Chapter 8
Cathodic Protection System Maintenance and Troubleshooting Procedures
Maintenance Program

• Periodic Surveys
• Coating Maintenance
• Rectifier and Anode Bed Maintenance
• Galvanic Anode Maintenance
• Test Station Maintenance
Coating Maintenance

• Above and Below Ground Coatings
• All damage should be repaired at time of discovery
• Repair should be as good or better than existing coating
• Repair crew should be trained in proper preparation and application (READ THE INSTRUCTIONS)
Coating Maintenance

• Keep records of type of coatings found and condition

• Documentation
  – Existing coating
  – Repair coating
  – Environmental conditions
  – Date
  – Weather conditions
Rectifier and Anode Bed Repair

• Impress current anode bed usually limited to a visual inspection
• Recent construction activity
• New underground structures near anode bed
• Inspect overhead power service
Galvanic Anode Maintenance

• Anode bed limited to visual inspect as previous mentioned
• Header cables should be large diameter wire (ex. #8 or #6 AWG)
• Test stations should have anode connections cleaned, free of corrosion (copper antiseize)
• Measure and record anode current output
  – To determine anode life and consumption rate
MEASURING CURRENT OUTPUT OF GALVANIC ANODE

FIGURE 8-5
Periodic Surveys

- Pipe to Soil Potential Survey
- Effective Coating Resistance
- Rectifier Inspection
- Impressed Current Anode Junction Box
- Impressed Current Ground Bed Resistance
- Galvanic Anode – Current Output and Ground Bed Resistance
- Bonds – Non Critical and Critical
Periodic Surveys

• Casings – Resistance and Potentials
• Isolation Joints – Working, Lightening Arrestors, Spark Gaps, and Grounding Cells
• Dynamic Stray Current Areas – Bonds, Drains and Switches
• Isolation Jumpers – Continuity
• Any other special equipment installed as part of cathodic protection system – AC mitigation, remote read equipment, etc.
Pipe to Soil Potentials Surveys

• **Equipment Required**
• High resistance volt meter — 10 meg-ohm or higher
• Test Leads
• Reference electrode  (Figure 8-1)
• Current Interrupter  (Figure 8-2)
PIPE-TO-SOIL POTENTIAL SURVEY

FIGURE 8-1
TO INTERRUPT THE AC POWER, REMOVE ONE OF THE TAP LINK BARS AND CONNECT INTERRUPTER. THIS CAN ONLY BE DONE WITH A SINGLE PHASE RECTIFIER.

CIRCUIT BREAKERS
OUTPUT FUSE
DUAL METER AMPS & VOLTS
DC CURRENT INTERRUPTER

TAP SETTING CONTROLS
METER SWITCH
RECTIFIER OUTPUT TERMINALS

CABLE TO ANODE BED

INSTALLATION OF THE CURRENT INTERRUPTER AT EITHER THE AC TAPS OR IN A DC LEG WILL INTERRUPT THE DC CURRENT OUTPUT.

RECORD THE RECTIFIER CURRENT OUTPUT WITH AND WITHOUT THE INTERRUPTER IN THE CIRCUIT.

INTERRUPTING A RECTIFIER

FIGURE 8-2
Pipe to Soil Potentials Surveys

• **Procedure**
• Install Current Interrupter *(if required)*
• Place reference electrode directly centered over pipeline
• Moisten dry soil
• Good soil contact, no loose stone or rocks, no dry leaves or grass
Pipe to Soil Potentials Surveys

• **Meter connection**
• Digital Meter – Pipeline = Positive Lead  
  (Display negative value)
• Analog Meter – Pipeline = Negative Lead  
  (Causes up scale needle movement)

Note: Follow your company standard
Pipe to Soil Potentials Surveys

• Calculating Ground Voltage Coupling to determine increase of current to meet a criteria
Ground Voltage Coupling

• Step #1 Calculate the potential change
  \[ \Delta V = V_{ON} - V_{OFF} \]
  \[ = -0.82V - (-0.65V) = 0.17 \text{ volt} \]

• Step #2 Calculate Ground Voltage Coupling
  \[ RVG = \frac{\Delta V}{I} = \frac{0.17V}{3A} = 0.057 \text{ volt/amp or ohms} \]
Ground Voltage Coupling

