Intermediate Course

Chapter 8 – CP System Maintenance & Troubleshooting Procedures

Mike Roberts, RCS

www.RCSWV.com

Appalachian Underground Corrosion Short Course

Why Are We Here?

- I've made it this far.
- My boss sent me.
- My company offered to pay for it.
- This is my 2^{nd} + time.
- I am an expert and plan to ask hard questions.
- The other class was full.
- I love ICCP Systems*

Chapter 8 Overview

- "The establishment of a cathodic protection maintenance program is vital if the system is to operate as intended. A system that is not properly maintained will undoubtedly experience premature failure."

1. Maintenance Program
2. Tests Used In Cathodic Protection System Troubleshooting

Maintenance Program Overview

1. Periodic Surveys
   - Status of CP
2. Coating Maintenance
   - Above and below grade
3. Rectifier and Anode Bed
   - Testing / Visual / 3rd Party
4. Galvanic Anode Maintenance
   - Testing / Visual / 3rd Party
5. Test Station Maintenance
   - Replacements / Parts / Accessibility

Maintenance Program – Periodic Surveys

<u>Pipe-to-Soil Potential Surveys</u>

1. Test Stations
2. CIS

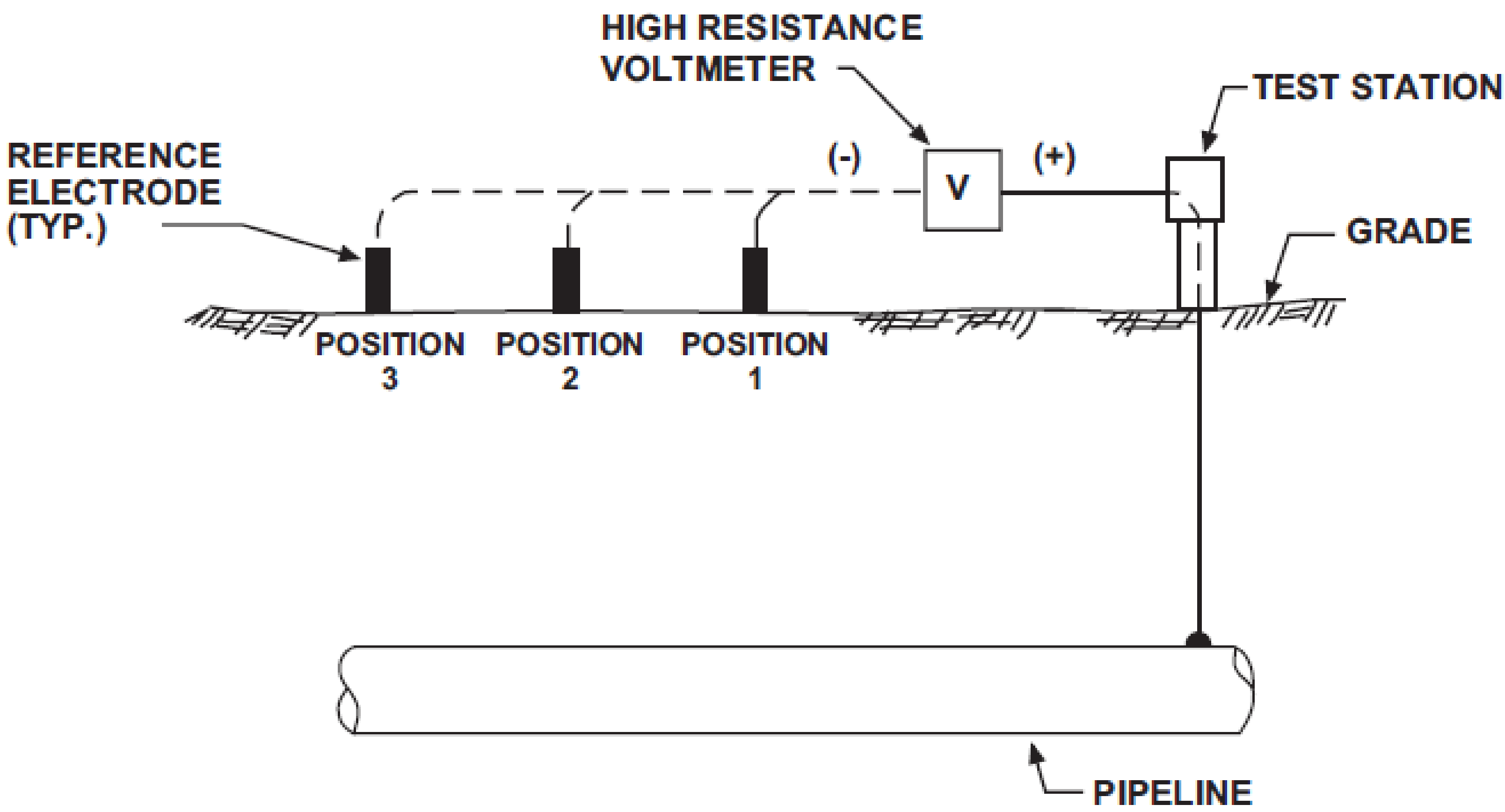
- Most Common *

- All CP systems need to be tested periodically.

1. High resistance voltmeter
2. $Cu\text{-}CuSO_4$ (CSE)
3. Electrical contact *

- (+) and (-)
- Dry soil?

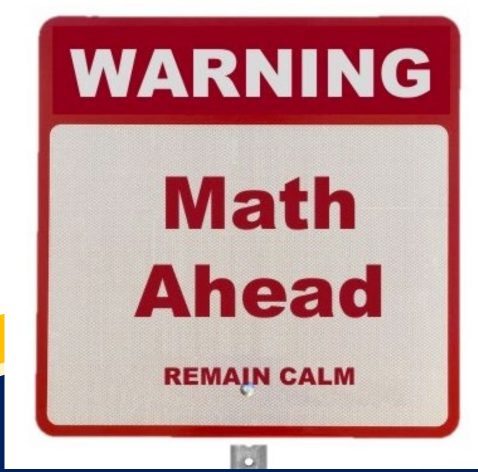
Maintenance Program – Periodic Surveys



Maintenance Program – Periodic Surveys

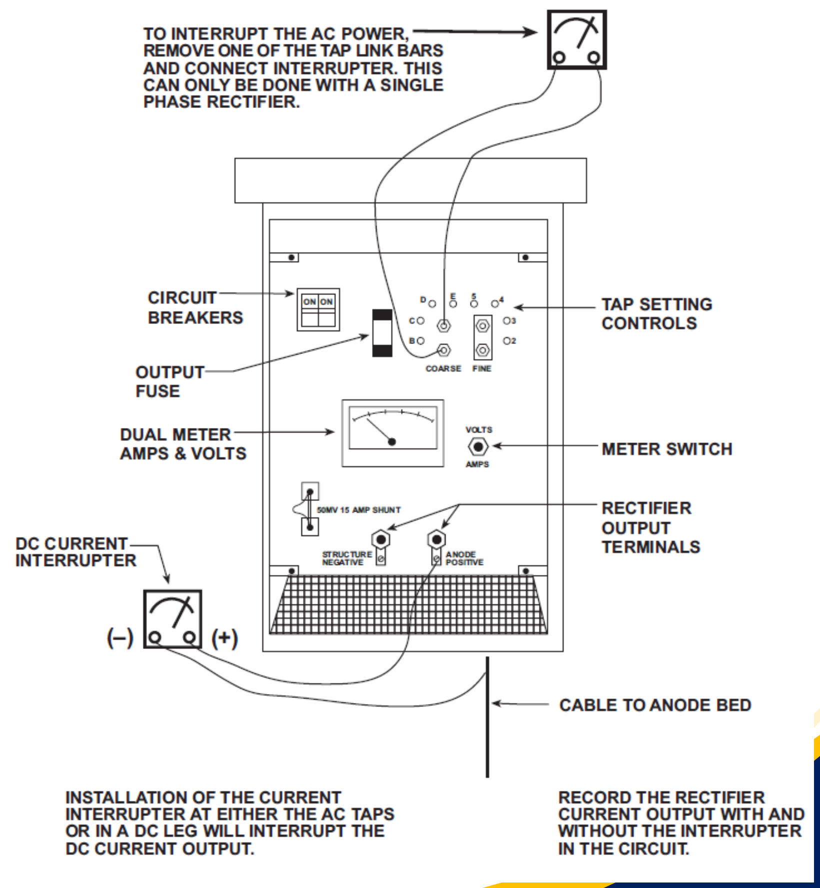
- During a potential survey, the pipeline's **resistance-to-earth** can be calculated if it is possible to interrupt the current source(s).
  - Equal to the potential change (ΔV) divided by the output current (I). The unit is ohms Ω.

