Induced AC Interference, Corrosion & Mitigation

Prepared for NACE / Pipeliners Joint Meeting
Atlanta, GA
April 8, 2013

Bryan Evans
Vice President
Corrosion & Integrity Solutions
Grayson, GA
770-985-0505
bevans@ci-solutionsllc.com

About the Speaker

Bryan Evans, E.I.T.
B.S. Civil Engineering Technology
Southern Polytechnic State University, Marietta, GA, 1993

- NACE Cathodic Protection Specialist – No. 9754
- NACE Coating Inspector Level 1 – No. 21458
- 15 years of experience in corrosion, cathodic protection, pipeline integrity and AC mitigation as a consultant & installation contractor. Experience in both field testing, design and construction.
- Former Chairman of the NACE Atlanta Section
- Currently, a co-owner/operator of a woman owned, small business providing consulting/contracting in corrosion and cathodic protection services based in Grayson, GA.
WHAT IS INTERFERENCE?

As understood in the pipeline industry:

“Any detectable electrical disturbance on a structure caused by a stray current”

To further clarify:

“Stray current is defined as unintended electrical path”
Possible Sources of Interference

 AC and DC Transit Systems
 Welding Operations
 Cathodic Protection Systems
 High-voltage DC transmission systems
 High-voltage AC transmission systems
 Low-frequency communication systems
 Telluric (Geomagnetically induced) currents

Types of Interference

 DC Interference - most commonly thought of within the pipeline industry and potentially most damaging

 AC Interference – becoming more common due to HVPL joint-use corridors

 Telluric Interference – least common but problematic due to dynamic changes
**DC 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 highly accelerated corrosion failures.

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 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.

**DC stray current corrosion can be a serious problem!!**
**AC Interference**

A pipeline can experience AC interference as a result of being in the proximity of any AC power line. However, the vast majority of interference problems are created by three-phase (3φ) power transmission systems because these involve both high currents (during steady-state and fault conditions) and high voltages. Moreover, these systems are more likely to run parallel to pipelines for long distances.

A 3φ power transmission system consists of three energized conductors; Each conductor ~ same voltage to ground, and each carries ~ same current.

---

**Why is AC Interference a Problem?**

AC Interference introduces a series of issues into the operation of pipeline system:

- Potential of Personnel Safety Issues
- Potential for AC Corrosion
- Potential for Pipeline and Coating Damage
**Telluric Interference**

Telluric currents are currents that are geomagnetically induced on the earth and on metallic structures, such as power lines and pipe lines, as a result of the interaction of solar particles on the earth’s magnetic field.

The solar plasma arises from two solar phenomena: sun spot activity and corona mass ejections (CME), which are commonly referred to as solar flares. The geomagnetic storms that result from the interaction of the solar plasma with the earth’s magnetic field cause currents to be induced in the earth and metallic structures on the earth.

Note: Solar activity typically runs ~ 11 year cycles of activity. The next solar maximum is predicted to peak in May 2013.

---

**Severity of Corrosion**

The severity of corrosion depends on the magnitude of the stray current and time as related by Faraday’s Law:

\[ W_{total} = \frac{(M/nF)}{t} * I_{corrosion} \]

Where:
- \( W_{total} \) = weight loss (grams) at anode or weight gain at cathode
- \( M \) = Atomic weight (grams) of the material corroding or being produced
- \( n \) = number of charge transfers through the oxidation or reduction reactions
- \( F \) = Faraday’s constant (96,500 coulombs per equivalent weight)
- \( t \) = time the corrosion cell operated (seconds)
- \( I_{corrosion} \) = corrosion current in (Amps)
**Alternating Current – Power Grid System**

A system of high tension cables by which electrical power is distributed throughout a region.

Power travels from the power plant to your house through a system called the power distribution grid.

---

**Basic Corrosion Mechanism**

- **Metallic Path**
- **Electrolyte** (water, soil, mud, etc.)
- **Cathode** (protected)
- **Anode** (corrodes)
- **Water**
- **Corrosion Current** (Conventional Current Flow)

In typical soils, at **Cathode**: Electrons consumed by water/oxygen – protective film forms.

