Control of DC and AC Interference on Pipelines

Tony G. Rizk, P.E.
Vice President
EMS USA Inc.
Houston, Texas
713-595-7600
trizk@emsglobal.net

Nigel Strike
Western Director
EMS USA Inc.
Houston, Texas
713-595-7600
nstrike@emsglobal.net

CORROSION

AND

CATHODIC PROTECTION

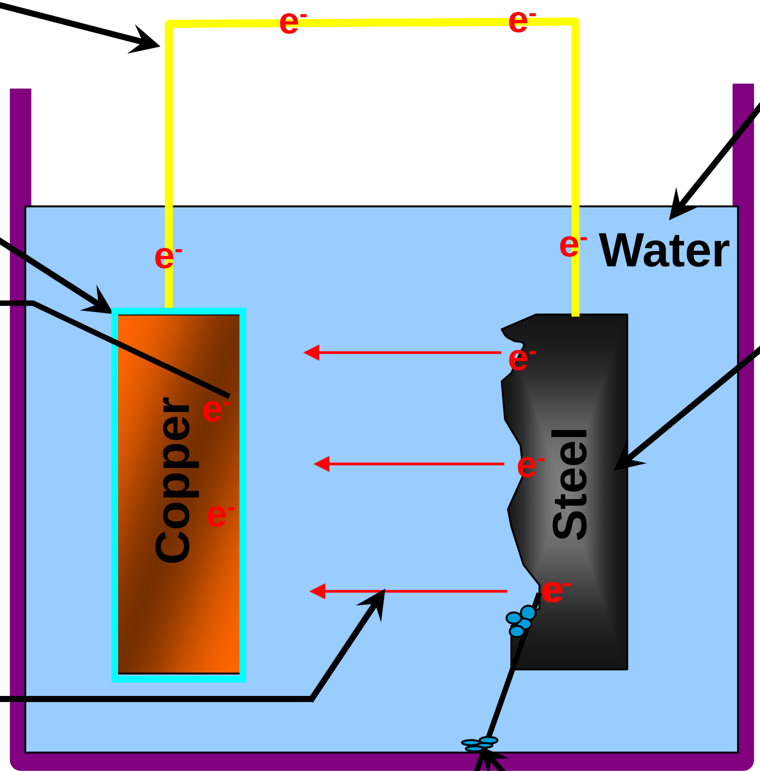
Basic Corrosion Mechanism

Metallic Path

Cathode (protected)

Electrolyte

(water, soil, mud, etc.)



Anode (corrodes)

In typical soils, at Cathode:

Electrons consumed by water/oxygen – protective film forms

Corrosion Current

(Conventional Current Flow)

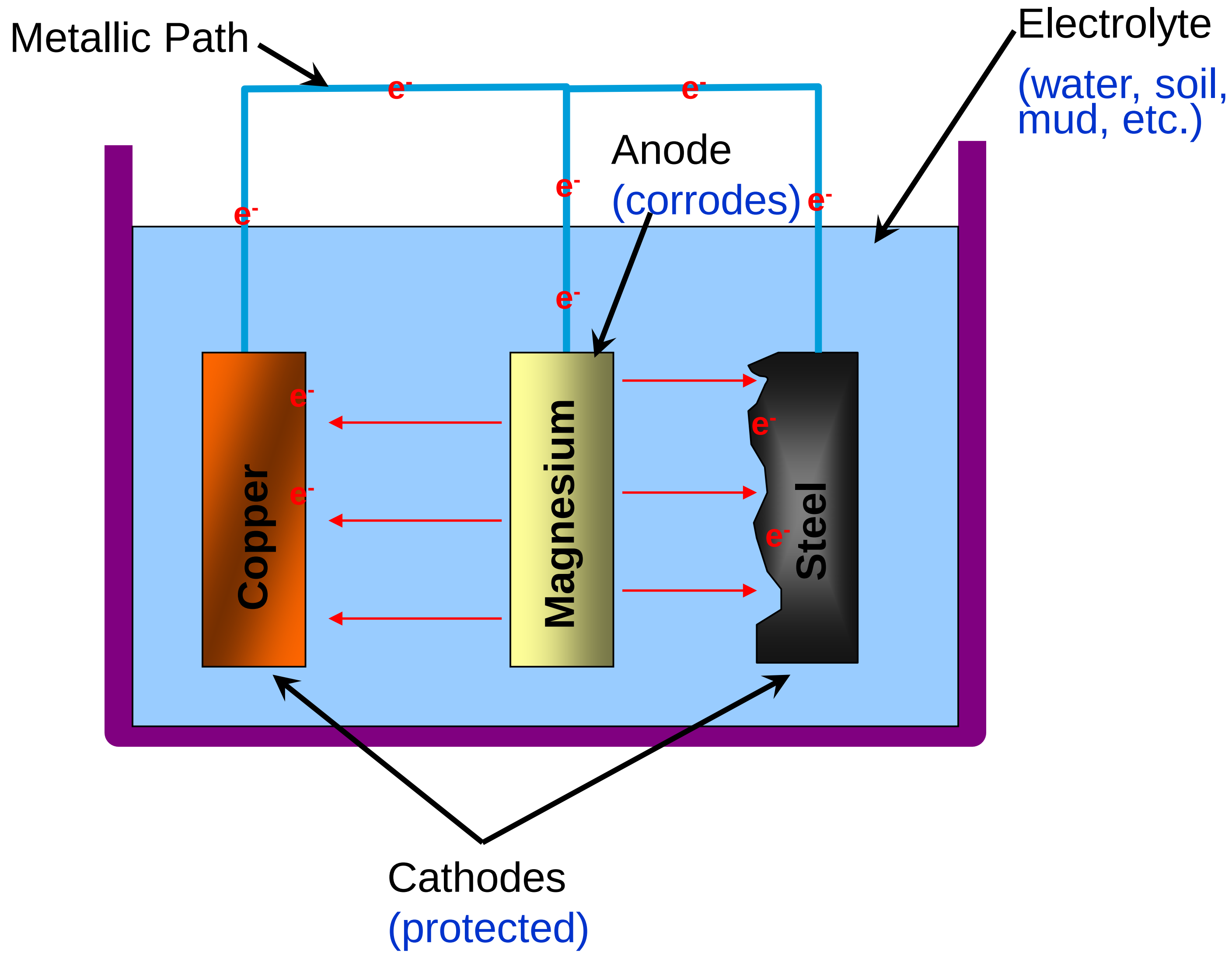
Corrosion Deposits

In typical soils, at Anode:

Iron goes into solution and combines with ions

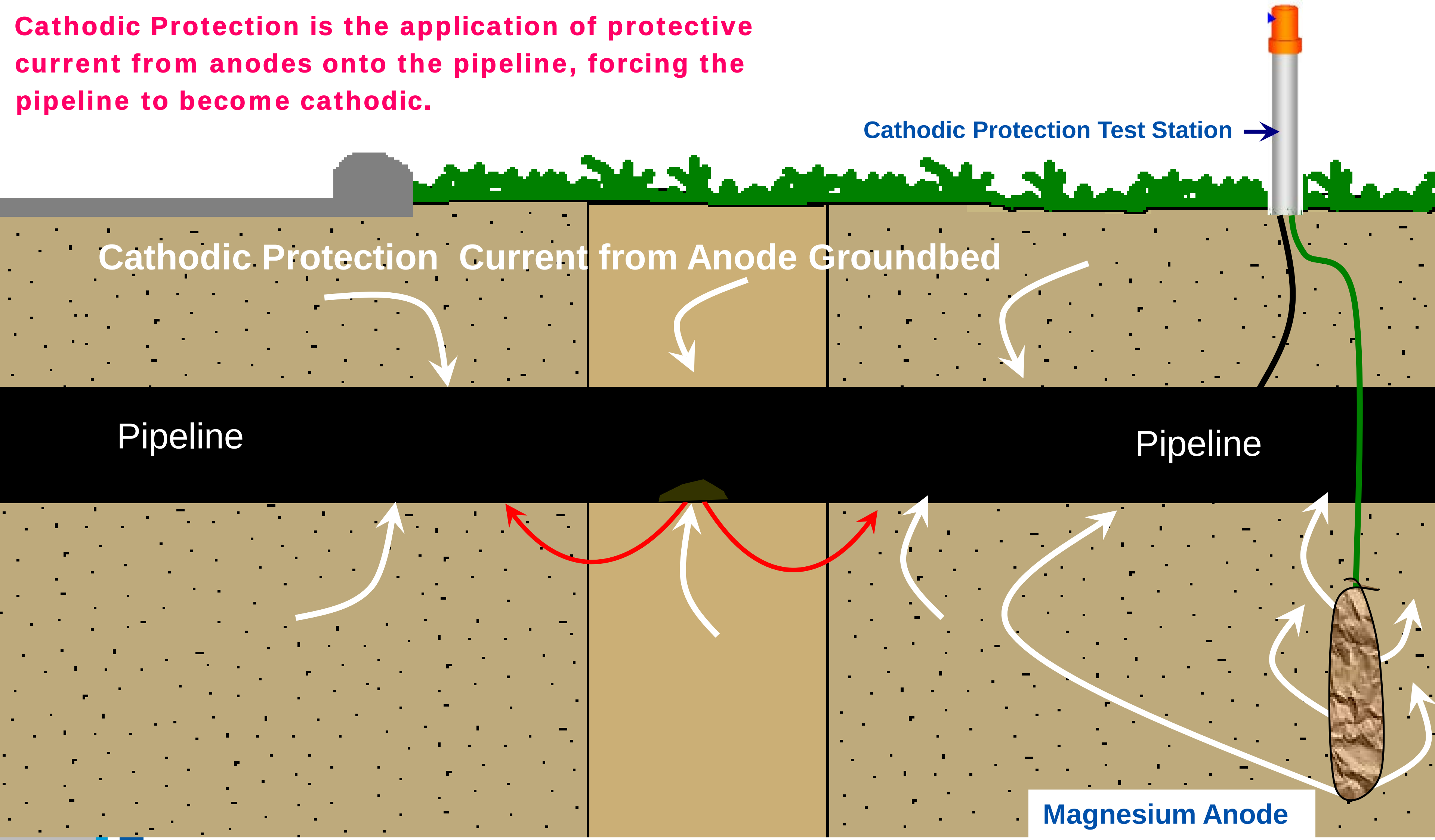
in the electrolyte to form corrosion Deposits