- Can be used to determine the amount of current required to change the potential.



Maintenance Program – Periodic Surveys

- First, we need to interrupt the current source.
- Documentation.



- The current output of a rectifier is 3 amps. Measured pipe-to-soil potentials are -0.82 V ON and -0.65 V OFF with the rectifier output interrupted. Determine the additional amount of current required (ΔI_{rqd}) to change the ON potential of the structure to -0.85 V (ΔV_{rqd} = 0.03V). *

1. Calculate the potential change (ΔV):

$$\Delta V = V_{on} - V_{off} = -0.82 - (-0.65) = 0.17 \text{ volt}$$

2. Calculate the resistance-to-earth (R_{vg}):

$$R_{vg} = \frac{\Delta V}{I} = \frac{0.17 \text{ V}}{3 \text{ A}}$$

$$= 0.057 \text{ ohms}$$

3. Calculate the additional current required to change the ON potential of the structure to the 0.85 V value:

$$I_{rqd} = \frac{\Delta V_{rqd}}{R_{vg}} = \frac{0.03 \text{ volts}}{0.057 \text{ ohms}}$$

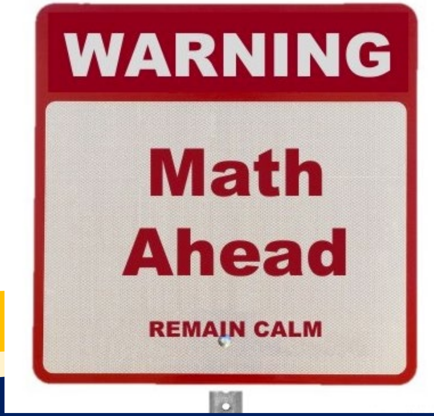
$$= 0.53 \text{ amps}$$

Maintenance Program – Periodic Surveys

- The quality of the coating (average resistance = R_c) can be calculated using the following formula:

$$R_c = R_{vg} \times \text{Surface Area of the Structure}$$

- Normally, good construction practices will result in average coating resistance values of **300,000 ohm-ft²** and greater, upon completion of the installation.



- A 12-inch pipeline has a resistance-to-earth (R_{vg}) of 8 ohms. The length of the pipeline is 32,000 feet. Determine the average coating resistance. *

$$R_c = R_{vg} \text{ x Surface Area of the Structure}$$

- $R_{vg} = 8\ \Omega$
- SA = $\pi \times D \times L$

$(3.14) \text{ x } (1) \text{ x } 32{,}000 = 100{,}480 \text{ ft}^2$

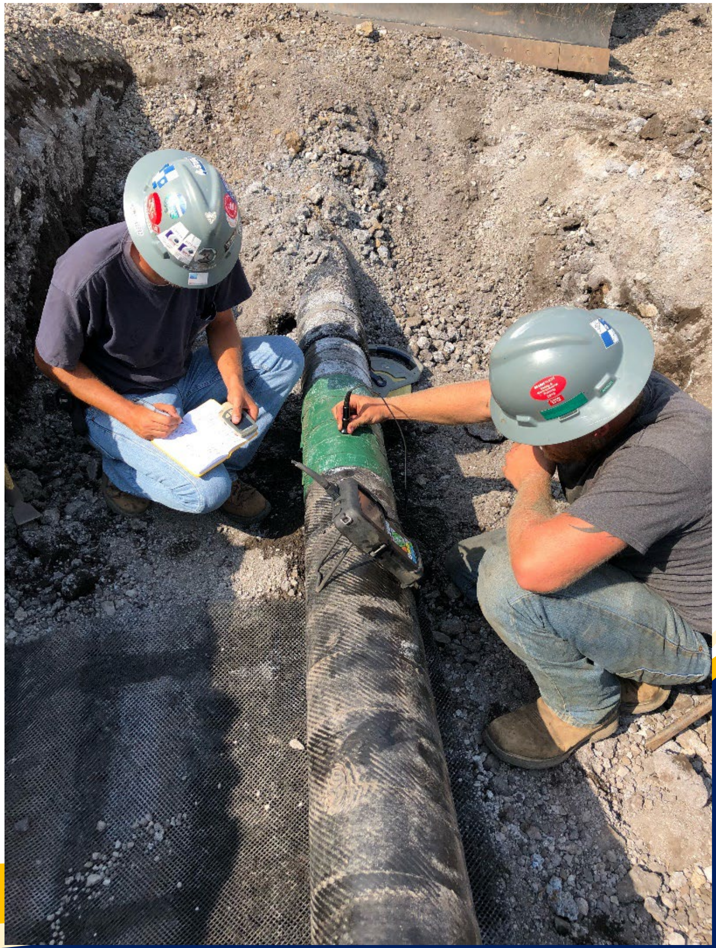
$8 \text{ x } 100{,}480 = 803{,}840 \text{ ohm-ft}^2$

Maintenance Program – Coating

- 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

Maintenance Program – Coating

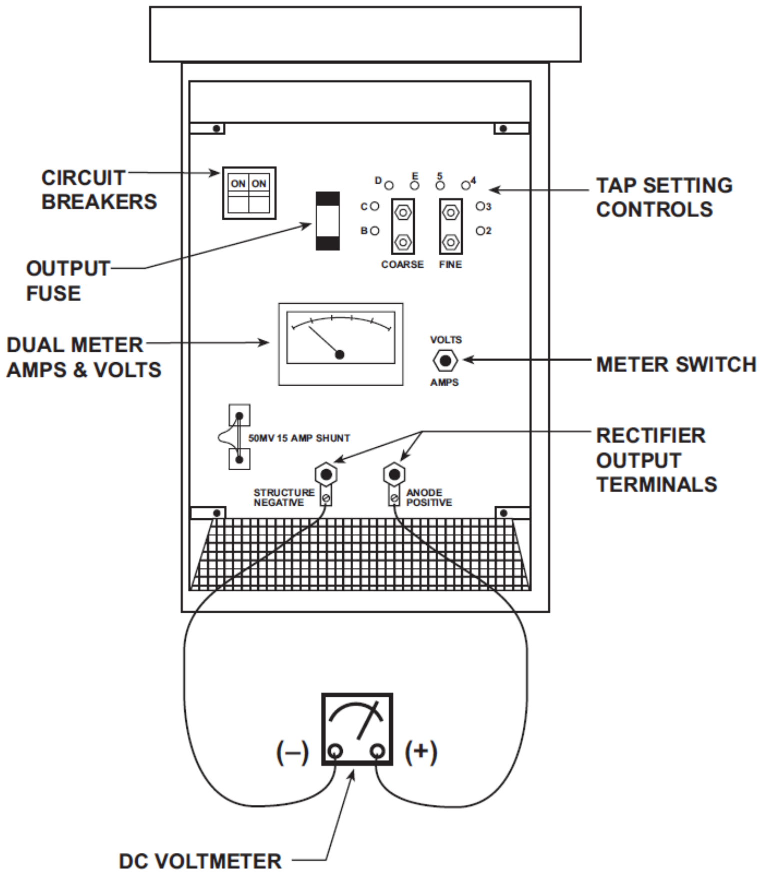
- Keep records of type of coatings found and condition
  - Documentation
  - Existing coating
  - Repair coating
  - Environmental conditions
  - Date
  - Weather conditions