In typical soils, at **Anode**: Iron goes into solution and combines with ions in the electrolyte to form corrosion Deposits.
AC Pipe-to-Soil Potential Measurement

- Copper-Copper Sulfate Reference Electrode
- High Impedance Voltmeter (Miller LC-4 Pictured)
- Polarization film detected by electrode
- Pipeline

Soil Resistivity Testing

Typically, completed via ASTM G57, "Wenner 4-Pin Method".

- Field Resistivity Measurements
- Single Pin Resistivity Measurements
- Soil Box Laboratory Resistivity Measurements

\[
\rho \Omega \cdot \text{cm} = 2\pi a R (a \text{ in cm})
\]

where:
- \( a \) = electrode separation, and
- \( R \) = resistance, \( \Omega \).

Using dimensional analysis, the correct unit for resistivity is ohm-centimetre.
Soil Resistivity Testing

Dataloggers
Close Interval Survey (CIS)

[Diagram showing the setup of a Close Interval Survey including a reference electrode, test station, copper wire, and various equipment like a voltmeter/logger and interrupter switch.]

Close Interval Survey (CIS)

[Graph showing data from a Close Interval Survey with various lines representing different parameters or measurements.]

4/9/2013
Direct Current Voltage Gradient (DCVG)

AC STRAY CURRENT INTERFERENCE
**Pipelines in Congested Power ROW**

**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, separation distance, etc.
Shared Right of Ways

- New (clear) Right-of-Ways are difficult to obtain for new pipeline applications
- More attractive option is to share an existing right-of-way with other pipelines or with existing right-of-way with an overhead electric power transmission system
- Due to the limited amount of land, and the cost associated with acquiring ROW shared right-of-ways will be more and more common in the coming years.

AC Interference

- The electromagnetic field created by AC power changes 60 times per second per phase.
- 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.
**Code – CFR 192**

Where AC Interference effects falls within the Code:


(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.

**Code – CFR 192**

§192.328 Additional construction requirements for steel pipe using alternative maximum allowable operating pressure. Special Permit Lines 80% SMYS

(e) Interference currents.

(1) For a new pipeline segment, the construction must address the impacts of induced alternating current from parallel electric transmission lines and other known sources of potential interference with corrosion control.
Standards & Guidance Documents

- NACE SP 0177 “Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems”.
- EPRI/AGA “Mutual Design Considerations for Overhead AC Transmission Lines and Gas Pipelines”.
- Canadian Electrical Code C22.3 No. 6-M1987 “Principles and Practices of Electrical Coordination between Pipelines and Electric Supply Lines”.

AC Interference

Electrostatic (Capacitive) Coupling
- Aboveground structures only
  (such as an aboveground 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 – Capacitive Coupling**

Caused by accumulation of electrostatic voltage resulting in a capacitance coupling (buildup) between the power line and the pipeline.

- Typically, occurs during construction when coated and ungrounded joints of pipe are near a HVAC power line
- Common at above ground components; such as: test stations, risers, valves etc.
- Unlikely on buried pipeline because of the low pipe-to-earth capacitance

**AC Interference – Inductive Coupling**

Caused by current flow in the power line which creates an electromagnetic field surrounding the paralleling pipe line.

- Occurs during normal operating conditions of the power line.
- Magnitude can reach 100’s of volts and presenting shock hazards
- Pipe lines within 1000 if of a HVAC power line should be investigated, in particular if they share a common ROW in parallel.
**AC Interference – Inductive Coupling**

Voltage and currents are electromagnetically induced on to a pipeline in the same manner that an inductive pipe locator induces an audio signal onto a pipeline.

**AC Interference – Resistive Coupling**

Direct contact between a live component of the power line and an exposed metallic structure. Occur during ground fault conditions or during lightning strikes.