Basic Cathodic Protection Mechanism

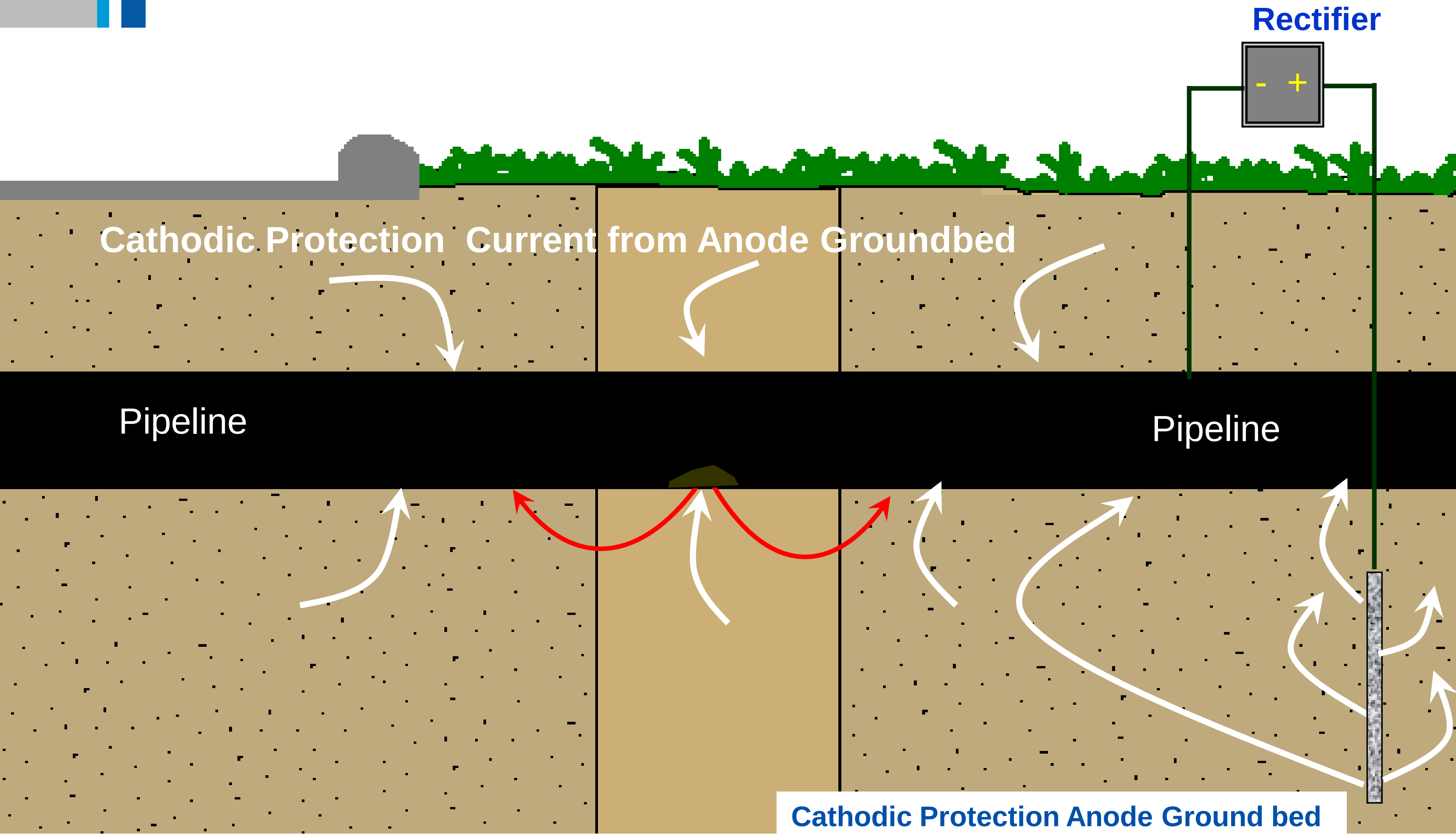


Cathodic Protection – Galvanic System

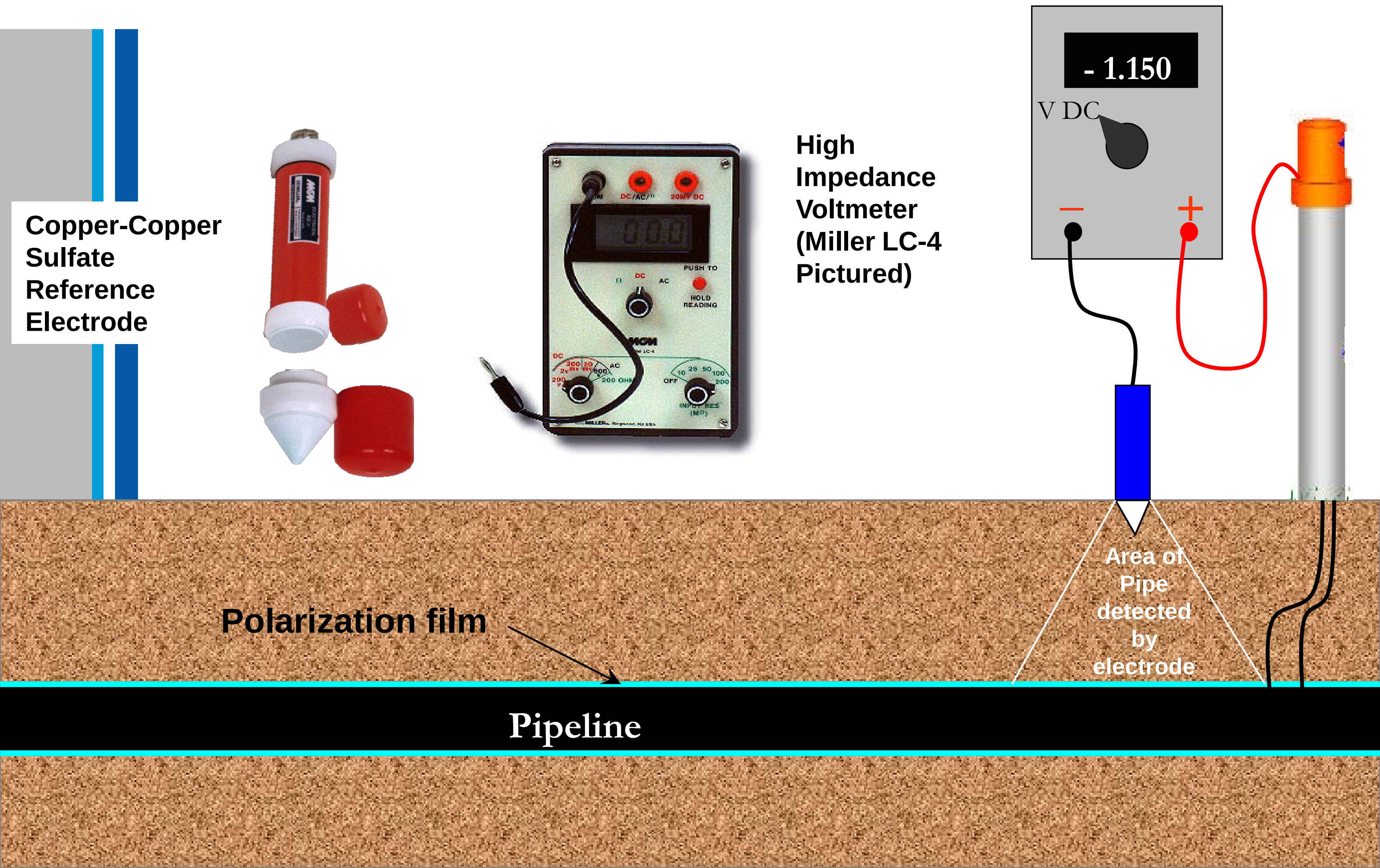
Cathodic Protection is the application of protective current from anodes onto the pipeline, forcing the pipeline to become cathodic.



Cathodic Protection – Impressed Current System



Basic Pipe-to-Soil Potential Measurement



DC STRAY CURRENT INTERFERENCE

DC Stray Current Interference

- Stray current interference occurs when DC current travels along a non-intended path.

- Where DC stray current is received by a structure, the area becomes cathodic and generally, no corrosion occurs

- Where DC stray current exits the structure to return to its source, corrosion occurs and depending on magnitude of stray current, can lead to accelerated corrosion failures.

DC Stray Current Interference

Using Faraday's Law, weight loss is directly proportional to current discharge and time ... Steel is consumed at ~21 lbs/amp-year

Example: A 1-inch diameter cone shaped pit in 0.500" thick steel would weighs 0.04 pounds.

One ampere of DC current discharging from a 1-inch diameter coating holiday would cause a through wall, cone shaped pit to occur in 0.0019 years or 16 hours.

Stray current corrosion can be a serious problem.