Maintenance Program – ICCP Systems

- Rectifiers and Anode Beds
  - Visual Inspection
  - Recent construction activity
  - New underground structures near anode bed
  - Inspect overhead power service
- Rectifier
  - Measure DC voltage and current
  - Visually inspect for burnt components, loose wires
  - Visually inspect and clean
  - Oil bath units - inspect oil level and fill if necessary
  - Calculate anode bed resistance

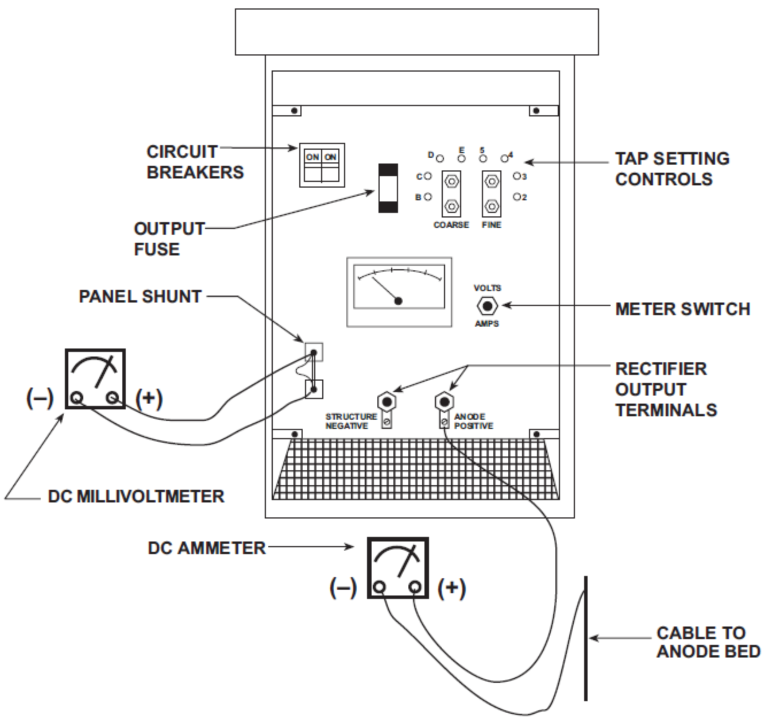
Maintenance Program – ICCP Systems



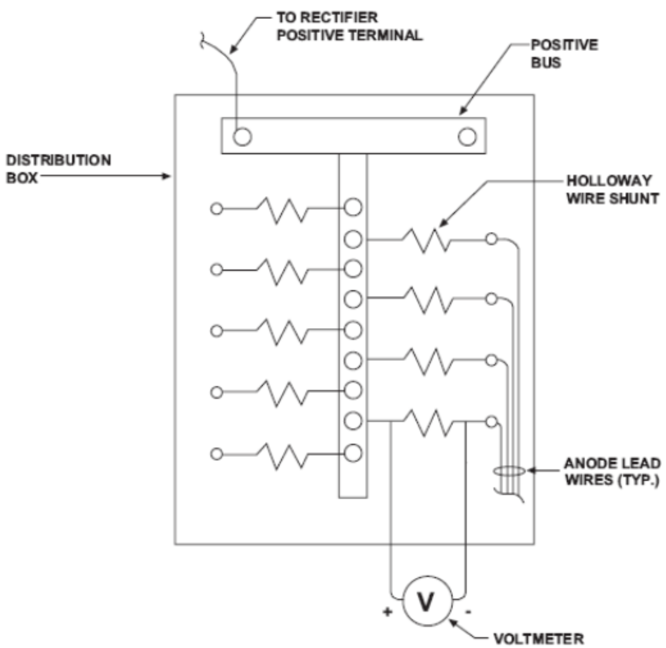
Maintenance Program – ICCP Systems

TWO METHODS:

1. DC AMMETER IN SERIES WITH ONE OF THE DC LEGS. CURRENT READ DIRECT IN AMPERES.
2. DC MILLIVOLTMETER IN PARALLEL WITH PANEL SHUNT. RATING OF SHUNT WILL USUALLY BE STAMPED INTO THE SHUNT.



Maintenance Program – ICCP Systems



MEASURING IMPRESSED CURRENT ANODE CURRENT
OUTPUT AT DISTRIBUTION BOX

FIGURE 8-6

Maintenance Program – ICCP / Galvanic

- 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

Maintenance Program – Galvanic

- Visual Inspection
- Header cables should be large diameter wire
- Test stations should have anode connections cleaned, free of corrosion.
  - Check annually *
- Measure and record anode current output
  - To determine anode life and consumption rate

Maintenance Program

- 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

Maintenance Program

- <u>Isolation Joints</u>
- Verify that isolation joints are functioning properly
- Inspect the spark gaps and grounding cells
- Inspect jumpers installed across isolation joints for continuity

Maintenance Program

- Any other Cathodic Protection Device:
  - Remote monitoring devices
  - Solar cells
  - Generators
  - AC Mitigation