- Not common.
- Very short duration (breakers will trip). Typically, 0.1 seconds or less on high voltage systems.
- Potentials can exceed 15,000 volts.
- Pipe line ruptures have occurred due to these fault conditions. Can cause melting or cracking of the pipe wall.
- Pipeline coating stress is a large concern.
- Metal loss due to AC currents \( \sim 2.0 \text{ lbs/amp-year (} \sim 10% \text{ of DC metal loss)} \); but the magnitude is potentially much higher. Especially, in ground fault conditions.
AC Interference – Resistive Coupling

CAUSES OF POWERLINE FAULT CONDITIONS

• On high voltage powerlines faults are most likely to occur as the result of lightning, which can ionize the air in the vicinity of an insulator.

• High winds

• Failure of the powerline structures or insulators.

• Accidental contact between powerlines and other structures (cranes, construction equipment, etc).

AC Interference

Factors contributing to AC Interference:

- Soil Resistivity.
- Magnitude of steady state current in power line.
- Geometry - Separation distance and orientation between power line and pipeline.
- Power line operating characteristics.
- Magnitude and duration of fault currents.
- Grounding characteristics.
- Pipeline coating type.
AC Interference

High Voltage AC Power Lines can cause:

1. Personnel Shock Hazard Due To Induced AC Voltages.
2. Corrosion of the steel.
3. Coating damage.

Personnel Safety

Industry standard for mitigation of induced AC voltage that a person should be exposed to is 15 volts to a copper-copper sulfate (CSE) reference electrode.

Safety standards for personnel are based on:

1. Step Potentials
2. Touch Potentials
**Personnel Safety**

Safety considerations should be considered at all times including:

1. Construction phase:
   - Temporary grounding connections (bonds).
   - Ground Rods.
   - Bare pipe casing.
   - Grounding straps on vehicles/equipment.

2. Typical Operation & Maintenance:
   - AC Mitigation Measures.
   - Employee PPE.

**AC Corrosion**

Characteristics of AC corrosion:

1. Typically areas of low soil resistivity.
2. Typically located at coating defects.
4. Typically results in rounded shaped pits.
5. Typically pit size larger than coating defect.
AC Corrosion

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

- No AC induced corrosion at AC current densities < 1.86 A/ft² (20 A/m²).
- AC corrosion is unpredictable for AC current densities between 1.86 A/ft² to 9.3 A/ft² (20 to 100 A/m²).
- AC corrosion typically occurs at AC current densities > 9.3 A/ft² (~100 A/m²).
- Highest corrosion rates occur at coating defects with surface areas between 0.16 in² – 0.47 in² (1 and 3 cm²).

\[ i_{w} = \frac{8V_{ac}}{\rho d} \]

- \( i_{w} \) – AC current density (A/m²)
- \( V_{ac} \) – AC Volts (V)
- \( \rho \) – Soil resistivity (Ω-m)
- \( d \) – holiday diameter (m)

AC Corrosion

Recent studies related to AC have concluded the following:

1. AC does not have any significant effect on the polarization or depolarization of cathodically protected steel.
2. It has been found that excessive amounts of CP can actually increase AC corrosion rates. This has been attributed to the lowering of the electrolyte resistivity immediately adjacent to the site of the holiday, which coincides with the high pH resulting from increased levels of CP.
**AC Corrosion: Case Study**

Here is an actual scenario:

A number of anomalies were discovered after a regularly scheduled ILI run. The key information is as follows:

- 24” Diameter x 0.375” wall Natural Gas Transmission Pipeline
- Located in LA
- Pipe was installed in 1992, and has a FBE coating
- Soil resistivity ranged from 800 to 2000 ohm-cm (4-pin) and as little as 400 ohm-cm (via soil box)
- pH at and around the immediate vicinity of the defect 12.5
- Pipeline had effective cathodic protection IR Free pipe to soil potentials of -1100 mV vs. CSE
- Pipeline was found to have 6.1 volts AC on the line at the defect location. Given < 15 VAC, this is not a personnel hazard issue.

**AC Corrosion: Case Study**

Power Line and Pipeline Alignment
AC Corrosion: Case Study

Anomaly #1

AC Corrosion: Case Study

Anomaly #1
AC Corrosion: Case Study

Anomaly #1

AC Corrosion: Case Study

Anomaly #1 – ~ 20% Wall Loss
AC Corrosion: Case Study

Anomaly #2

AC Corrosion: Case Study

Anomaly #2 – 50% Wall Loss
**AC Corrosion: Case Study**

Anomaly #2

**Fault Conditions - Pipeline Damage**

- Fault currents from power lines can be collected and discharged from pipeline lines in the vicinity of the fault.