Sources of DC Stray Currents

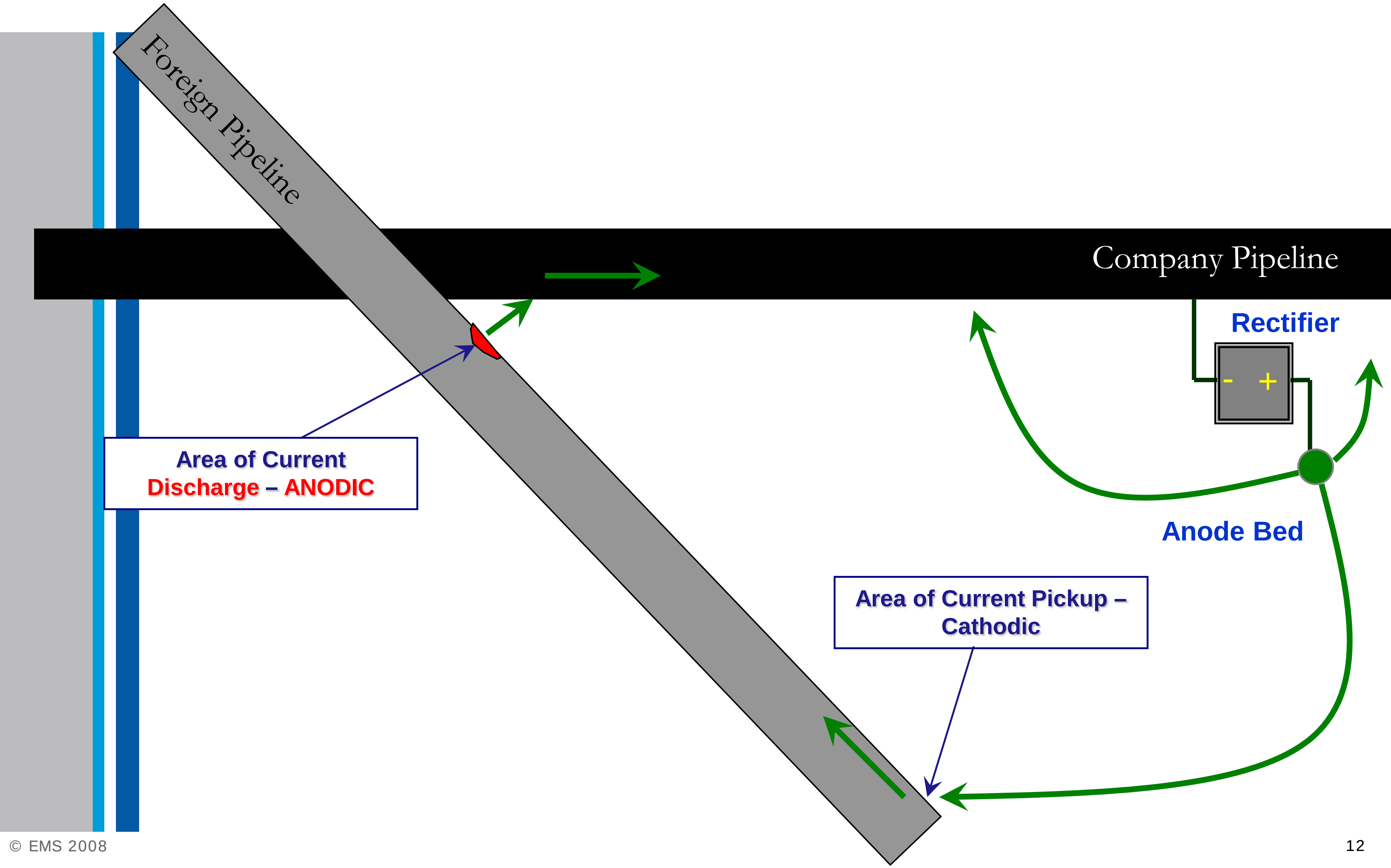
Static DC Currents:

- Foreign Cathodic Protection Systems

Dynamic DC Currents:

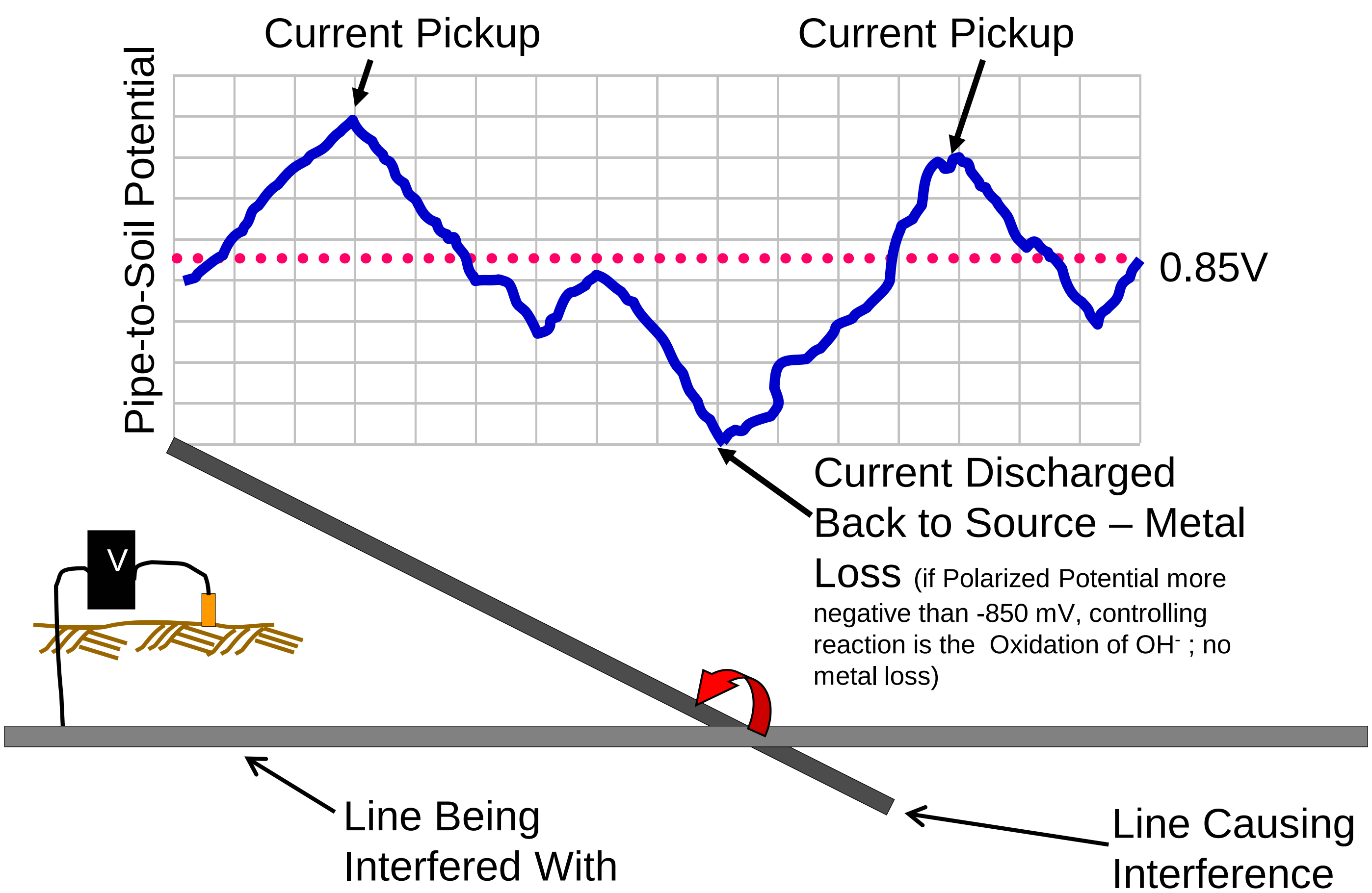
- DC Traction Power Systems: Transit, People Movers, Mining Transport Systems
- HVDC : Imbalance, Monopolar Earth Return
- Welding Equipment with Improper Ground
- Geomagnetic (Telluric) Earth Currents

Corrosion Caused by Stray Current



Testing and Identifying DC Stray Current

Potential measurements (Close Interval Surveys) are typically used to identify stray current areas.



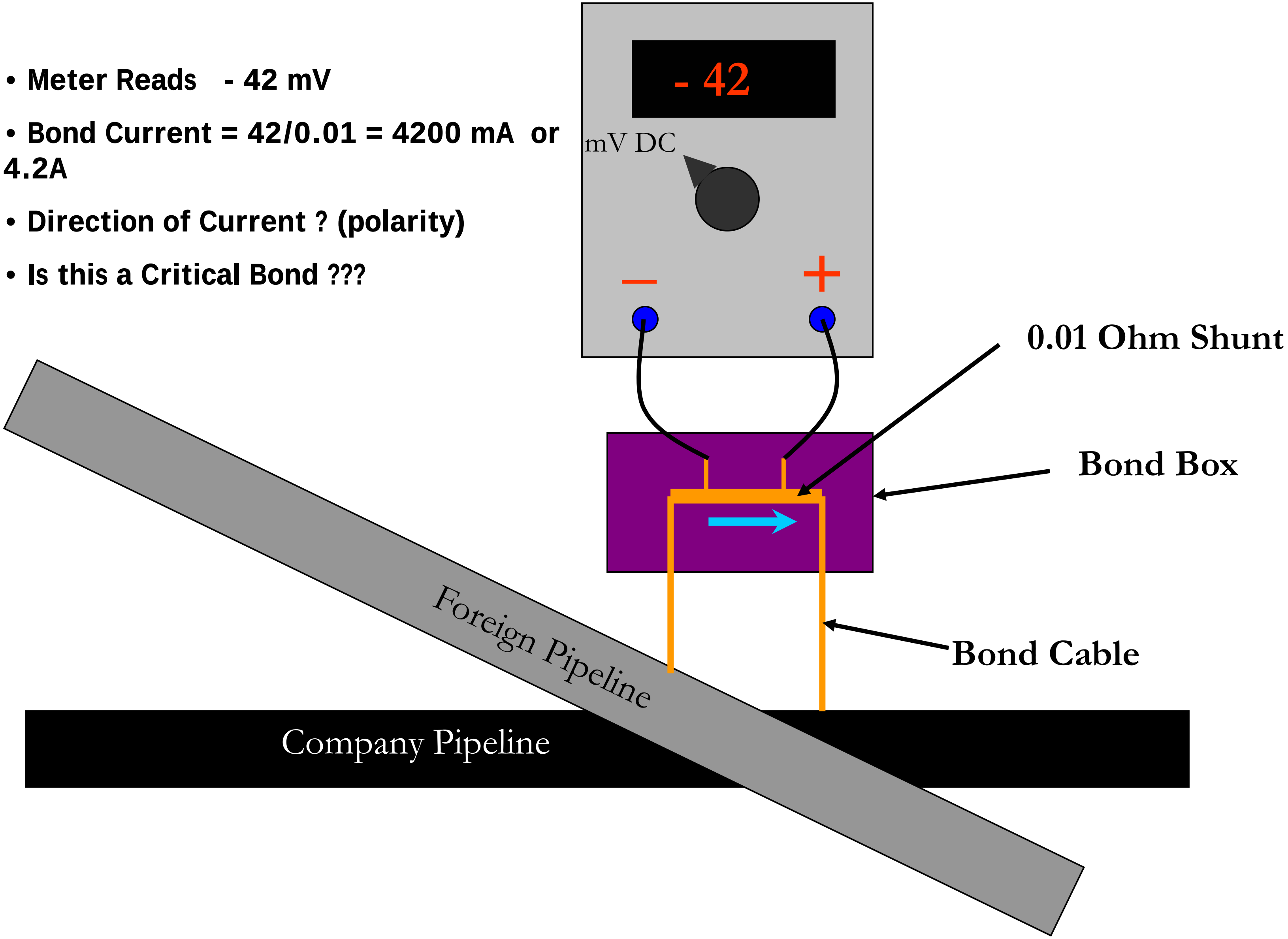
Mitigation of DC Stray Current

There are several methods to control/eliminate DC stray currents:

1. Eliminate the source, if possible
2. Bond (direct bond or resistance bond)
3. Recoating
4. Shields
5. Drain sacrificial anodes

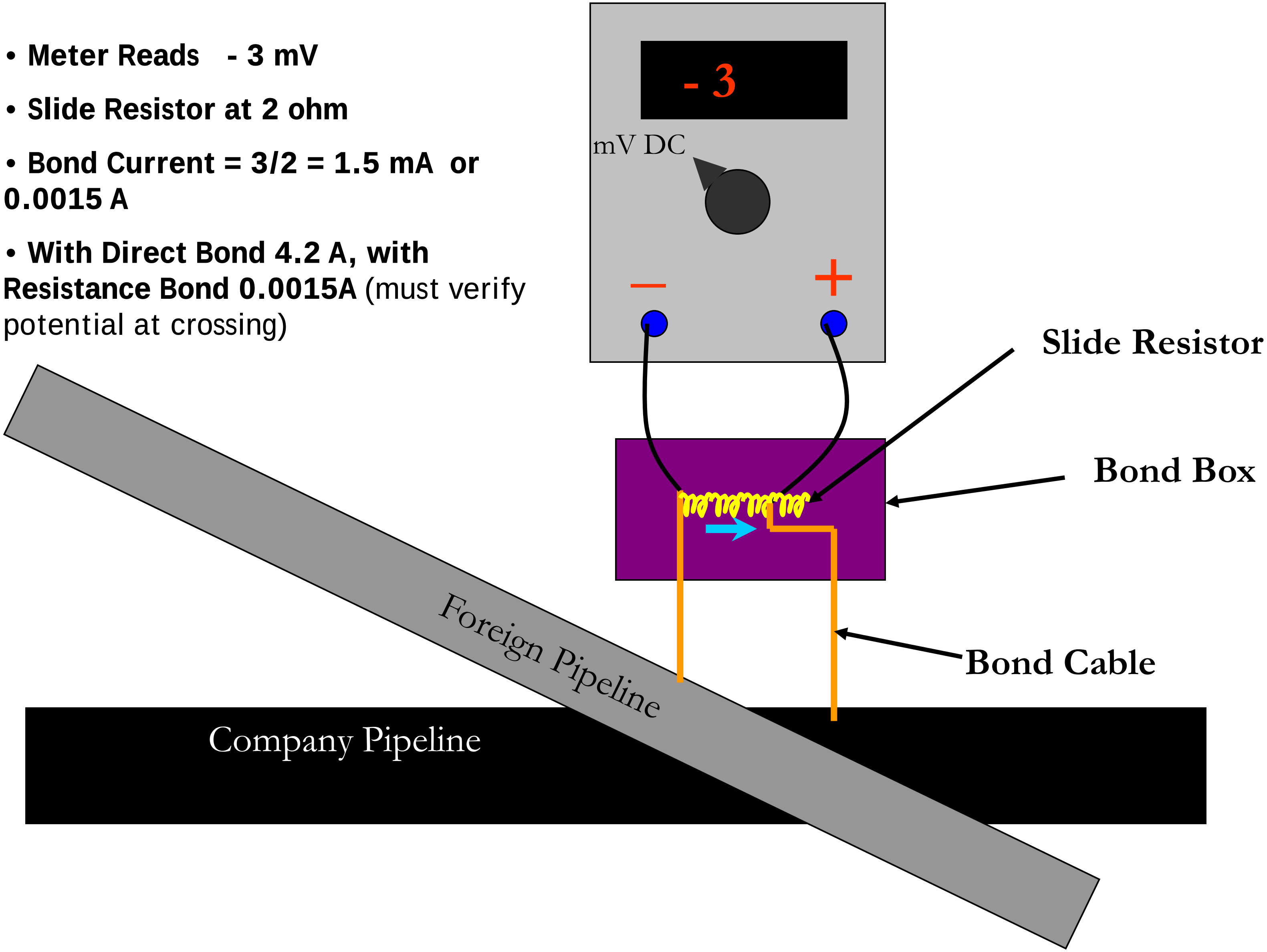
Mitigation of DC Stray Current - Direct Bond

- Meter Reads - 42 mV
- Bond Current = 42/0.01 = 4200 mA or 4.2A
- Direction of Current ? (polarity)
- Is this a Critical Bond ???

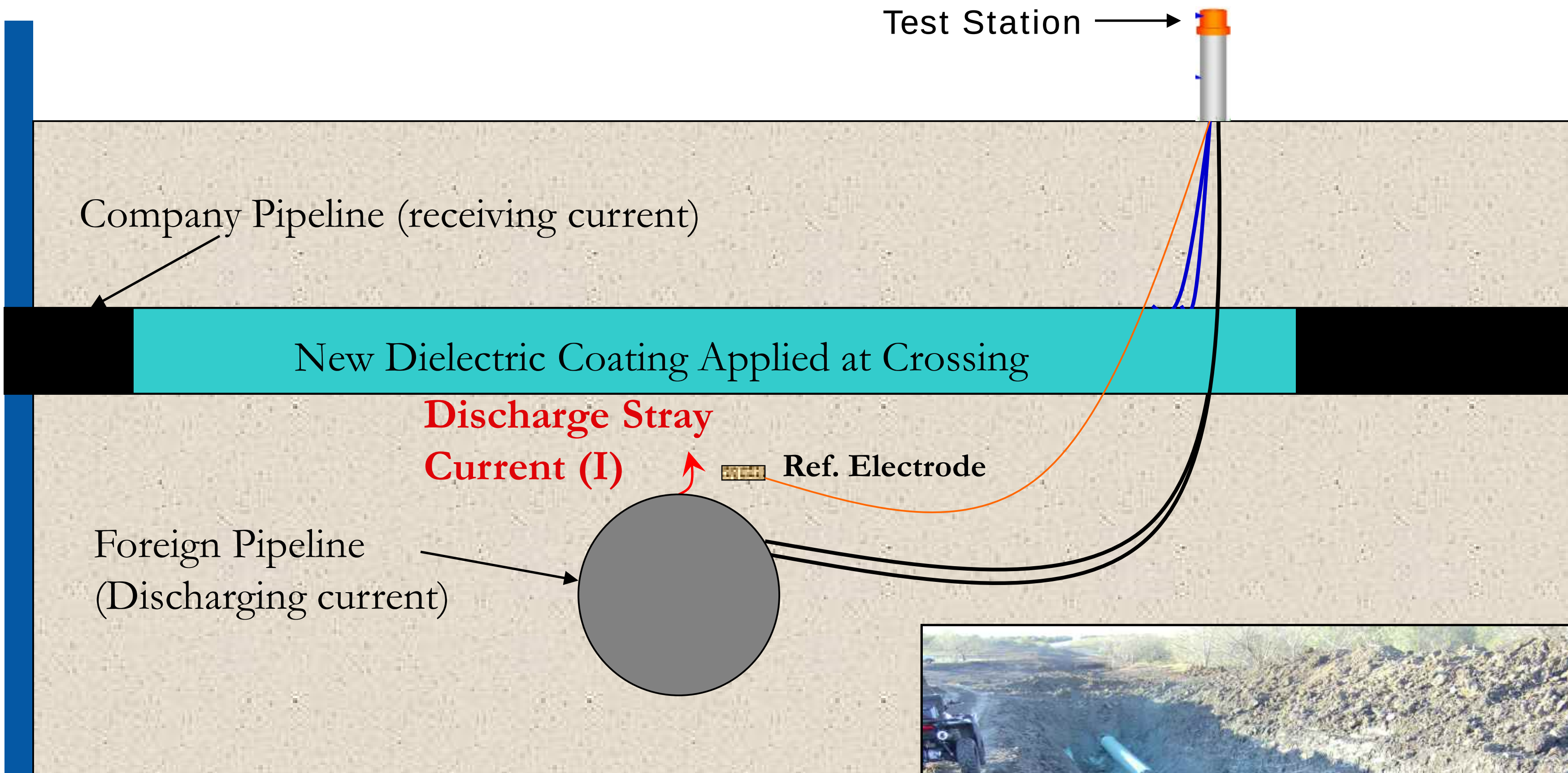


Mitigation of DC Stray Current - Resistance Bond

- **Meter Reads - 3 mV**
- **Slide Resistor at 2 ohm**
- **Bond Current = 3/2 = 1.5 mA or 0.0015 A**
- **With Direct Bond 4.2 A, with Resistance Bond 0.0015A** (must verify potential at crossing)