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

End of Period - Break

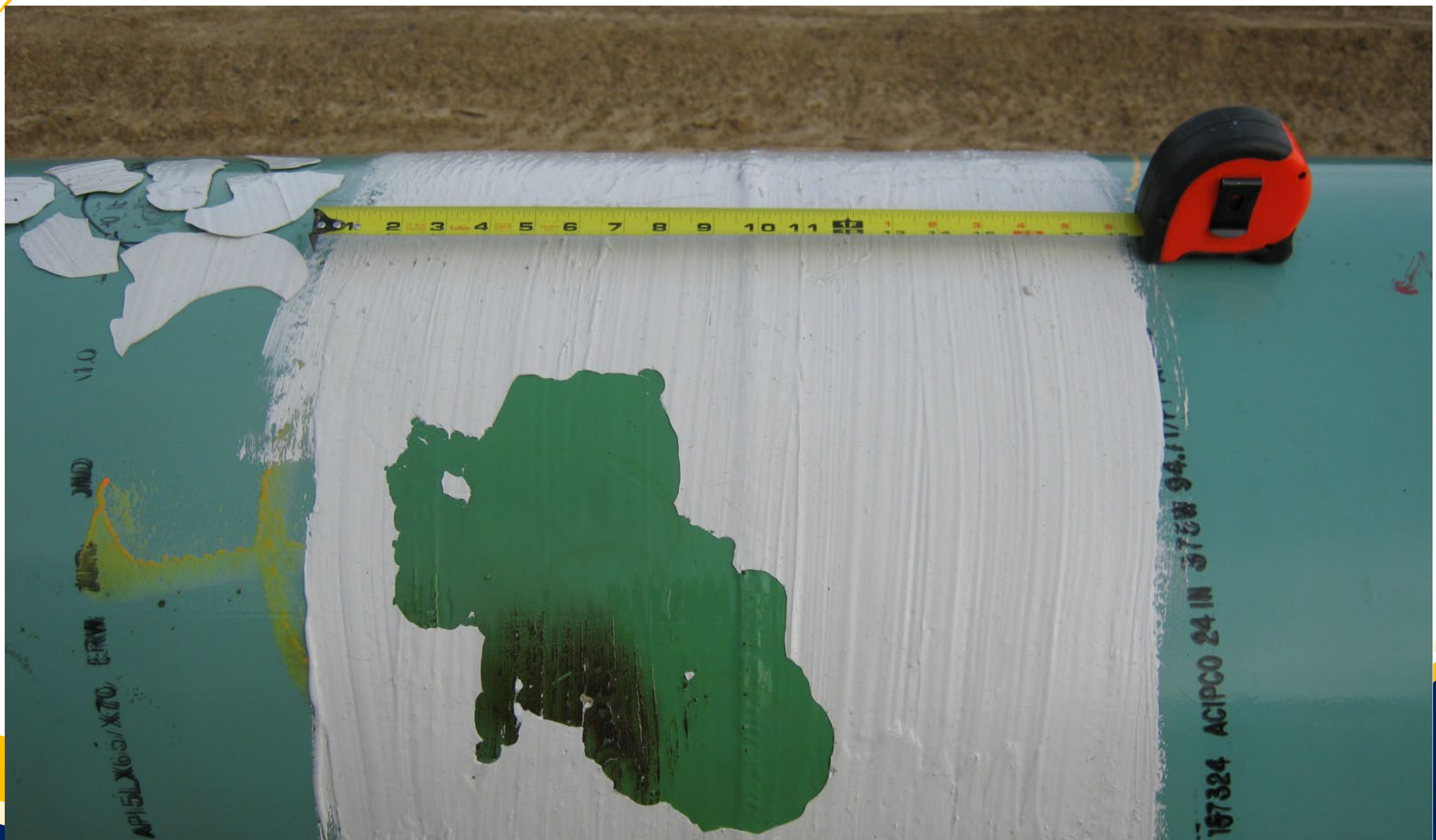
Repairs and/or Replacements

- Coatings
- Rectifiers
- ICCP Systems
- Galvanic Anodes
- Test Stations

Coatings

- Recoating is expensive
- May be necessary when cathodic protection requirements become too great
- Recoat material should be selected to with stand environment of pipeline
- Installed to company or manufacturers procedures
  - Properly trained installers

Coatings



Coatings

Rectifiers

- 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

Rectifiers

Checked output:

0.00 V and 0.00 A

Checked output:

12.65 V and 0.00 A

Checked output:

26.50 V and 1.20 A (last reading was 10.25 A)

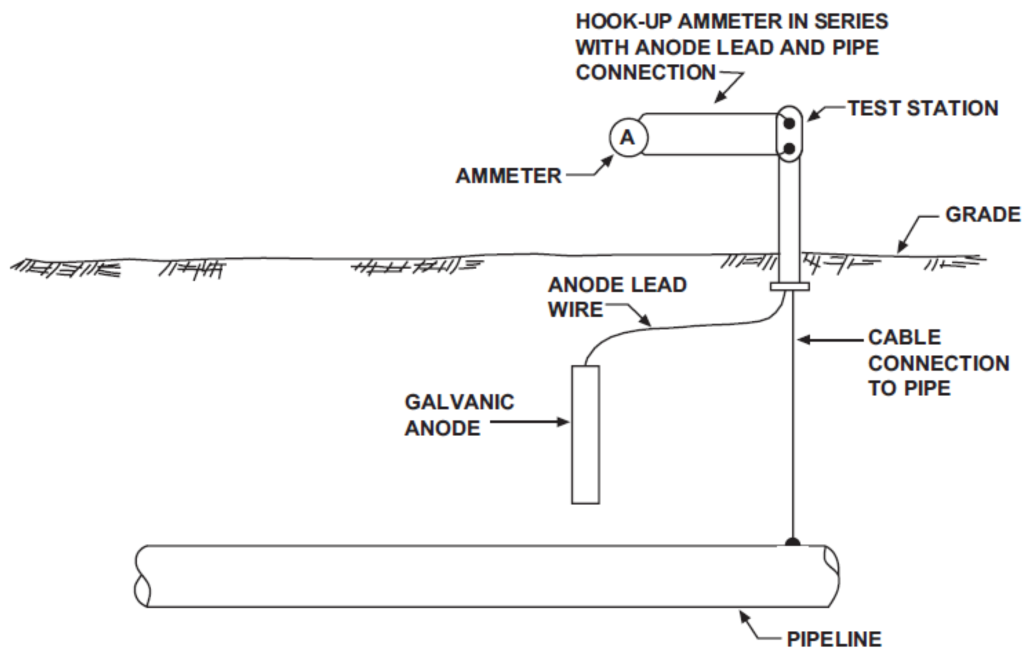
Rectifiers

Impressed Current Anode Beds

- Damaged or broken cable
- Damaged anodes
- Consumed anodes
- Improper installation of splices
- Improper installation of splice isolation kits
- A common failure point is the (+) cable *

Galvanic Anodes

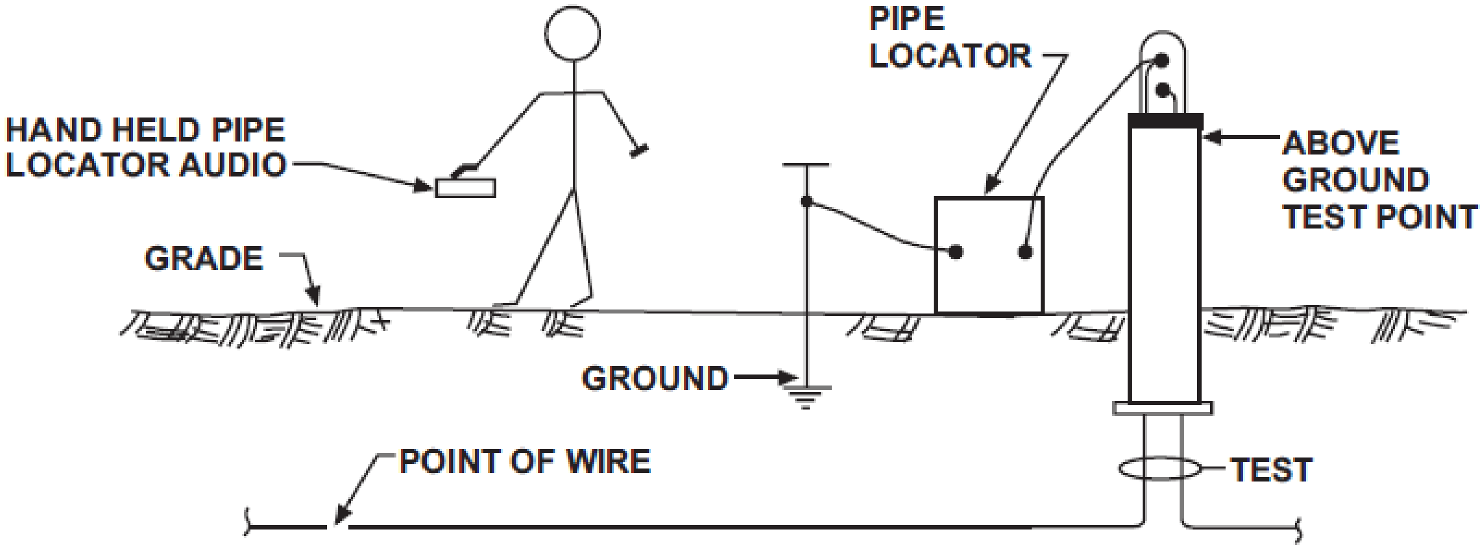
- Broken or damaged wires
- Depleted anodes
  - As galvanic anodes approach the end of their useful life, current output will diminish.



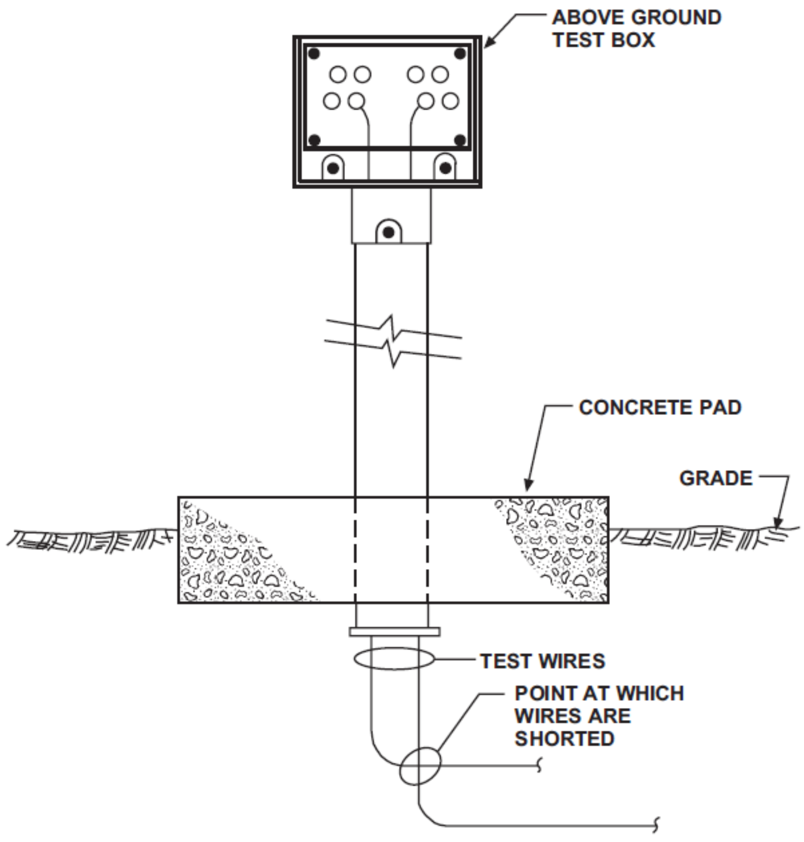
Test Stations

- 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)