- Coating damage can occur when the current picked up by the pipe line exceeds the dielectric strength of the coating material. Coating stress voltages:
  - 2 kV for tape wraps and coal tar coatings
  - 3 to 5 kV for fusion bonded epoxy and polyethylene

- Arching resulting from the discharge of the fault current can cause structural damage to the pipeline in excess of >5000 volts
REVIEW – KEY POINTS:

Most important things to remember related to AC Voltages:

- 15 volt Limitation for Protection of Personnel
- Voltages of 1000 volts - 3000 volts Causes Coating Damage
- >5000 volts Can Cause Pipe Structural Damage
- AC does not have any significant effect on the polarization or depolarization of cathodically protected steel
- AC corrosion typically occurs at AC current densities greater than 100 A/m² (~9.3 A/ft²).
- Highest corrosion rates occur at coating defects with surface areas between 1 and 3 cm² (0.16 in² – 0.47 in²)

AC Interference Study – Data Necessary

Data required for AC Computer Modeling:

1. Soil conditions. Resistivity via ASTM G-57 (Wenner 4-Pin) at various spacings – to develop an “Apparent Resistivity”
   - Barnes Layer Analysis (Empirical Modeling)
   - Inverse Modeling Software
   - Curve Matching
2. Pipe line characteristics (materials of construction).
3. Pipe line and power line alignment.
AC Interference – Data Necessary

Data required for AC Computer Modeling:

4. Power system characteristics:
   - Operating Voltage.
   - Peak Loading
     - Day time vs. night time
     - Seasonal: summer vs. winter
     - Weekday vs. weekend
   - Fault Currents.
   - Phase Transpositions – change in phase arrangement
   - Tower Configurations – height, horizontal distance, phase arrangement, shield wire arrangement
   - Horizontal separation from pipeline
   - Static (Shield) Wire.
   - Grounding Design.
   - Counterpoise Data.
   - Substation locations.

Note: Must consider steady state, peak loading, times of lower resistivity, and times of fault conditions.
**AC Interference – Data Necessary**

*Note: Must consider steady state, peak loading, times of lower resistivity, and times of fault conditions of each HVPL in the corridor*

---

**Methods for collecting Power Line Data:**

Sub-meter GPS – Data Loggers
Methods for collecting Power Line Data:

Survey Grade – Laser Range Finders

Pipeline Electrical Characteristics:

Longitudinal Electric Field (LEF):
The electromagnetic field produced by the powerline current generates an electric field running longitudinally with the pipeline. This is known as the LEF. It is a complex number that has both magnitude and a phase angle.
- Voltages that are induced on the powerline are directly proportional to the magnitude of the LEF.
- LEF is directly proportional to the electromagnetic field, and directly proportional to the powerline phase currents.
- Because electromagnetic field strength varies with distance, so does LEF.
- LEF is also a function of how conductors are arranged on the HVAC tower.
- Separation distance between phase conductors is a key factor. LEF increased linearly with increasing conductor separation.

\[ E = I_p Z_0 \]

The LEF resulting from a phase current in a powerline conductor is a function of the mutual impedance \( Z_0 \) between the pipeline and the powerline.

Pipeline-Powerline Geometry for Calculation of LEF
**Longitudinal Electric Field (LEF):**

In the “Single Horizontal Circuit” example shown, Phase C has the most effect on the pipe line and Phase A the least. The greater the separation distance the less effect by that Phase. **Figure to Right**

**HVAC Tower Configurations:**

In the “Single Horizontal Circuit” example shown, Phase C has the most effect on the pipe line and Phase A the least. The greater the separation distance the less effect by that Phase. **Figure to Right**

**Phase Arrangements for Double Vertical Circuit**

**Effect of Phase Conductor Separation**

**Phase Transposition**
AC Interference – Computer Modeling

• **Typical AC Conditions Modeled:**
  - Steady State Induced AC Levels
  - Pipe Potentials Under Phase-to-Ground Fault
  - Potentials to Remote Earth
  - Step Potentials
  - Touch Potentials
  - Identify high risk areas (phase transpositions, power line crossings, areas of convergence/divergence, etc.)