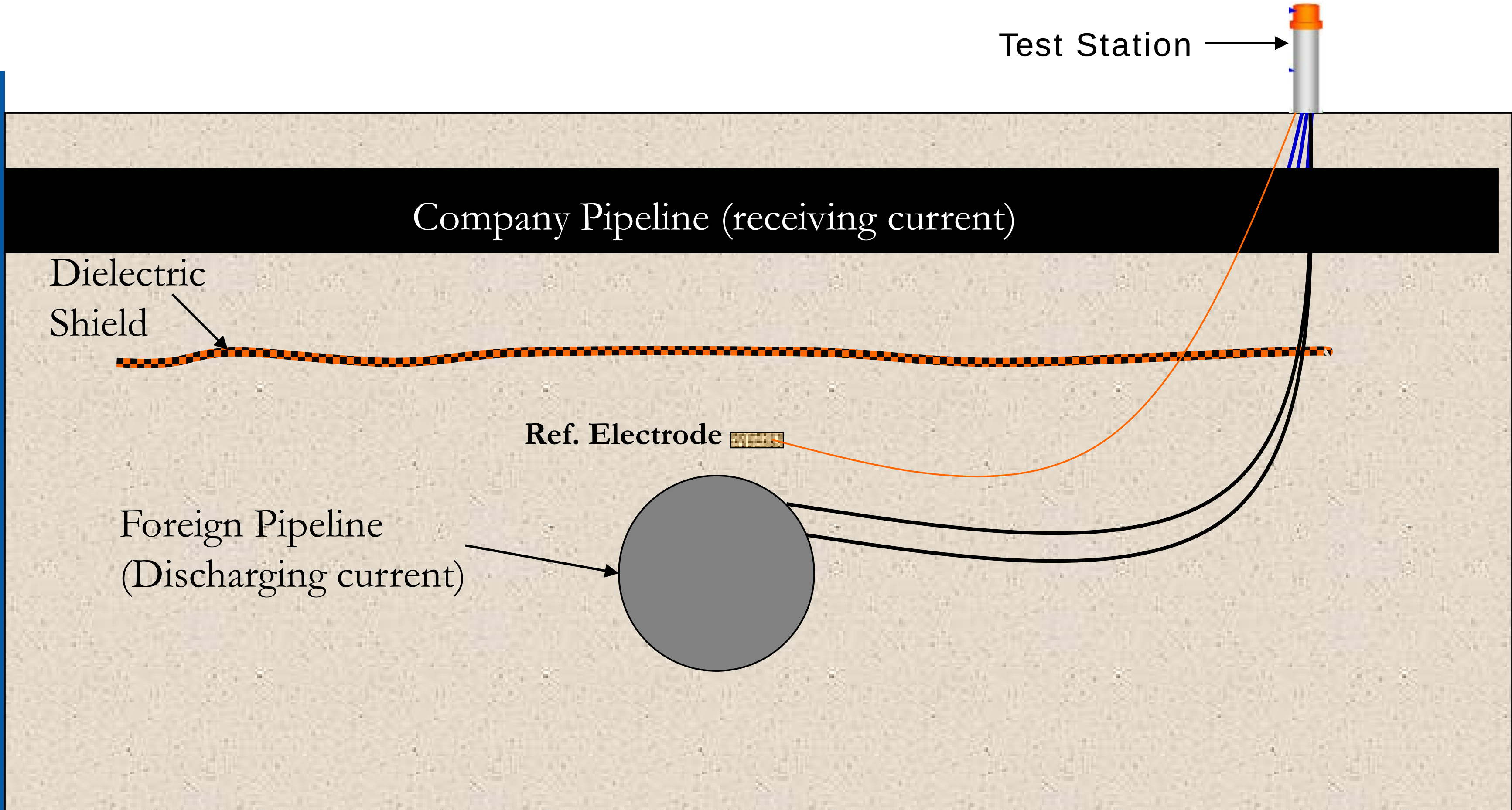


Mitigation of DC Stray Current - Recoating



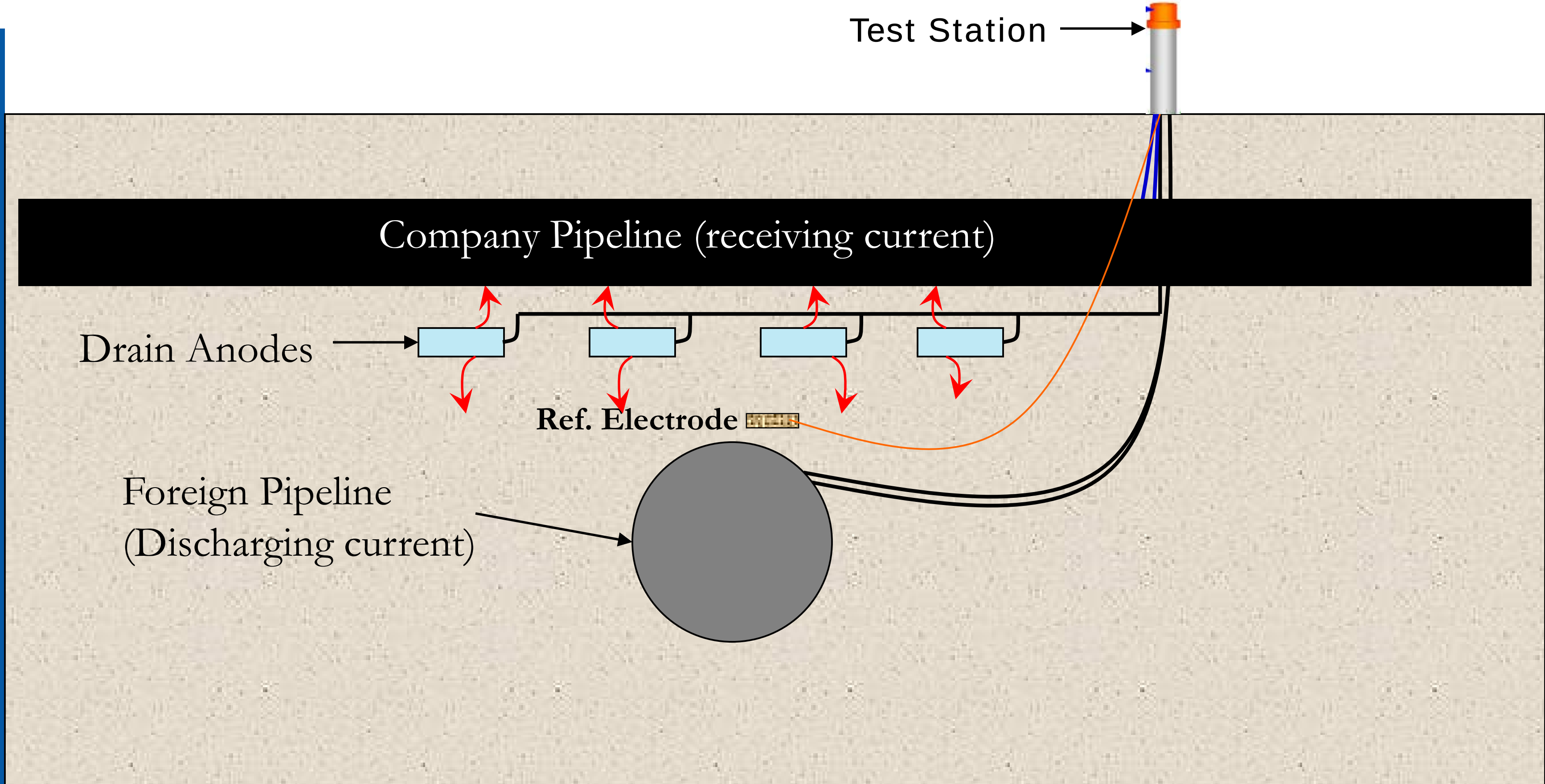
The application of the coating increases the resistance between the two pipelines, resulting in large reduction (and possibly elimination) of the Discharge Stray Current

Mitigation of DC Stray Current - Shields



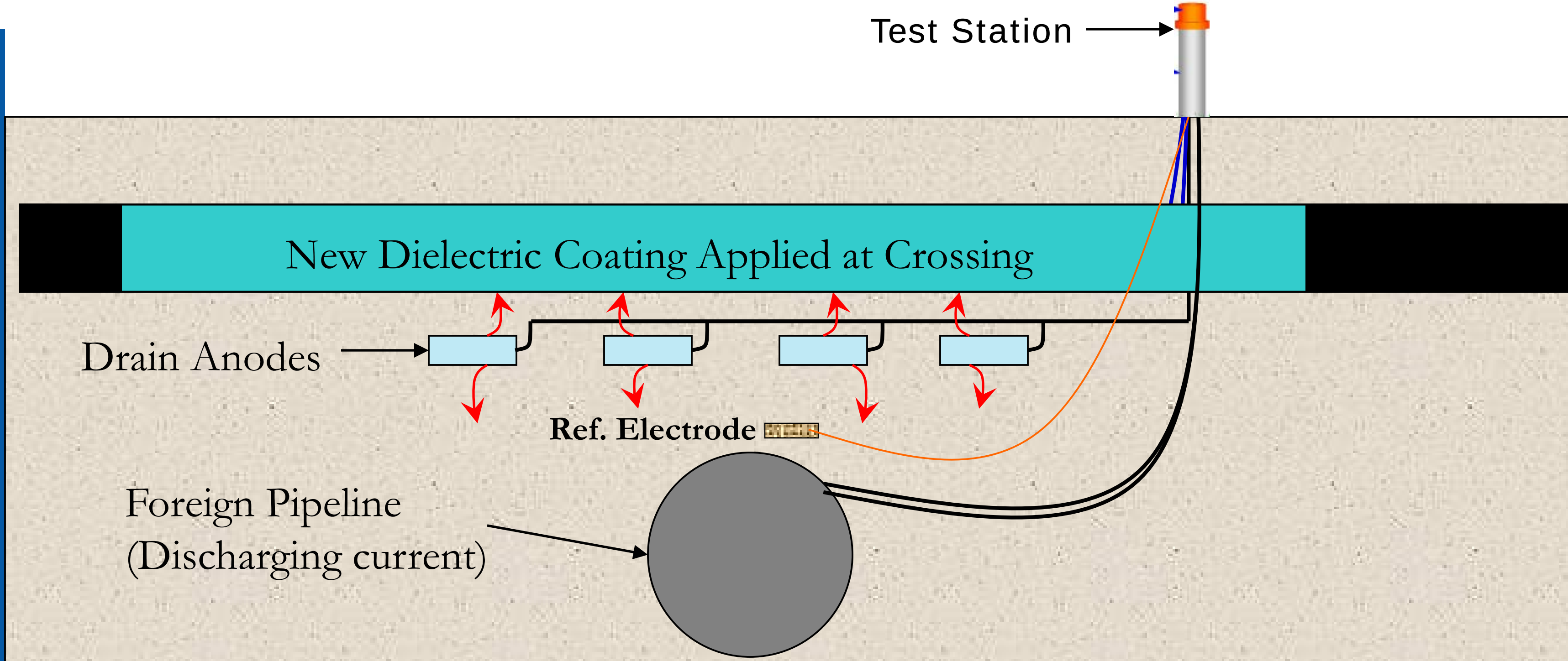
The application a non-conductive shield increases the resistance between the two pipelines, resulting in large reduction (and possibly elimination) of stray current

Mitigation of DC Stray Current - Drain Anodes



The sacrificial anodes are installed to allow for a very low resistance path between the two pipelines, forcing the stray DC currents to discharge from the anodes (instead of the pipeline). Proper design of these anodes (number, size) is critical.

