Static Stray DC Current Interference Testing

Period 6

Intermediate Corrosion Course 2017
Agenda

• What is Stray current?

• How do,
  – we recognize stray current?
  – we test for stray current?
  – we remediate stray current?
Definition of Stray Current

*Stray current* is defined as “current through paths other than the intended circuit”.
Types of Interference

There are two types of stray current interference

• **Static**
  
  • Static interference is a steady, continuous stray current source: such as an impressed cathodic protection rectifier
  
  • Normally can be found with a typical data logging method

• **Dynamic**
  
  • Dynamic interference fluctuates in magnitude and direction, from sources such as, mines, subways, and light rail cars
  
  • Normally requires recording charts to catch the stray current data due to the fluctuations

This class deals with static current. The following class will cover dynamic current
When Stray Current is Identified

• Time is of the essence

• Leakage can occur within days or weeks

• This is because stray current can be large – many amps
### Basic Faraday's Law

#### Rates of Metal Loss

<table>
<thead>
<tr>
<th>Metal</th>
<th>Rate (Lbs/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe (Iron) / STEEL</td>
<td>20Lbs /Amp/ Year</td>
</tr>
<tr>
<td>Al (Aluminum)</td>
<td>6.5 Lbs</td>
</tr>
<tr>
<td>Cu (Copper)</td>
<td>45.7 Lbs</td>
</tr>
<tr>
<td>Pb (Lead)</td>
<td>74.5 Lbs</td>
</tr>
<tr>
<td>Mg (Magnesium)</td>
<td>8.8 Lbs</td>
</tr>
<tr>
<td>Zn (Zinc)</td>
<td>23.6 Lbs</td>
</tr>
</tbody>
</table>
Given: 1 amp of current discharging from a pipeline for 1 year.

Metal loss: Approximately 20 lbs.

EQUIVALENT METAL LOSS

<table>
<thead>
<tr>
<th>Pipe Diameter/W.T.</th>
<th>Pipe Weight/Foot</th>
<th>Equivalent Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>4” = 4.500” O.D. x 0.188 W.T</td>
<td>8.66 lbs/ft.</td>
<td>2.31 ft.</td>
</tr>
<tr>
<td>6” = 6.625” O.D. x 0.280 W.T</td>
<td>18.97 lbs/ft.</td>
<td>1.05 ft.</td>
</tr>
<tr>
<td>10” = 10.750” O.D. x 0.188 W.T</td>
<td>21.21 lbs/ft.</td>
<td>0.94 ft.</td>
</tr>
<tr>
<td>16” = 16.000” O.D. x 0.250 W.T</td>
<td>42.05 lbs/ft.</td>
<td>5.70 in.</td>
</tr>
<tr>
<td>20” = 20.000” O.D. x 0.250 W.T</td>
<td>52.73 lbs/ft.</td>
<td>4.55 in.</td>
</tr>
</tbody>
</table>
Identifying

• Pipe to soil potentials indication of possible interference situation
• Structural effect of stray current pickup and discharge
• Foreign lines or other structures with CP being applied nearby
Identifying

• *Pipe to soil potentials indication of possible interference situation*

  – Area of monitoring or surveying, Pipe to soil readings of high negative potentials and some with more positive potentials, may indicate pick up and discharge areas of stray current
Identifying

• *Structural effect of stray current pickup and discharge*
  – Corrosion takes place very rapidly
  – Leakage occurs despite CP system
  – Coating disbondment
  – At pipeline crossings, signs of corrosion or pitting (metal loss)
Identifying

• **Foreign lines or other structures with CP being applied nearby**
  – *Such as* -
    • other pipelines
    • buried tanks or petroleum facilities
    • New constructions
    • New rectified installation
      – Local corrosion committees
Conventional Current Flow

• Conventional current will flow - from positive to negative,
  – From the foreign ground bed system to the company pipeline pickup area
  – Through the pipeline to the discharge area
  – From the discharge area (company pipe surface) to the foreign structure through the electrolyte
Conventional Current Flow – Rectified System

- Anode bed
- Positive (+)
- Rectifier Unit
- Negative (-)
- Pick Up
- Discharge
- Structure - Pipeline

Current Flow
Ion Flow

• If adequate polarization exists, the current discharge will lead to an ionic exchange and no metal loss
  • No corrosion occurs
  • Reduces the level of cathodic polarization
  • So long as potential of interfered line remains at or above the criterion, no corrosion will occur
Ion Flow

- If inadequate polarization exists, the discharge of current will cause metal loss
2017 Underground Corrosion Short Course

February 21-23, 2017 Mike Placzek – ARK Engineering

Rectifier

Area approaches positive state – considered discharge area

Area approaches negative state – considered pick up area

Company Pipeline

Foreign Pipeline

H₂O

H₂O

H₂O

H₂O

H₂O

H₂O
Foreign Stray Current Affect on Polarization

• Stray current pickup increases polarization, this is represented by the higher, more negative, pipe-to-soil readings

