>
<td>Records</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>DCVG</th>
<th>CIPS</th>
<th>SOIL RESISTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>% IR</td>
<td>ON Potential</td>
<td>Soil Resistivity</td>
</tr>
<tr>
<td>Corrosion Status</td>
<td>OFF Potential</td>
<td>Change in Soil Type</td>
</tr>
<tr>
<td>Current Demand</td>
<td>Large Coating Fault Location</td>
<td>Moisture Content</td>
</tr>
<tr>
<td>Shape &amp; Orientation</td>
<td>Effective range of CP</td>
<td>Average Soil pH</td>
</tr>
<tr>
<td>Effective Range of Rectifier</td>
<td>Weak Areas of CP</td>
<td>Presence of Rock or Stones</td>
</tr>
<tr>
<td>% Efficiency of Casings, Foreign Structures, etc</td>
<td>Interference Effects</td>
<td>Location of Coating Faults</td>
</tr>
<tr>
<td>Attenuation of CP</td>
<td>Soil Composition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Voltage Variations</td>
<td></td>
</tr>
</tbody>
</table>

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Current Flow Through the Soil to Coating Fault Generates a Voltage Gradient

Gradient Forming and Dissipating as CP switched ON/OFF by Interrupter, 0.45 Sec ON, 0.8 Sec OFF

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% IR Severity Rating:

% IR Severity = \frac{\text{OL/RE}}{\text{P/RE}} \times 100 \times \frac{\text{Calculated MV to remote earth (RE)}}{X 100}

<table>
<thead>
<tr>
<th>Severity %IR</th>
<th>Visual size</th>
<th>Action required</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 15</td>
<td>Small</td>
<td>Repair Unlikely</td>
</tr>
<tr>
<td>16 to 35</td>
<td>Medium</td>
<td>Consider Repair</td>
</tr>
<tr>
<td>36 to 70</td>
<td>Medium / Large</td>
<td>Consider Early Repair</td>
</tr>
<tr>
<td>71 to 100</td>
<td>Large</td>
<td>Immediate Excavation for Investigation.</td>
</tr>
</tbody>
</table>

Corrosion Characterisation of a Coating Fault:

<table>
<thead>
<tr>
<th>Interpretation</th>
<th>Shorthand Representation</th>
<th>Corrosion Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cathodic / Nil</td>
<td>(CPON/CP OFF)</td>
<td>Protected CP On or Off</td>
</tr>
<tr>
<td>Cathodic / Cathodic</td>
<td>(CPON/CP OFF)</td>
<td>Protected CP On or Off</td>
</tr>
<tr>
<td>Cathodic / Anodic</td>
<td>(CPON/CP OFF)</td>
<td>Protected CP On Unprotected CP Off</td>
</tr>
<tr>
<td>anodic / anodic</td>
<td>(CPON/CP OFF)</td>
<td>Unprotected CP On or Off</td>
</tr>
</tbody>
</table>

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Pipeline from 0 to 174,311 feet, Texas USA

Uncultivated

Fault Severity v Distance

The Soil pH has an Effect on the Corrosion Status of Pipe buried beneath

Cultivated

Fault Severity %IR

Distance (m)

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Examples of GPS Locations Using Google Earth
Example of Coating Defects

Failure mechanism: Scrape from an Excavator as a result of mechanical damage.

Crown Cracking of Coal Tar Coatings has long sausage shaped voltage gradient iso-potential plot

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Examples of GPS Locations Using Google Earth.
Close Interval Pipe-To-Soil Potential Surveys - CIPS / CIS
Satellite Synchronised with Interrupters

Typical CIPS Equipment

CIPS Data Logger

Typical CIPS Equipment

Pipe Locator

Satellite Aerial

Trailing 30swg Wire

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SPIKE ERRORS WHEN SWITCHING RECTIFIER ON/OFF

Anodic Spike

IR Error

Polarised Potential

OFF Measurement

ON Measurement

ON

OFF

Cathodic Spike

Time

Potential
NO SYNCHRONISATION OF DATA LOGGER WITH INTERRUPTERS

TYPICAL SYNCHRONISED CIPS SURVEY DATA

Pipe to Soil Potential

Distance

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Exponentially Corrected Fault Epicentre Potentials

Defects epicentre potentials (-mV)

Survey Direction

Distance (ft)

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Lateral/Trailing CIPS

- Close Interval Pipe-to-soil Potential Survey with Additional Reference Electrode at 90° or trailing behind.
Pipe-To-Soil Potentials vs Lateral Gradients

Figure J: Section 1. ON/OFF Close Interval Potential Survey and Lateral Gradients.

- Rectifier
- Rock Layer?
- Anodic Area
- Coating Faults

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One Pass Two Surveys

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ELECTROMAGNETIC SOIL RESISTIVITY

To Determine Right of Way Soil Corrosivity.

An important input of where to dig. This technique which has been used for +30 years. Speeds of 15 Km/day achievable with readings at one metre spacing.

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Corrosion Classification of Soils

<table>
<thead>
<tr>
<th>Soil Classification</th>
<th>Resistivity (ohm.cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly Corrosive</td>
<td>&lt; 500</td>
</tr>
<tr>
<td>Corrosive</td>
<td>500 – 1000</td>
</tr>
<tr>
<td>Moderately Corrosive</td>
<td>1000 – 5000</td>
</tr>
<tr>
<td>Lightly Corrosive</td>
<td>5000 – 10,000</td>
</tr>
<tr>
<td>Non Corrosive</td>
<td>&gt; 10,000</td>
</tr>
</tbody>
</table>

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Portable Electrochemical Noise Measurement Device - ProCoMeter

➢ Non destructive technique so ideal for site use or continuous monitoring of corrosion behaviour.

➢ Predicting types of corrosion under coating such as pitting, crevice corrosion.

➢ Identify areas of poor coating hence potential locations for corrosion.

➢ No activation signal is required thus non intrusive. It uses the natural occurring potential and current fluctuation under-film corrosion.

➢ Real time monitoring.

➢ Analysis of electrochemical noise involves calculating the noise resistance (Rn).

➢ Rate the protective nature of coatings according to the noise resistance criteria based on The Bacon Smith and Rugg criteria: >1E8ohms.cm²: Good coating, 1E6-1E8ohms.cm²: fair coating and <1E6ohms.cm² poor coating.
Example of one of the 5 modes – Basic No Connection To Substrate (BNCS)
- No contact is made to coated metal sample to carry out measurements.

2 Sets of 512 simultaneous current & Voltage measurements recorded, one every 0.5 seconds. Each set saved. It also starts with a 30sec pause at the beginning (settling step) and between each 2 sets.
Portable Electrochemical Noise Measurement Device - ProCoMeter

- Museum Artefacts
- Ships
- Aircraft
- Monuments
- Storage Tanks
- Rebar in Concrete
- Water Pipelines
- Off Shore Platforms
- New Coatings
- Bridges
- Testing Inhibitors
- Oil and Gas Pipelines

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Conclusion

- Monitoring corrosion protection of pipelines or any other infrastructure needs to be non-destructive but still gather information about the important properties that can be obtained at coating faults, where corrosion is most likely to occur.

- Need to consider both the properties of the coating and the interaction of the coating with the local environment.

- Need to combine information gathered about the condition of the cathodic protection system along with the coating system to understand the full extent of corrosion control.
Thank You.