Mitigation of DC Stray Current Combination of Control Measures



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AC STRAY CURRENT INTERFERENCE

AC Interference

High Voltage AC Power Lines Can Cause:

1. AC Corrosion of The Steel

2. Personnel Shock Hazard Due To Induced AC Voltages

AC Corrosion

AC current can cause corrosion of the steel pipeline.

Courtesy NACE

AC Corrosion

Based on recent studies of AC corrosion related failures, the following guideline was developed:

- AC induced corrosion does not occur at AC current densities less than 20 A/m^2; (~ 1.86 A/ft^2)
- AC corrosion is unpredictable for AC current densities between 20 to 100 A/m^2; (~ 1.86 A/ft^2 to 9.3 A/ft^2)
- AC corrosion typically occurs at AC current densities greater than 100 A/m^2; (~9.3 A/ft^2)
- Highest corrosion rates occur at coating defects with surface areas between 1 and 3 cm^2 (0.16 in^2 – 0.47 in^2)

AC Induced Current Calculation

$$i_{ac} = \frac{8V_{ac}}{\rho \pi d}$$

i_{ac} – AC current density (A/m^2)

V_{ac} – AC Volts (V)

ρ – Soil resistivity (Ω–m)

d- holiday diameter (m)

Courtesy NACE

Example:

A holiday area of 1.5 cm^2, with an induced voltage of 5.4 V would produce an AC Current Density of 100 A/m^2 in 1000 ohm-cm soil.

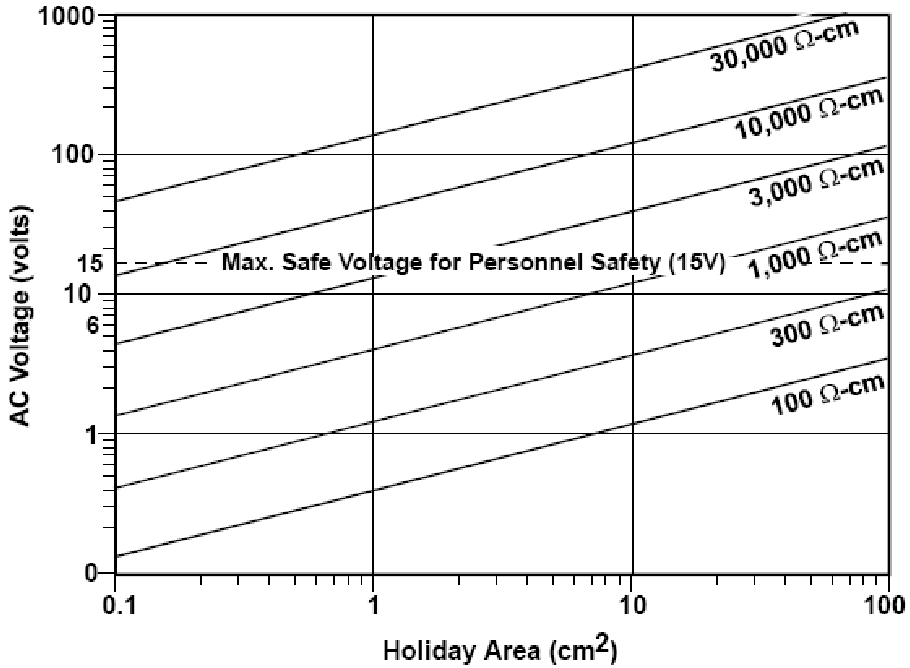
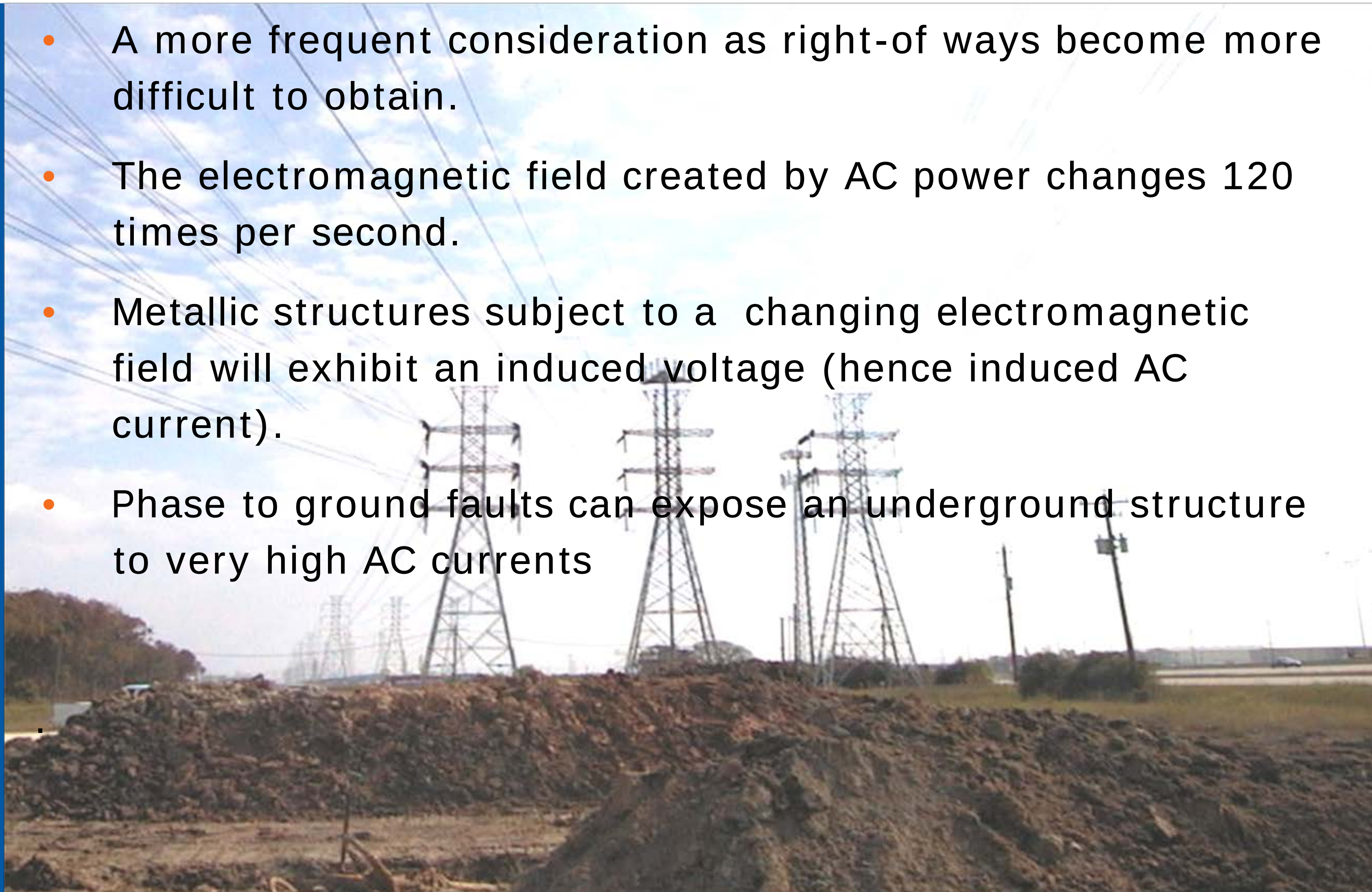


Figure 3-55: AC Voltage Required to Produce 100 A/m^2 Current Density for a Variety of Holiday Sizes and Soil Resistivities