• Stray current discharge decreases polarization, this is represented by a more positive or less negative pipe-to-soil readings
Pick Up and Discharge Areas

• Need to identify areas of Pick up and Discharge
  – Pick up area,
    • More negative
  – Discharge area,
    • More Positive

• Determine locations by CIS or other pipe to soil potential survey
  – Interrupting foreign structure
  – Data logger is the best tool to use
Interference Consideration

• Separation and routing of facilities
• The location of the interfering current source
• Magnitude of the current
• No external coating on the structures involved
• Presence and location of mechanical joints of high electrical resistance and/or isolators
Conventional Current Flow

Current returns through the soil

Static interference caused by a cathodic protection system
Conventional Current Flow

Foreign Line Crossing and Stray Current Pickup and Discharge
Discharge Area

• Indicated in CIS as the most positive potential reading
• The area considered anodic
• The area that will corrode
  – Faraday's law = 1amp = 20lbs per yr
• Most likely found at the point of crossing or the maximum exposure to the foreign line
• The location for the bond to be established
Connect Interrupter in series with the structure or ground cable. In this case, we used the structure cable.
Interrupter MCM used to find peak and valleys of reads.
Graph of Stray Current Pickup and Discharge on Bare Pipeline
Graph of Stray Current Pickup and Discharge on Coated Pipeline
Pipe-to-Soil Readings Through Foreign Influence and Resultant Depression in Potentials
Rules of Thumb - Interference Testing

1. Current must always return to its source.

2. Get the “big picture” of all metallic structures and possible stray current sources.
Interference Testing Rules of Thumb

4. Follow the data if practical by finding the corresponding stray current discharge point when a stray current pickup is found.

5. Simplest test is to measure the metallic voltage shifts.
The greatest voltage shift
Beware of Interference Testing Difficulties

• Limited access to the pipelines due to blacktop or concrete requires drilling to obtain measurements

• Testing is complex and time consuming

• Testing may require substantial number of current interrupters that are synchronizable
Beware of Interference Testing Difficulties

If you have more than one rectifier, you need to have synchronizable current interrupters.

Time programmable
Master – Slave
GPS
Testing Criterion

• It is necessary prior to conducting any field-testing to gain agreement on what criterion will be utilized to test, evaluate, interpret, and mitigate any stray current problems that may be identified.

• Prior to conducting field tests all parties should agree to the standard remediation requirements.
Interference Testing Outline

Summary

Why an ON/OFF Survey?

• An ON survey alone does not give insight into the actual condition of pipe regarding its actual cathodic protection

• “ON” potentials have included in the measurement
  – IR through the soil
  – IR in the pipe
  – Chemical activity representing polarization
  – Native potential of the steel
Interference Testing Outline Summary

Why an ON/OFF Survey?

Continued

• Instant “OFF” potentials include only the static potential of the steel and the chemical polarization. By simultaneously shutting off the current, the IR through the soil and steel of the pipe is eliminated

• The actual (chemical) polarization of the pipeline is determined after static potentials are obtained

Instant OFF – Static = chemical Polarization
Interference Testing Outline Summary

Determine the Acceptable Amount of Interference:

• If the potentials of the pipeline is above the .850-V CSE criteria with the foreign line CP operating, this indicates adequate polarization on the Company’s pipeline to prevent corrosion

• However, you must consider the IR drops
Interference Testing Outline Best Practice

- Interrupt the foreign structure
- Perform CIS over the Company’s structure
- Set interrupter
- Log survey on data logger
- Identify Low points & High points on the “ON” cycle
- Identify & measure Voltage shift to the most positive direction (maximum exposure area)
- Mark locations
Mitigation
Mitigation of Stray Current

1. Design and install electrical bonds of proper resistance between the affected structures.

2. Cathodic protection current can be applied to the affected structure at those locations where the interfering current is being discharged. The source of cathodic protection may be galvanic or impressed current anodes.

3. Adjustment of the current output from the interfering cathodic protection rectifiers may resolve interference problems.
Mitigation of Stray Current

4. Relocation of the groundbeds of cathodic protection rectifiers can reduce or eliminate the pickup of interference currents on nearby structures.

5. Rerouting of proposed pipelines may avoid sources of interference current.

6. Properly located isolating fittings in the affected structures may reduce interference problems.

7. Application of external coating to current pickup area(s) may reduce or resolve interference problems.
Resolution of Interference Problems

Indications that interference or stray current problems have been resolved:
• Interrupt system (Foreign structure)
• Perform CIS with data logger
• Indication that “interfered line is returned to its “natural potential”
• Indication of no voltage shift or very little (“no swing” method. Requires more drain current than “natural potential”)
Bond at foreign pipeline crossing
Reverse Switch or Diodes Used

• Diodes are used to prevent back flow of current through the bond – from protected line to the interfered line
Setting a Resistant Bond – Best Practice