Test Stations

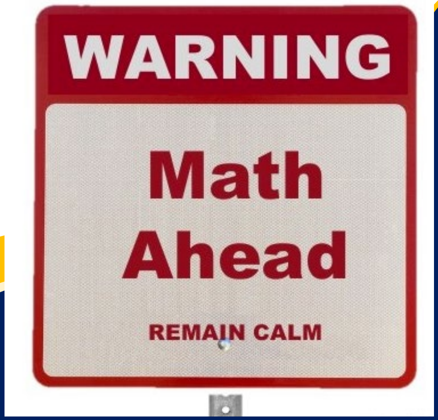


Test Stations



Test Stations

- Where two test wires are thought to be shorted below ground at a test station, the distance from the terminal board to the point of the short circuit may be determined. *
  - Measure resistance between the two wires
  - Need wire size, look up resistance per foot
  - Calculate number of feet of wire to the short
  - Half of this length will be the distance from the terminal board to the short.



- Using an ohmmeter, the resistance between terminals 1 and 2 is measured at the test station. The measured resistance is 0.074 ohm. According to an electrical handbook, the resistance of No. 12 AWG wire is 0.00162 ohm/ft.

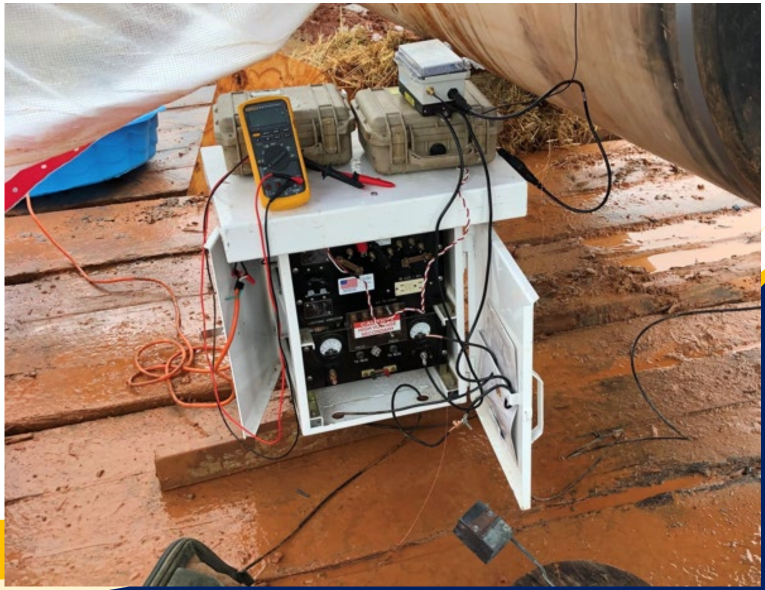
Distance (x) = ½ (measured resistance/wire resistance)

x = ½ (0.074/0.00162)

x = 22.84 ft.

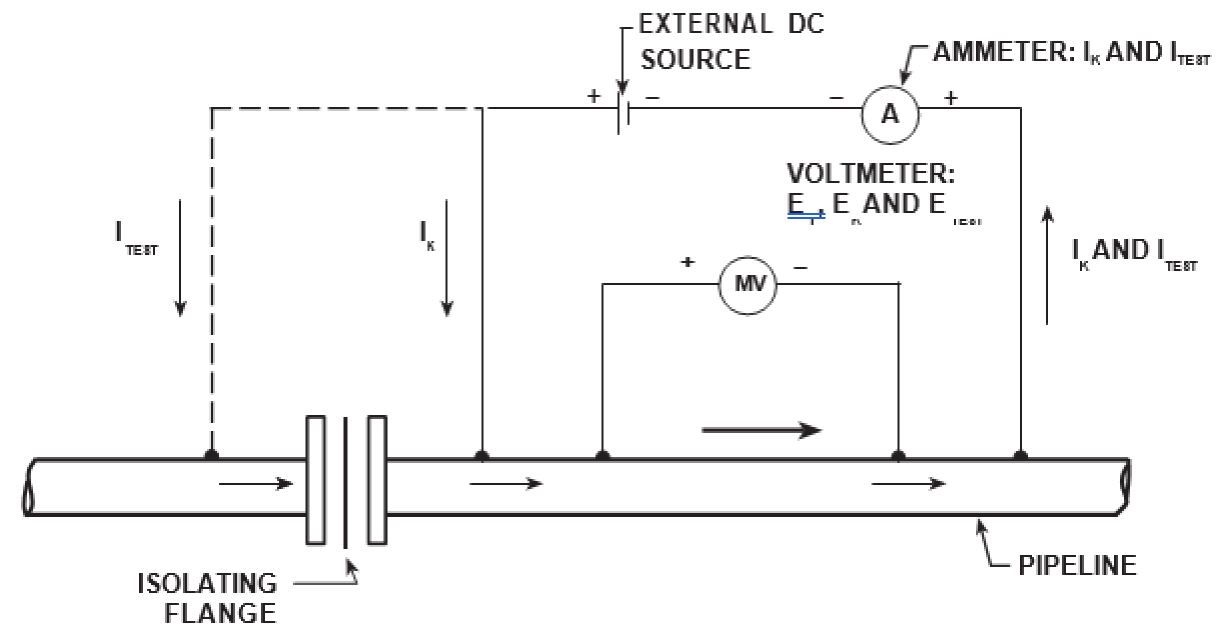
Tests Used in CP System Troubleshooting

- Percent Leak Test
- System Current Profile
- Surface Potential Surveys
- Testing for Pipelines in Contact with Casings