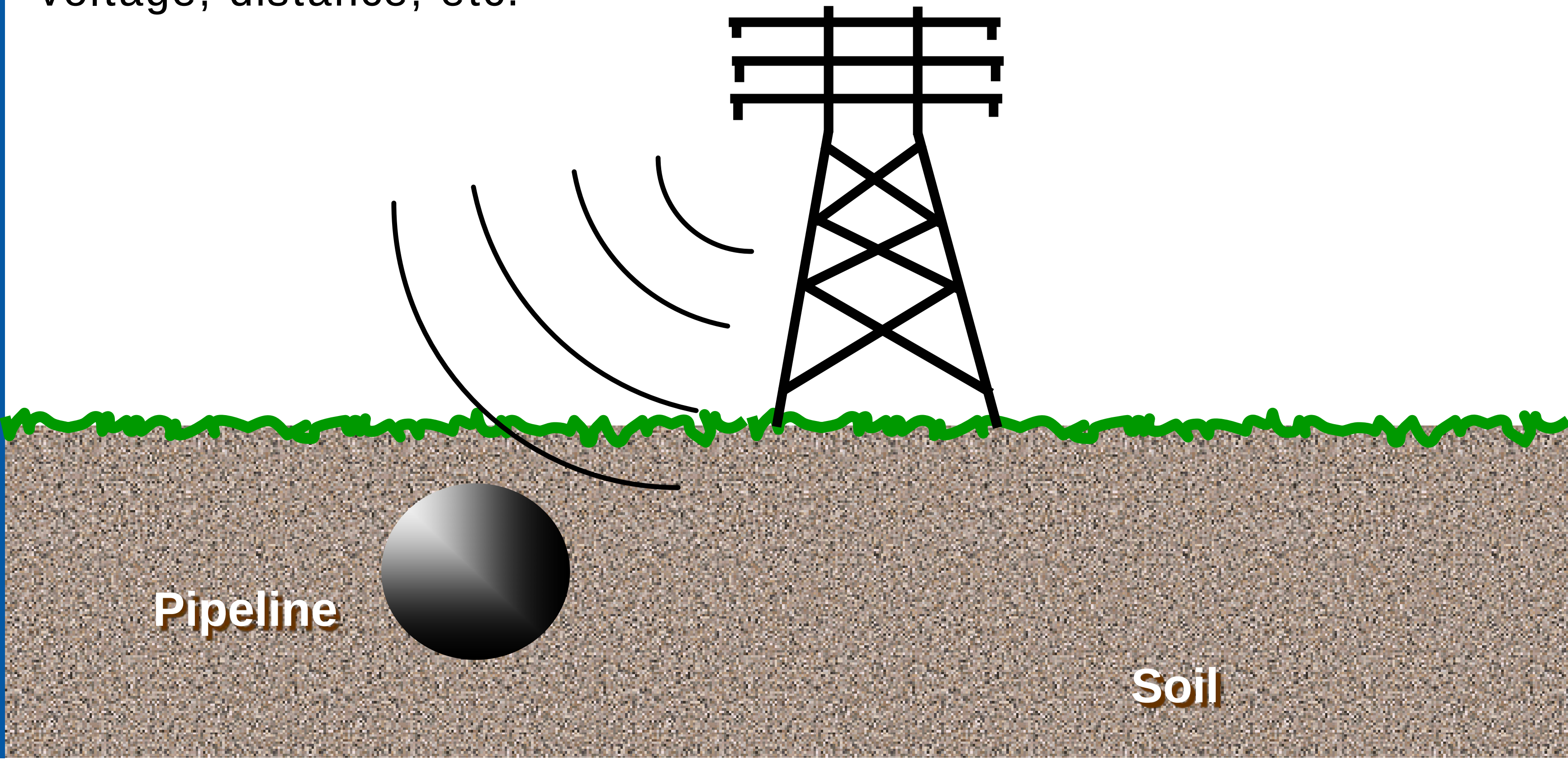
AC Interference

- A more frequent consideration as right-of ways become more difficult to obtain.
- The electromagnetic field created by AC power changes 120 times per second.
- Metallic structures subject to a changing electromagnetic field will exhibit an induced voltage (hence induced AC current).
- Phase to ground faults can expose an underground structure to very high AC currents



AC Interference

The magnetic field generated by the overhead power lines induces an AC voltage onto the pipeline (which creates AC currents). The magnitude of such currents depend on many factors such as coating condition, soil composition, power line voltage, distance, etc.



AC Interference

Electrostatic (Capacitive) Coupling

- Aboveground Structures Only

(such as an above ground test station, a car, or pipe stored near ditch)

Electromagnetic (Inductive) Coupling

- Structure Acts As Secondary Coil
- Structure Above Or Below Ground

(most important component, causes AC corrosion of steel as well as personnel hazard potential)

Conductive (Resistive) Coupling

- Buried Structures Only (during line faults)

AC Interference – Computer Modeling

Conditions Modeled:

- Steady State Induced AC Levels
- Pipe Potentials Under Phase-to-Ground Fault
- Potentials to Remote Earth
- Step Potentials
- Touch Potentials

- 15 volt Limitation for Protection of Personnel
- 1000 volts - 3000 volts Causes Coating Damage
- >5000 volts Can Cause Pipe Structural Damage

AC Interference – Mitigation Measures

- Separate Structure and AC Line
- Use Dead Front Test Stations (to eliminate shock hazard)
- Install Polarization Cells to Ground (grounding)
- Install Semiconductor Devices to Ground (grounding)
- Use Bare Steel Casings or anode beds as Grounds with DC Decoupling devices (capacitors, polarization cells)
- Install Equipotential Ground Mats at valves, test stations (for shock hazard)
- Use Sacrificial Anode and paralleling zinc ribbon or Copper wire as Ground Electrodes (normally with decoupling devices)

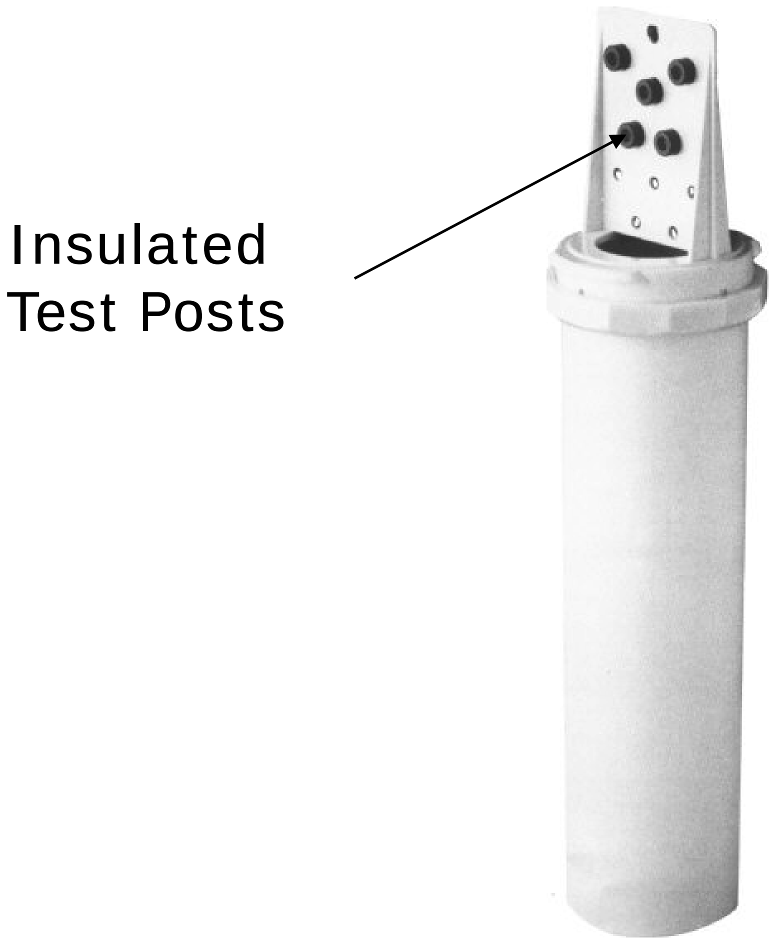
Codes and Standards

- EPRI/AGA "Mutual Design Considerations for Overhead AC transmission Lines and Gas Pipelines"

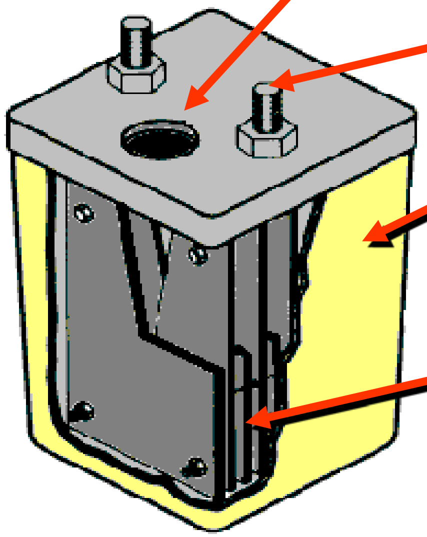
- NACE RP 0177 "Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems"

- Canadian Electrical Code C22.3 No. 6-M1987 "Principles and Practices of Electrical Coordination between Pipelines and Electric Supply Lines"

Dead Front Test Station (Personnel Protection)



Polarization (Kirk) Cell - Grounding



Model	Rated Capacity for 0.5 seconds (amps)	Steady State Rating (amps)
K-5A	5,000	30
K-25	25,000	175
K-50	50,000	350

Semiconductor Decoupling Devices - Grounding

PCR – Polarizartion Cell Replacement

Courtesy of Dairyland

SSD – Solid State Decoupler

Examples of De-Coupling Devices - Rating

Polarization Cell Replacement (PCR)