• Attach two no. 8 and no. 12 wires onto both structures (Company and foreign structure)
• Wire sizes may change due to design of higher expected ampere output greater than 60 amps of current
• Mark the foreign structure wires for easy identification (normally with white or red tape)
• Connect an high impedance volt meter to the company no. 12 wire and place the CSE over the maximum exposure area
• Document wire configuration
Setting a Resistant Bond – Best Practice

• Connect an amp meter in series with the Company and the foreign structure to achieve the maximum current drain reading
  – Set meter at its highest setting to prevent blowing fuses
  – Conventional current flow – correct polarity
• Connect a temporary bond rated for the ampere measured
• Normal practice for most static stray current locations– set up a one ohm slide resister, with the setting half way (= .5 ohms)
• Measure potentials @ maximum exposure area before and after temporary connected
Setting a Resistant Bond – Best Practice

• If potential shift over structure goes from a depressed state to an impressed state, resistance is too low
• If potential shift over structure is still in a depressed state, resistance is too high
• Keep adjusting slide resistance till desired criterion is met by checking maximum exposure area
• Interrupt the foreign line during the measuring the potentials to visualise the shift change and determined the depression or impression state
Different Types of Resistant Interference Bonds

NiCad Wire used

Slide resister
Resister Wire Application

The amount of Resistance is made by the Length of the Wire.
Slide Resister Application
Disconnect Bond Wire for Amp Drain Reading
Shunt Resister
Installation of Anodes

• Method is not preferred
  – Due to large amount of current discharge normally consumes anode in rapid time frame, requiring regular replacement
  – Must connect the anode bed into the test station box for amp drain measurements
  – Decrease in amp drain measurements, may indicate depletion of anodes
  – Galvanic anodes used (Magnesium)

\[ \Delta E \text{ from anodes must be } > + \Delta E \text{ from interference} \]
Galvanic anodes used to drain current
Hydrogen Embrittlement

• Pick area needs to be lowered below –1.20 V CSE (polarized) due to possible coating disbondment from hydrogen build up and possible hydrogen embrittlement that can cause pipe failure

• Normal resolution to problem, after bond is set, high potentials exist, rehabilitate coating to increase resistance
  – Bond may need readjusting after completion of tasks
Example 1

- With our rectifier “on” the pipe-to-soil potential for our line is -0.990
- Foreign pipeline has a pipe-to-soil potential of -0.960
- Rectifier switched “off”
- Our potential becomes more positive (-0.850)
- Foreign pipeline becomes more negative (-0.980)
Foreign Line
- ON: -0.960 V
- OFF: -0.980 V
- ΔV: +0.020 V

Our Line
- ON: -0.990 V
- OFF: -0.850 V
- ΔV: -0.140 V
Conclusion

• Based on the recorded test data, our line is considered to be protected
• The potential on the foreign line decreased (became more positive) when the rectifier was switched on
• There is a possibility a holiday exists near the point of crossing
• The reduction is not sufficient to indicate loss of protection, no corrective measures required
Example 2

• With our rectifier “on” the pipe-to-soil potential for our line is −1.150
• Foreign pipeline has a pipe-to-soil potential of -0.580
• Rectifier switched “off”
• Our potential becomes more positive (-1.040)
• Foreign pipeline becomes more negative (-0.880)
Foreign Line
ON    - 0.580
OFF   - 0.880
$\Delta V$ + 0.300

Our Line
ON    - 1.150
OFF   - 1.040
$\Delta V$ - 0.110
Conclusion

• Based on the recorded test data, our line is considered to be protected
• The potential on the foreign line decreased (became more positive) when our rectifier was switched on
• Need to set a resistance bond to bring the foreign pipeline “ON” potential back to the “OFF” potential
Negative Bond

A negative bond occurs when the interfering pipeline has a pipe to soil potential less negative than the desired potential of the interfered line. In this case, the interference cannot be solved with a bond.
DOT

• P/P -

• DOT Part 192.465 (c)

Critical Bonds

6 times each calendar year, not to exceed 2 ½ months

Non-Critical Bonds

once each calendar year, not to exceed 15 months
DOT

• DOT Part 192.473 (a).
  Each operator whose pipeline system is subjected to stray currents shall have in effect a continuing program to minimize the detrimental effects of such currents.
What Defines a Critical Bond?

• Definition of Critical bond - where the pipeline is conducting current through the bond and the measured potentials with the bond disconnected create a difference below the operators chosen criterion

• DOT allows the operator to chose the CP criteria and what criteria's are considered a critical bond

• If potentials of the company pipeline is below the CP criteria (determined by the operator) due to interference of a foreign structure, then this should be considered as critical
Annual Monitoring
Best Practice

• Monitoring

Bonds utilizing a diode or reverse current switch:

A pipe-to-soil potential reading

Bond current measurement

Test to ensure the blocking device is operative
Annual Monitoring
Best Practice

• Monitoring

All other bonds:

Pipe-to-soil potential of all structures with the bond connected
Pipe-to-soil potential of all structures with the bond disconnected
Measurement of the bond current

Typically five readings obtained
THE END!