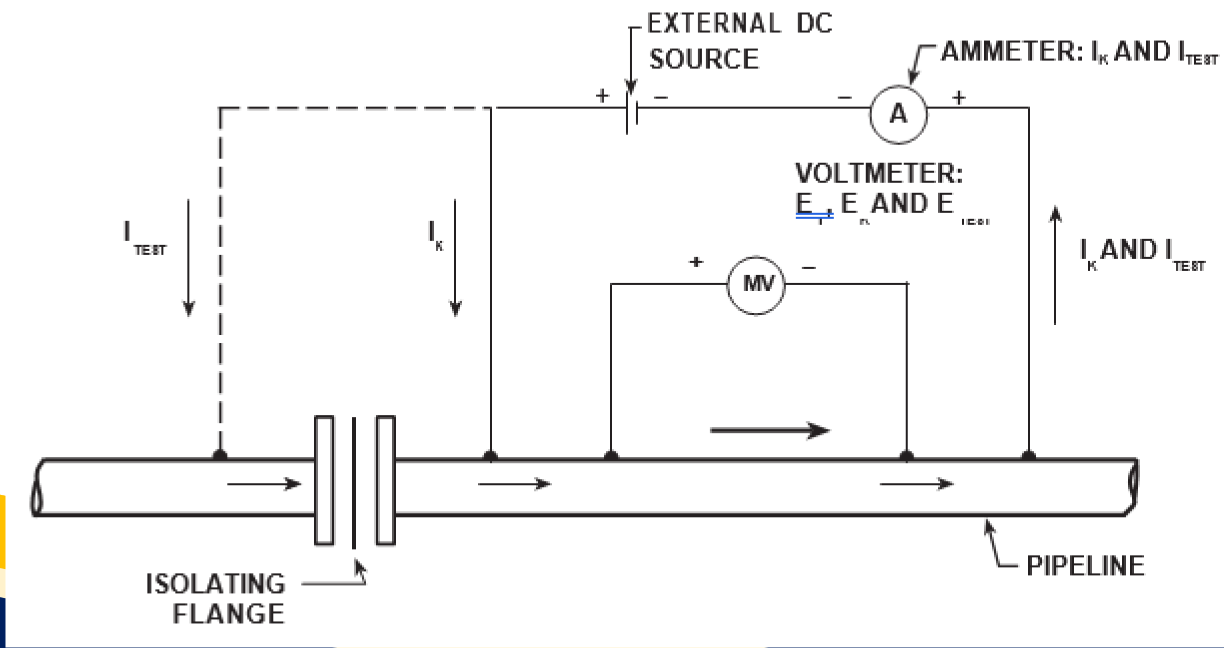
Percent Leakage Current Test *

- A calibration current (I_K) from an external DC source must be provided. This current is allowed to flow through a short section of the pipeline and return as shown in the figure.



Percent Leakage Current Test *

- Begin the test by measuring any voltage drop present in the calibration section (E_1). Then connect the calibration current (I_K). The current flow will cause a voltage drop (E_K).



Percent Leakage Current Test *

- Both the current flow and its associated voltage drop are measured so that a calibration factor for the test set-up can be calculated using the following formula:

$$K\ (\text{amp} / \text{mv}) = \frac{\text{calibration current}}{\text{calibration voltage drop}}$$

or

$$K = \frac{I_k}{E_k - E_1}$$

Percent Leakage Current Test *

- Using the external DC source again, make connections to the pipe as shown in the figure to enable test current to flow from one side of the isolating joint to the other. The voltage drop across the calibrated section (E_{TEST}), and the test current (I_{TEST}) are then measured.

$$\text{Percent Leakage} = \frac{K \times (E_{TEST} - E_1)}{I_{TEST}} \times 100$$

Percent Leakage Current Test *

- A calibration current of 34 amperes (I_K) is allowed to flow from the line side of the isolating joint through the pipeline causing a voltage drop of 28 millivolts (E_K). A test current of 5 amperes (I_{TEST}) is allowed to flow across the isolating joint through the pipe causing a voltage drop of 4.7 millivolts (E_{TEST}). Determine the percent leakage current. E_1 was found to be 1.0 mV.

Percent Leakage Current Test *

- Calculate the calibration factor (k):

$$K = \frac{I_k}{E_K - E_1} = \frac{34}{28 - 1} = 1.26 \text{ amps / mv}$$

- Calculate the percent leakage current:

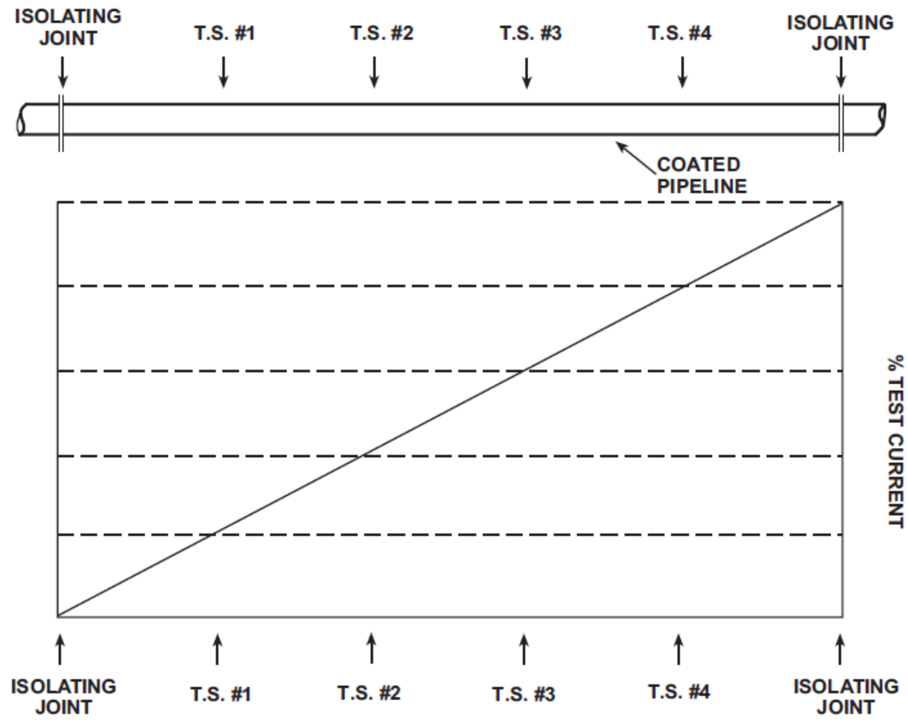
$$\text{Percent Leakage} = \frac{K \times (E_{TEST} - E_1)}{I_{TEST}} \times 100$$

$$= \frac{1.26 \times (4.7 - 1)}{5} \times 100$$

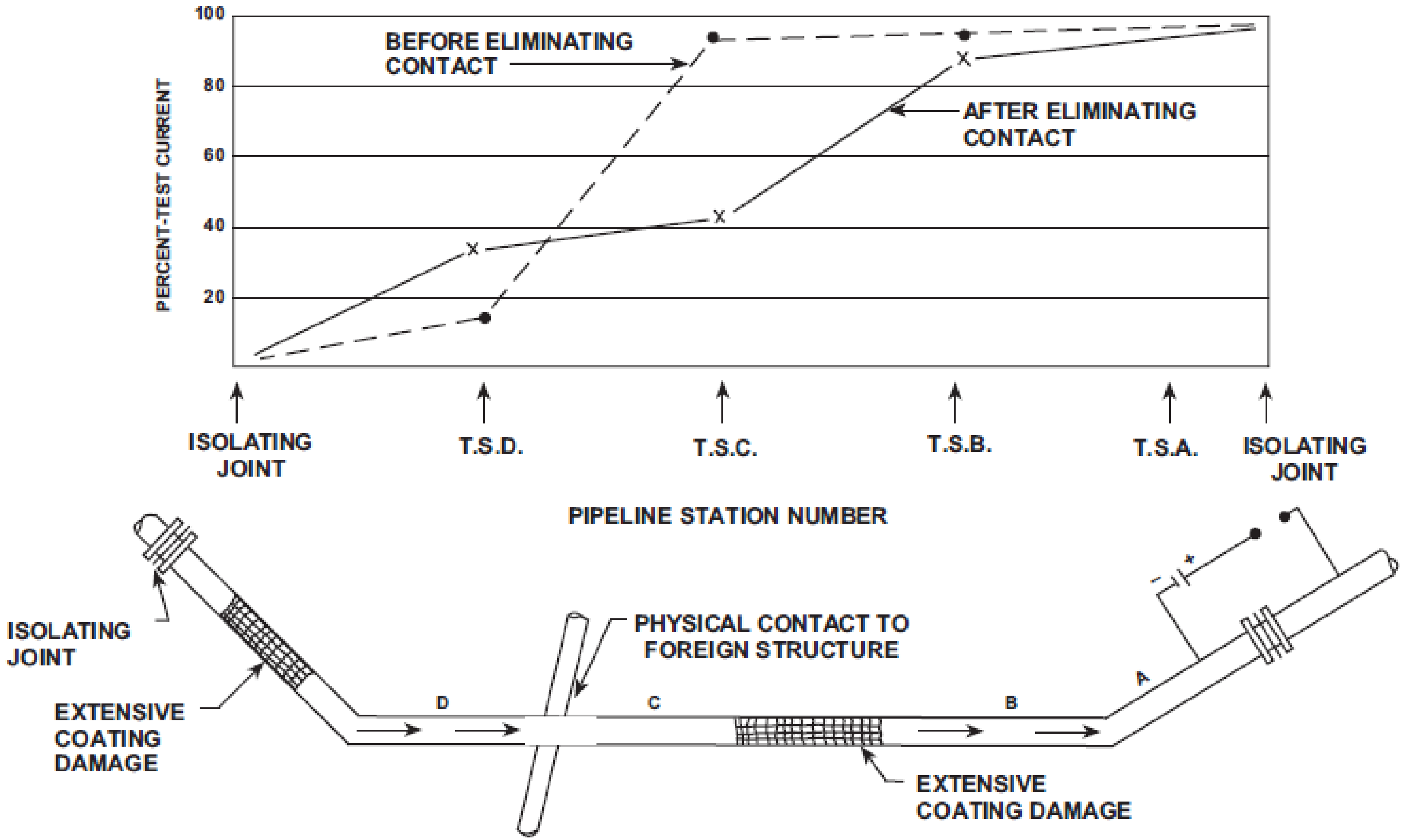
$$\text{Percent Leakage} = \quad 93.2\%$$