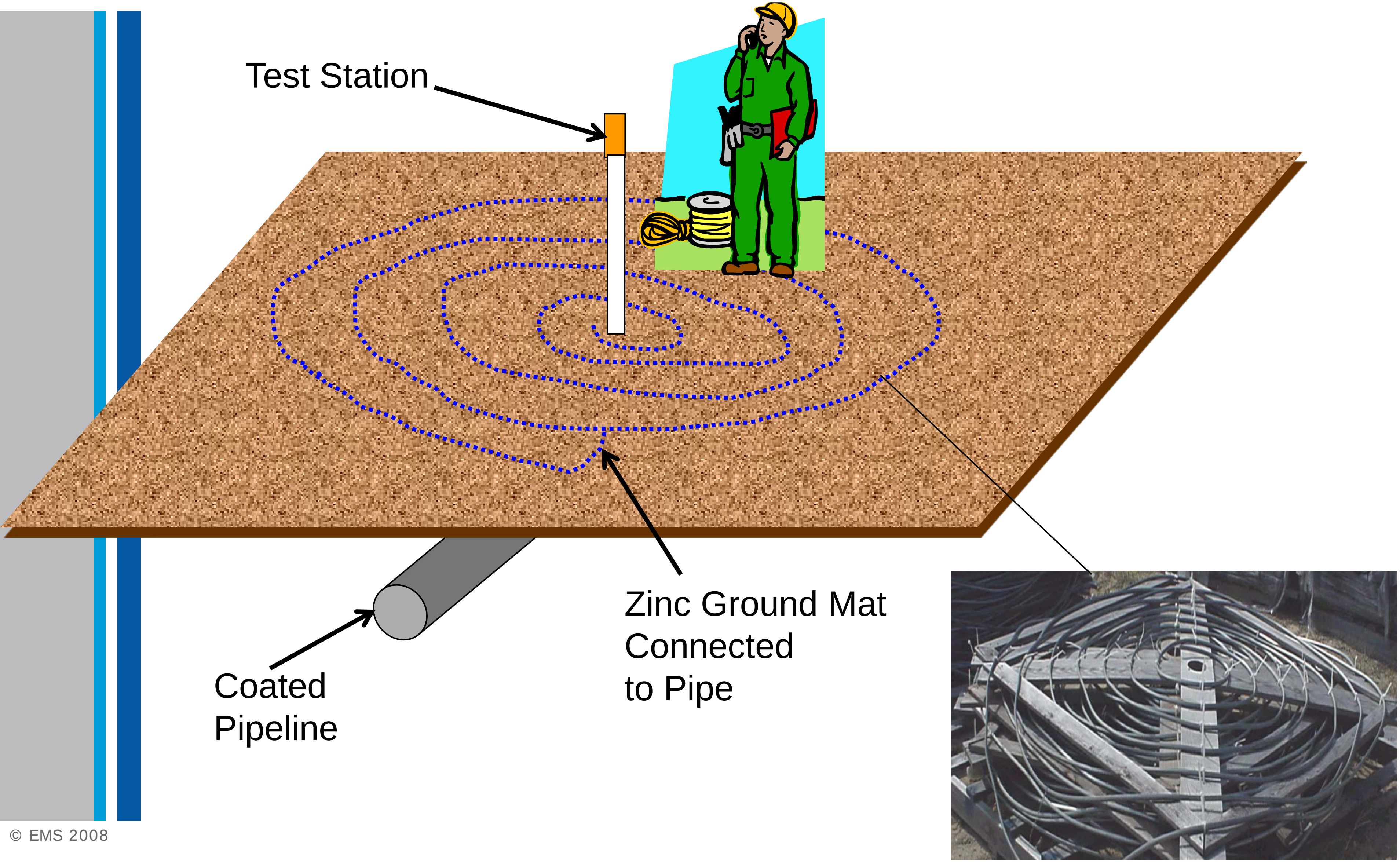
- 60 Hz Fault Current @ 1 cycle: 6,500; 20,000; 35,000 A
  @ 3 cycles: 5,000; 15,000; 27,000 A
- Lightning Surge Current @ 8 X 20 µseconds: 100,000 A
- Steady State Current Rating: 45 or 80 amps AC

Solid State Decoupler (SSD)

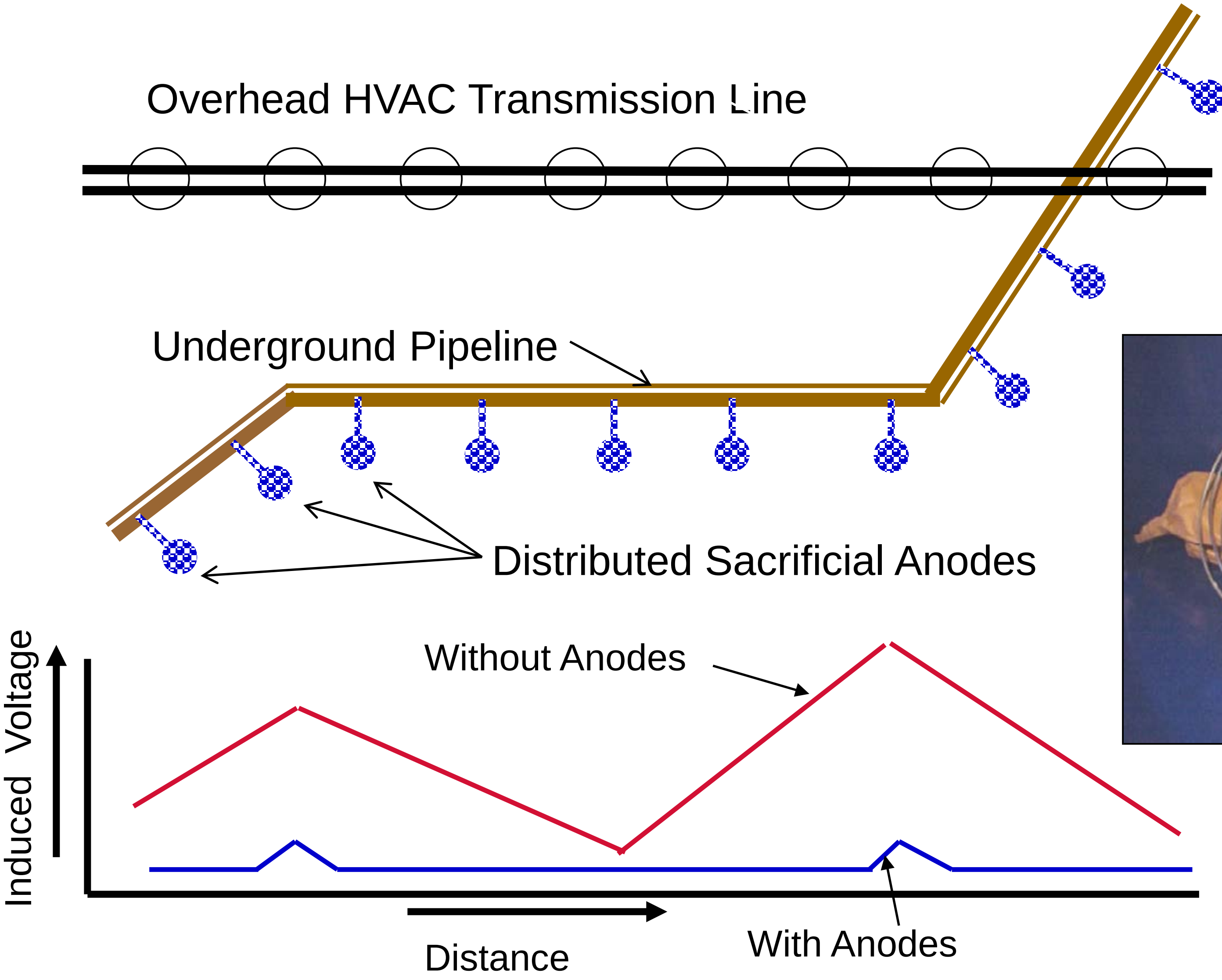
- 60 Hz Fault Current @ 1 cycle: 2,100; 5,300; 6,500; 8,800 A
  @ 3 cycles: 1,600; 4,500; 5,000; 6,800 A
- Lightning Surge Current @ 4 X 10 µseconds: 100,000A ; 75,000 A
- Steady State Current Rating: 45 amps AC

Zinc Ribbon Installation for AC Mitigation - Grounding

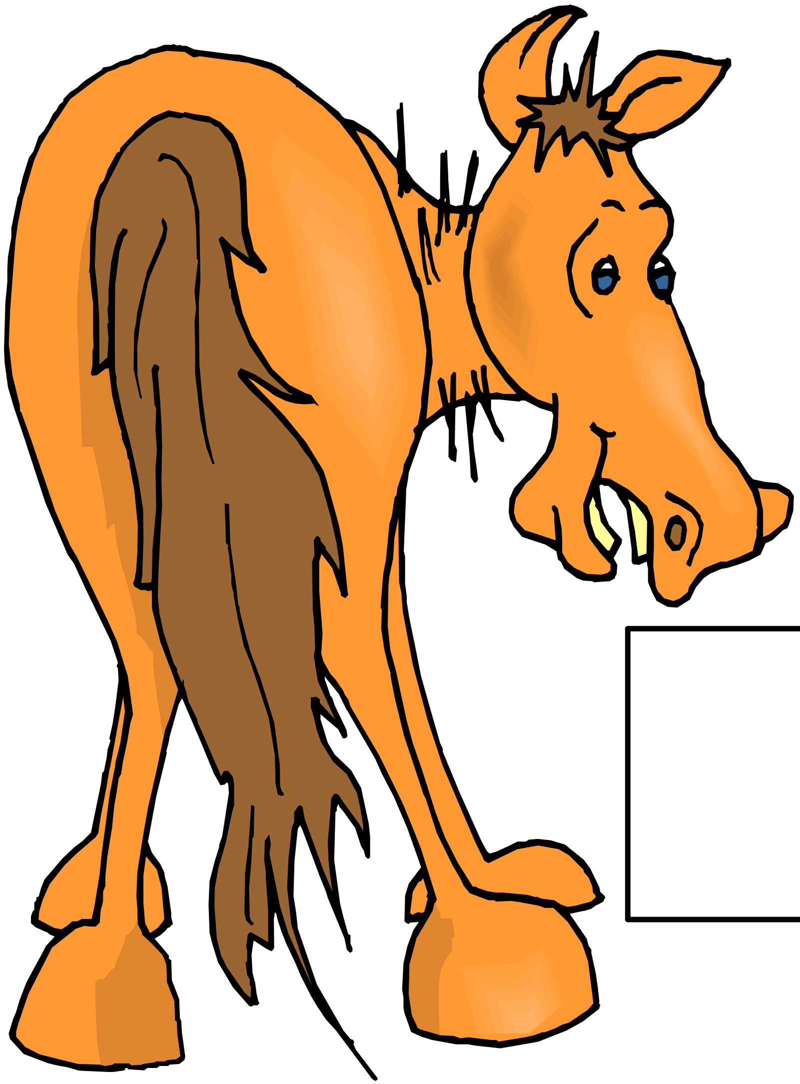
Equipotential Ground Mat - Used to Protect Personnel from Electric Shock (at test stations, valves, etc.)



Mitigation of AC Interference Using Distributed Galvanic Anodes



THE END



Thank You!

Questions?