• 15 volt Limitation for Protection of Personnel

• 1000 volts - 3000 volts Causes Coating Damage

• >5000 volts Can Cause Pipe Structural Damage

AC Interference – Computer Modeling

Several organizations and companies have developed software to model complex Right-of-Way conditions related to induced AC voltages. This is the most efficient means to effectively evaluate “What if Scenarios” during the design phase. The modeling involves very complex mathematical formulae to analyze the various scenarios.

The range from affordable to very expensive (~ $50,000/license), and all have Pro’s and Con’s. Some industry available models are as follows:

- Pipeline Research Council International (PRCI)
- Safe Engineering Services & Technologies
  - CDEGS
  - Safe ROW
- ELSYCA
- OTHERS

**RULE OF THUMB COSTS FOR FIELD DATA COLLECTION, MODELING AND DESIGN FEES FOR AC MITIGATION**
RANGE FROM $1,500 TO $3,500 /mile on up
For computer modeling only, $1,000 to $1,500 on up depending on complexity of the HVPL corridor.
**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 copper cables or zinc ribbon as grounds with DC decoupling devices (capacitors, polarization cells, ISPs).
- Install equipotential ground mats at valves, test stations (for shock hazard) and casing vents.
- Use no casing vents or non metallic.

---

**COTT Dead Front Test Station (Personnel Protection)**

![COTT Dead Front Test Station](image)
**COTT Dead Front Coupon Test Station**  
*(Pipeline Simulation – Corrosion Rates)*

**Features:**
- **Test Plug** – Brakes circuit between pipe and coupon for fast, easy start-off potential measurement.
- **Access Tube** – for quick, unobstructed placement of reference electrode close to the coupon.
- **CP Wire** – for underground service and easily coded for easy lead identification.
- **Steel Ring Coupon** – certified API 111 with 0.01” standard exposed area for easy calculation. Coupon surface cleaned and protected from contamination. Coupon weight verified, marked, and reported (optional).
- **PE Shrink Fittings** – isolate coupon and eliminates “edge effects”. All annular spaces epoxy sealed.
- **Puna Ceramic Alloy Plug** – prevents contamination of the “wattbridge” – keeps sensing post 1” from the coupon.
- **Big Fink CP Test Station** – proven convenience and durability.
- **COTTShunt (optional)** – to measure current direction and magnitude.
- **COTTPipe PC** – support and access tube made from high strength poly-carbonate (same as Big Fink) which ensures that the electrode access stays open. Cott Pipe PC available in all colors and lengths from 6” to 60”.

---

**Pipeline Decoupling:**

**DEALING WITH CONFLICTING ELECTRICAL REQUIREMENTS:**

- Structures must be cathodically protected (CP)
- CP systems require DC decoupling from ground
- All electrical equipment must be AC grounded
- The conflict: **DC Decoupling + AC Grounding**
**Pipeline Decoupling:**

*Reasons to DC Decouple From AC Mitigation and Electrical System Ground*

If not decoupled, then:

- CP system attempts to protect grounding system
- CP coverage area reduced
- CP current requirements increased
- CP voltage may not be adequate

---

**Polarization (Kirk) Cell – Grounding/Decoupling**

<table>
<thead>
<tr>
<th>Cell Model</th>
<th>Rated Capacity for 0.5 seconds (amps)</th>
<th>Steady State Rating (amps)</th>
<th>No. of Plates (pairs)</th>
<th>Conductor sizes (mm²)</th>
<th>Total WT. (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-5A</td>
<td>5,000</td>
<td>30</td>
<td>5</td>
<td>#8-2 AWG (10-35)</td>
<td>6 (2.7)</td>
</tr>
<tr>
<td>K-25</td>
<td>25,000</td>
<td>175</td>
<td>12</td>
<td>#2 AWG-250 MCM (35-125)</td>
<td>74 (33.5)</td>
</tr>
<tr>
<td>K-50</td>
<td>50,000</td>
<td>350</td>
<td>25</td>
<td>#1/0 AWG-500 MCM (50-250)</td>
<td>90 (40.8)</td>
</tr>
</tbody>
</table>