System Current Profile

- Using millivolt drop measurements along the pipeline.
- Plot of test station location vs percent test current.



System Current Profile



System Current Profile

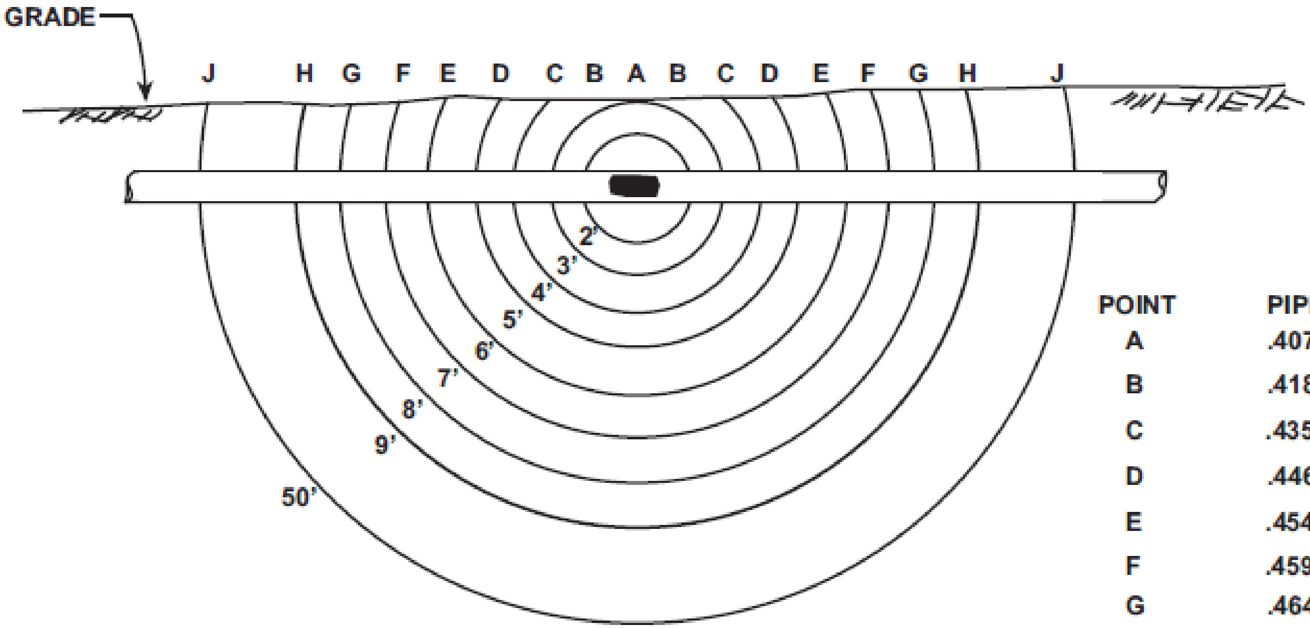
- After problem areas are located through the use of the current profile, further tests should be conducted in these areas. These tests should include the use of special electronic equipment such as short locators and/or surface potential survey techniques, or more extensive mill-volt drop tests.

Surface Potential Surveys

- Identically calibrated reference electrodes
- Measures current flow direction in soil
- Useful to locate holidays, anodes, and anodic areas on pipelines
- Single electrode <u>method</u> and two electrode <u>method</u>
- Can be combined with side drain measurements
- Commonly called “cell to cell”