- Step #3 Calculate addition current required to raise pipe to soil

\[
I_{\text{req}} = \frac{\Delta V_{\text{req}}}{R_{vg}} = \frac{0.03 \text{ volts}}{0.057 \text{ volts/amp}} = 0.53 \text{ amps}
\]

0.53 amps required to raise to -0.85V
\[ K = \frac{\Delta I}{\Delta E_{MV}} = X \, \text{A/mv} \]

WHERE: \( \Delta I \) = AMPS  
\( \Delta E_{MV} \) = MILLIVOLTS

CALIBRATION OF IR DROP SPAN

FIGURE 8-13
\[ I_{\text{CALCULATED}} = \Delta E_{\text{MV}} \times K \]

\[ \% I_{\text{TEST}} = \frac{\Delta E_{\text{MV}} \times K \times 100}{I_{\text{TEST}}} \]

WHERE: \( K \) = CALIBRATION FACTOR IN AMPS/MV

INDIRECT MEASUREMENT OF CURRENT

FIGURE 8-14
Coating Effectiveness

- \( R_c = R_{vg} \times \text{Surface Area of the Structure} \)
- Surface Area = \( \pi \times \text{diameter} \times \text{length (ft)} \)
- = \( 3.14 \times (1) \times 32,000 = 100,480 \text{ FT}^2 \)

- \( R_c = 8 \text{ ohms} \times 100,480 \)

- \( R_c = 803,840 \text{ ohm-ft}^2 \) greater than 300,000
Rectifier Inspection

- Measure DC voltage, current and Pipe to Soil potential (Figures 8-3, 8-4)
- Collect information to calculate efficiency
- Visually inspect for burnt components, loose wires
- Visually inspect and clean if necessary top and bottom screens
- Oil bath units inspect oil level and fill if necessary
- Calculate anode bed resistance
MEASURING RECTIFIER VOLTAGE

FIGURE 8-3
TWO METHODS:

1. DC AMMETER IN SERIES WITH ONE OF THE DC LEGS. CURRENT READ DIRECT IN AMPERES.

2. DC MILLIVOLT METER IN PARALLEL WITH PANEL SHUNT. RATING OF SHUNT WILL USUALLY BE STAMPED INTO THE SHUNT.

MEASURING RECTIFIER CURRENT

FIGURE 8-4
Impressed Current Junction Box

• Measure current output to each anode and compare with previous measurements(Fig 8-6)
MEASURING IMPRESSED CURRENT ANODE CURRENT OUTPUT AT DISTRIBUTION BOX

FIGURE 8-6
Bonds – Critical and Non Critical

• Measure Pipe to Soils of each structure bonded and unbonded
• Measure current flow thru bond and identify current flow direction

Use your company standard for meter connection
Casings

• Measure resistance between casing and carrier

• Periodically perform Casing Short Test
  – How to set up and perform test later in chapter
Dynamic Stray Current Areas

• Verify that bonds, switches, or other corrective methods are functional
• Periodically set data recording instruments to measure pipe to soil and current flow
Isolation Joints

• Verify that isolation joints are functioning properly
• Inspect the spark gaps and grounding cells function properly
• Inspect jumpers installed across isolation joints for continuity
Any Other Cathodic Protection Devices

- Inspect and test all other devices for proper function
- Remote monitoring devices
- Solar cells
- Generators
Records and Data Sheets

- Date and Time
- Technician or Technicians
- Weather Conditions
- Location of test or inspection
- Instruments – serial and model numbers
- Polarity (+/-)
- Meter scale if non auto ranging
Records and Data Sheets

• Conditions when data was taken:
  – Rectifier on/off
  – Bonds in/out
  – Current source
  – Type of reference cell and location
  – Soil conditions
  – Any unusual conditions
Repair or Replacements

• Coatings
• Rectifiers
• Impressed Current Anode Beds
• Galvanic Anodes
• Test Stations
Coatings

• Recoating is expensive
• May be necessary when cathodic protection requirements become too great
• Recoat material should be selected to withstand environment of pipeline
• Installed to company or manufacturers procedures
  – Properly trained installers
Rectifiers (Figure 8-7)