**DISADVANTAGES:**

1. Potassium Hydroxide Solution – Hazardous Caustic
2. Disposal of hazardous materials
**Semiconductor Decoupling Devices - Grounding**

PCR – Polarization Cell Replacement

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
**Solid State Decoupling Isolating Devices**

- Gradient Control Mat
- OVP

**MATCOR – “The Mitigator”**

**ADVANTAGES**
- A complete integrated grounding system with a copper conductor in flexible tube that is machine packed with an essential insulating boot designed for grounding systems.
- 400% more surface area than bare #10 copper cable.
- Significantly lower system impedance.
- Utilizes a #1 stranded #10 bare copper cable for enhanced flexibility and ease of installation.
- Also available in #1/0 and #2/0.
- Reduces the noise with green coded booting to identify the grounding cable assembly.
- Can be easily installed using cable pliers or conventional threading.
- Available in 365, 1,000, and longer end lengths.
- Machine packed with special purpose grounding bootfill to maintain intimate contact with the copper conductor.
- Additives are added to the bootfill to inhibit corrosion of the copper conductor.
PLATLINE– Zinc Ribbon

<table>
<thead>
<tr>
<th>Specification Chart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Description</td>
</tr>
<tr>
<td>PLATLINE- Zinc Ribbon</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Packaging</th>
<th>Wooden Box</th>
<th>Plastic Bag</th>
<th>Wood Rack</th>
<th>Wood Box</th>
</tr>
</thead>
</table>

LORESCO – Earth Backfills

PowerSet
Copper Wire
Earth or Fill

Grid Construction

Typical Vertical Rod Installation using PowerSet™

Resistance to Earth Resistance = 30 ohms

Without Grounding Backfill
1/4" x 4" Ground Rod - 100 lbs

With PowerSet™ or PowerSet™
1/4" x 4" Ground Rod - 40 lbs

LORESCO

PowerFill™
OS PowerSet™

EXAMPLE:

204 lbs: 2.5 ft x 4 ft = 704 lbs

A foot of PowerFill™ required for 10 lbs of 2.5 ft x 4 ft. For a ground resistivity of 30 Ohms, 10 lbs = 30 lbs x 10 lbs = 300 lbs of PowerFill™ required for 100 lbs of PowerSet™.
ERICO – Earth Grounding Materials

Typical AC Mitigation Design Layout
Typical AC Mitigation Design Layout

Zinc Ribbon Installation for AC Mitigation - Grounding
Equipotential Ground Mat

Used to Protect Personnel from Electric Shock 
(at test stations, valves, etc.)
Other AC Mitigation Design Layouts

- Point Grounding “Deep Anode Grounding Well”
- Faraday Cage
- Grounded Systems (Non-Decoupled)
- Combination / Multi Application Systems

Testing the Effectiveness of AC Mitigation:

- AC pipe-to-soil potential (at test stations and above ground appurtenances) to test for shock hazard voltage
- A CIS (both $V_{DC}$ and $V_{AC}$) to test the effectiveness of the cathodic protection system as well as the AC potentials on the line.
  Note: For ON/OFF surveys, the use of decouplers is critical to collect OFF (IR Free) potentials.
- Calculation of $I_{AC}$ to determine risk of AC corrosion
- Locate/identify additional localized mitigation measures, if needed.
  Note: Collect additional, soil resistivity measurements at remaining high $V_{AC}$ locations
Testing the Effectiveness of AC Mitigation:

- AC Current Drains
- Ground Resistance

Testing the Effectiveness of AC Mitigation:

- Coupon Test Stations
Questions???

Thank You

My contact information for any other follow-up questions or comments:

Bryan Evans
Vice President
Corrosion & Integrity Solutions
Grayson, GA
770-985-0505
bevans@ci-solutionsllc.com