Surface Potential Surveys

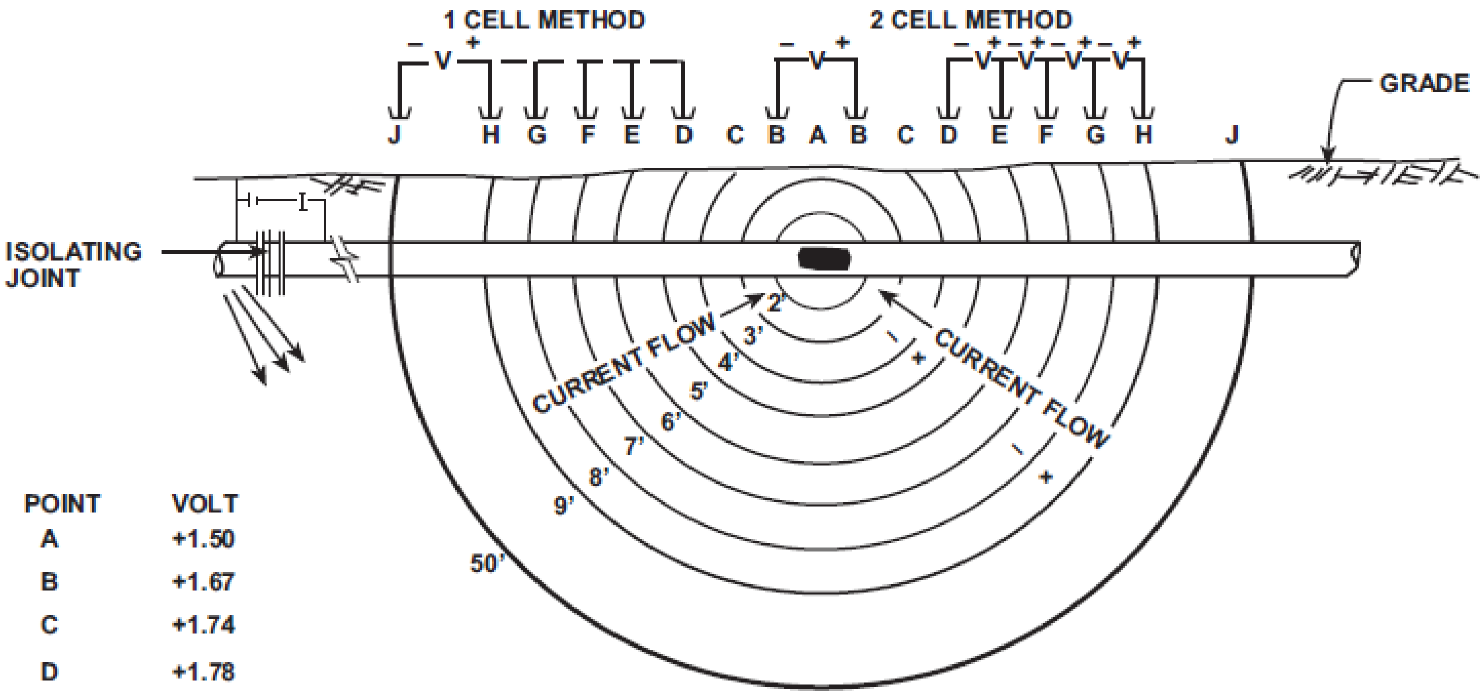
Surface Potential Surveys



POINT	PIPE
A	.407
B	.418
C	.435
D	.446
E	.454
F	.459
G	.464
H	.480
J	.500

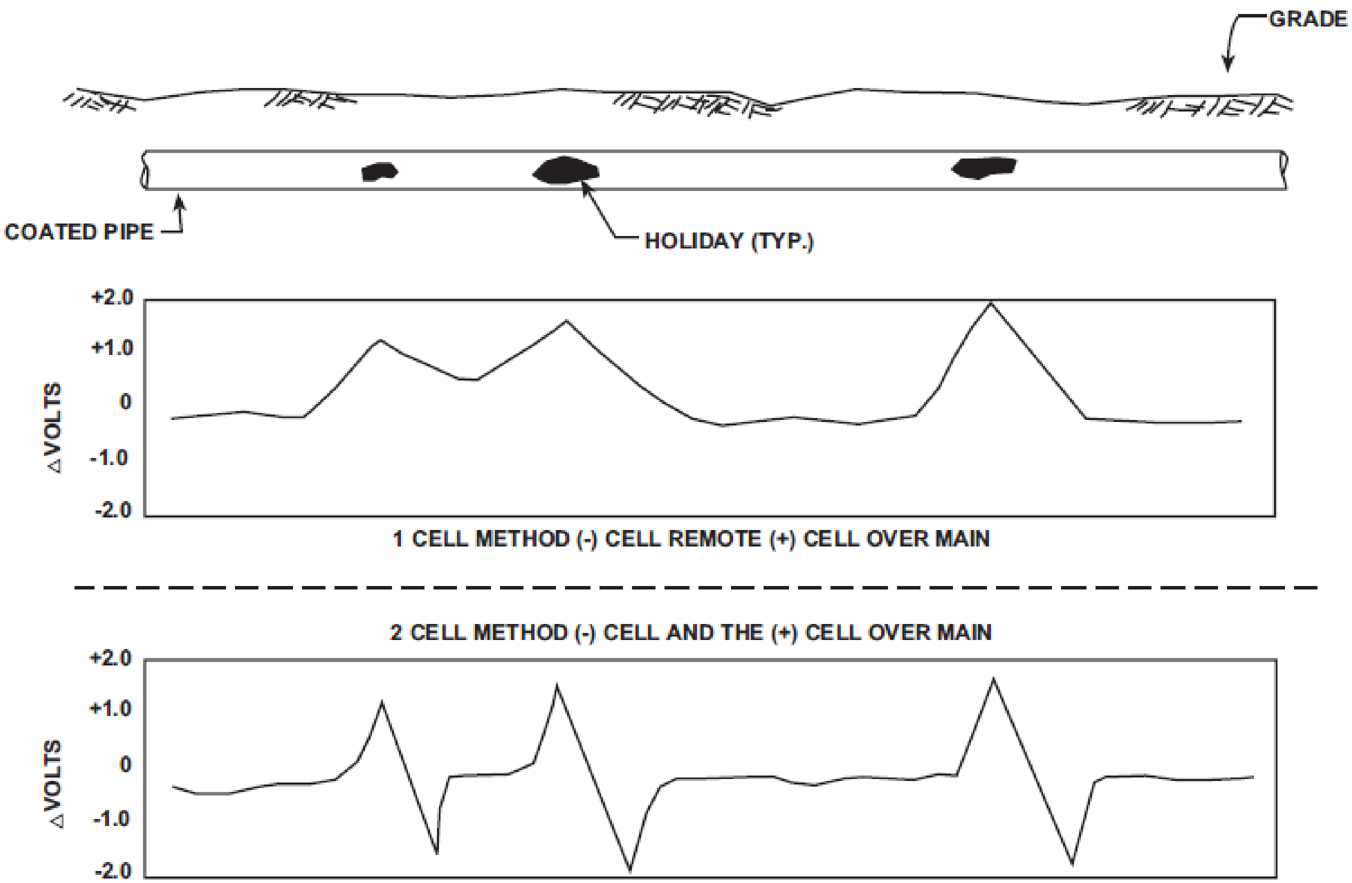
VOLTAGE GRADIENTS DEVELOPED AT A HOLIDAY FROM CATHODIC PROTECTION CURRENT CHANGING PIPE TO SOIL POTENTIAL OF PIPE 0.50 VOLTS.

Surface Potential Surveys



POINT	VOLT
A	+1.50
B	+1.67
C	+1.74
D	+1.78
E	+1.82
F	+1.84
G	+1.86
H	+1.92
J	+2.00

Surface Potential Surveys

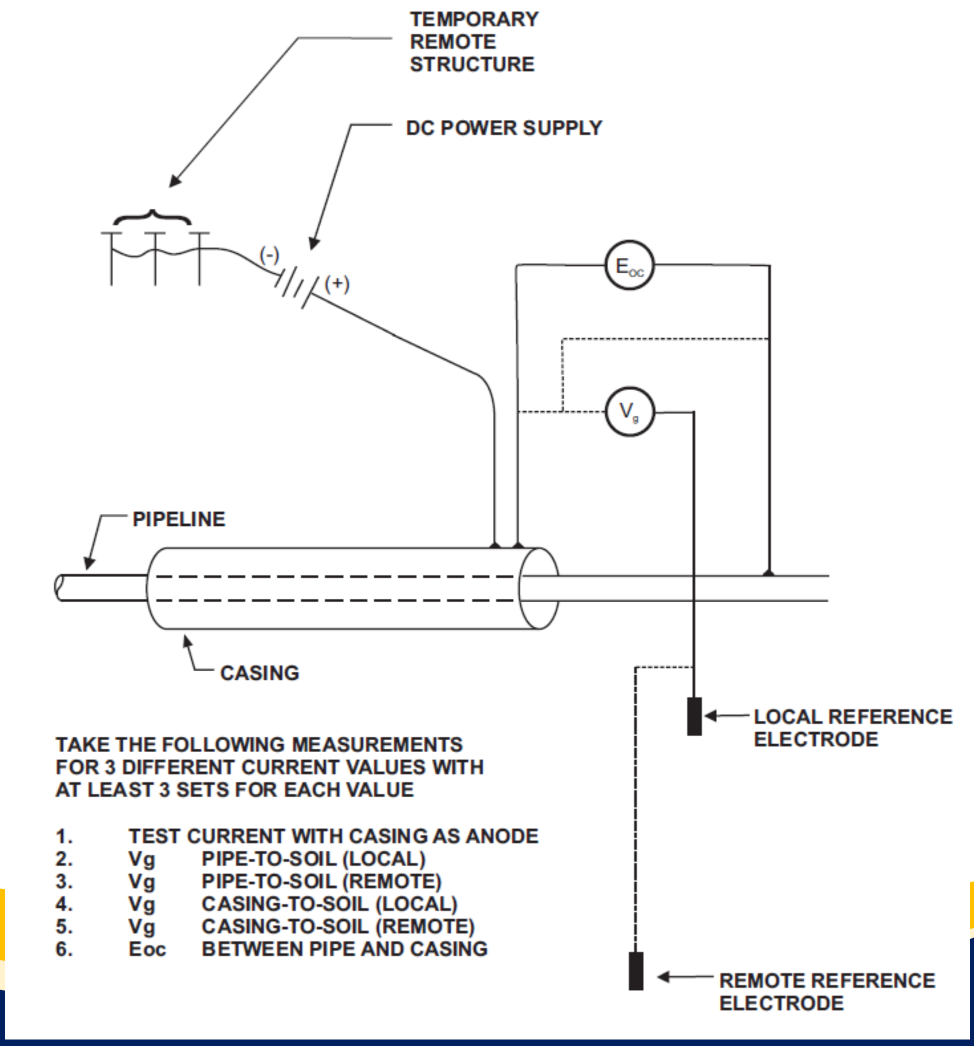


Testing for Pipelines in Contact with Casings

- 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 affect the operation of the cathodic protection system
  - A bare casing will act as a large holiday on the system *

Casings

Testing for Pipelines in Contact with Casings



End