• Troubleshooting
• READ MANUAL and SCHEMATIC
• Turn off when possible to troubleshoot
• Check fuses and circuit breaks first
• Use senses: touch, smell and sight
• Start with AC input side work to DC output
• Take specific class for troubleshooting
TYPICAL RECTIFIER CIRCUIT

FIGURE 8-7
Impressed Current Anode Beds

- Damaged or broken cable
- Damaged anodes
- Consumed anodes
- Improper installation of splices
- Improper installation of splice isolation kits
Galvanic Anodes

- Broken or damaged wires
- Depleted anodes
Test Stations

• High resistance connections
• Broken wires – Use locator to perform “over wire survey” to find break (Figure 8-8)
• Measure resistance of wires, to calculate resistance/foot to determine break location (Figure 8-9)
OVER THE WIRE SURVEY USING
PIPE LOCATOR

FIGURE 8-8
Tests Used in Cathodic Protection
System troubleshooting

• Percent Leak Test (Figure 8-10)
• System Current Profile (Figures 8-11, 8-12)
• Surface Potential Surveys
  (Figures 8-15, 8-16, 8-17)
• Testing Pipeline in Contact with Casing
  (Figure 8-20)
MEASURING PERCENT LEAKAGE THROUGH ISOLATING JOINT

FIGURE 8-10
Percent Leak test

\[ K \text{ (amp/mv)} = \frac{I_k}{E_k - E_1} \]

- \( K \text{ (amp/mv)} \): calibration current
- \( I_k \): calibration voltage (mV)
- \( E_k - E_1 \): calibration voltage (mV)
Percent Leak Test

\[
\text{Percent Leakage} = \frac{K \times (E_{\text{test}} - E_1)}{I_{\text{test}}} \times 100
\]
System Current Profile
(Fig 8-11 & Fig 8-12)

- Using millivolt drop measurements
- Plot of test station location vs percent test current
- Problem areas are located and further test should be performed
- Other tests: short locating, surface potential surveys, more extensive millivolt drop tests, and current flow direction tests
IDEAL CURRENT PROFILE FOR PROTECTED PIPE SECTION

FIGURE 8-11
"CURRENT PROFILE"
TO EVALUATE COATING QUALITY

FIGURE 8-12
Surface Potential Surveys
(Fig 8-15, Fig 8-16, Fig 8-17, Fig 8-18, & Fig 8-19)

• Identically calibrated reference electrodes
• Measures current flow direction in soil
• Useful to locate holidays, anodes, and anodic areas on pipelines
• Single electrode method and two electrode methods
• Can be combined with side drain measurements
HOLIDAY GRADIENTS

FIGURE 8-15

VOLTAGE GRADIENTS DEVELOPED AT A HOLIDAY FROM CATHODIC PROTECTION CURRENT CHANGING PIPE TO SOIL POTENTIAL OF PIPE 0.50 VOLTS.
SURFACE POTENTIAL SURVEY
MEASURING HOLIDAY VOLTAGE GRADIENTS

FIGURE 8-17
SURFACE POTENTIAL SURVEY
MEASURING ANODE VOLTAGE GRADIENTS

FIGURE 8-19
SURFACE POTENTIAL SURVEY
MEASURING ANODE VOLTAGE GRADIENTS

FIGURE 8-16
Testing Pipelines in Contact with Casings

• Two types of contacts – electrolytic or metallic
• Electrolytic = annular space is filled with water or other electrolyte
• Metallic = carrier and casing are in direct contact with each other
• A low resistance contact will effect the operation of the cathodic protection system
Testing Pipelines in Contact with Casings

• Casing short test (Fig 8-20)
TAKE THE FOLLOWING MEASUREMENTS FOR 3 DIFFERENT CURRENT VALUES WITH AT LEAST 3 SETS FOR EACH VALUE

1. TEST CURRENT WITH CASING AS ANODE
2. $V_g$ PIPE-TO-SOIL (LOCAL)
3. $V_g$ PIPE-TO-SOIL (REMOTE)
4. $V_g$ CASING-TO-SOIL (LOCAL)
5. $V_g$ CASING-TO-SOIL (REMOTE)
6. $E_{oc}$ BETWEEN PIPE AND CASING

DETERMINATION OF TYPE OF CASING "SHORT"

FIGURE 8-20