Induced AC Mitigation for Safety and Corrosion Control
Good morning...

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Two Reasons to be aware of Induced AC on a pipeline

- Personnel Safety
- Integrity of pipeline
• Personnel Safety
  – NACE RP0177-2000 and OSHA Standard 2207, Part 1926
    • AC voltage potentials shall remain below 15 Volts (rms) open circuit
    • Source current less than 5mA
    • This equates to a resistance in the body of 3000 Ohm
### TABLE 3: Human Resistance to Electrical Current\(^{(A)}\)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry skin</td>
<td>100,000 to 600,000 ohms</td>
</tr>
<tr>
<td>Wet skin</td>
<td>1,000 ohms</td>
</tr>
<tr>
<td>Internal body—hand to foot</td>
<td>400 to 600 ohms</td>
</tr>
<tr>
<td>Ear to ear</td>
<td>(about) 100 ohms</td>
</tr>
</tbody>
</table>


### TABLE 4: 60-Hz Alternating Current Values Affecting Human Beings

<table>
<thead>
<tr>
<th>Current</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mA or less</td>
<td>No sensation—Not felt.</td>
</tr>
<tr>
<td>1 to 8 mA</td>
<td>Sensation of shock—Not painful; individual can let go at will; muscular control not lost.</td>
</tr>
<tr>
<td>8 to 15 mA</td>
<td>Painful shock—Individual can let go at will; muscular control not lost.</td>
</tr>
<tr>
<td>15 to 20 mA</td>
<td>Painful shock—Muscular control lost; cannot let go.</td>
</tr>
<tr>
<td>20 to 50 mA</td>
<td>Painful shock—Severe muscular contractions; breathing difficult.</td>
</tr>
<tr>
<td>50 to 100 mA</td>
<td>Ventricular fibrillation—Death will result if prompt cardiac massage not administered.</td>
</tr>
<tr>
<td>(possible)</td>
<td></td>
</tr>
<tr>
<td>100 to 200 mA (certain)</td>
<td>Defibrillator shock must be applied to restore normal heartbeat. Breathing probably stopped.</td>
</tr>
<tr>
<td>200 mA and over</td>
<td>Severe burns—Severe muscular contractions; chest muscles clamp heart and stop it during shock (ventricular fibrillation if prevented). Breathing stopped—heart may start following shock, or cardiac massage may be required.</td>
</tr>
</tbody>
</table>

Source: Unknown
• Induced AC – Electromagnetic interference similar to the operation of a transformer.
  – Proportional to power line current
  – Proportional to length of parallelism
  – Inversely proportional to separation distance
• How to Protect People
  – Bring down voltages
    • Locally with grounding mats
      – Zinc tied directly to pipe at above ground sites like block valves, blow down pipes
    • Existing grounding facilities at valve sites, trap sites, meter stations, compressor/pump stations
      – Must use decoupling device if tying to non CP protected structures
    • Globally with long grounding cable along pipeline
      – Zinc ribbon
        » Be careful of life, galvanic ribbon is consumable
      – Bare copper with decoupling device
        » Can install in coke breeze to lower cable to ground resistance
        » Deeper may be more moist and less susceptible to seasonal resistivity changes. Check layer resistivity in design phase
      – Electrically isolate short sections of pipeline from each other. IF’s at 1000 foot intervals. Not very practical for impressed CP system
      – Have poor coating ;(
• Consideration should be given not only to steady state AC voltages but also spikes from fault currents and lightning - Conductive Coupling
  – Design should consider max fault current possible by consultation with local power company
  – Size connecting wires and decoupling device accordingly.
• Example of damage from medium voltage fault current on line
Personnel Safety During Construction

- Sections of welded pipe on or in the ditch during construction can generate substantial open circuit voltages and even high currents if long enough.
- Working on existing lines in the ground in AC corridors can be very dangerous.

Ways to address

- Temporary ground rods at each end of joint or continuous section of joints. 1 in. x 6 ft. with #2 or greater connecting wire
  - Connect with metallic circumferential clamp, pipe end clamp, 50 lb pull magnets
  - 1 rod for less than 200 feet of pipe, 2 for 200 feet or more
- Temporary grounding mats of zinc or even galvanized fencing bonded to valves, risers, etc.
- Rubber tired equipment to have 10 foot or longer chain attached to frame and drug when on ROW
- Grounded fuel trucks bonded to equipment being fueled
- Like working with half cell, be sure to make your ground connection first and disconnect it last.
Notes:
1. Welding ground clamps may be used in lieu of magnet connectors.
2. Connection of ground wire to pipe can be made inside pipe or on outside in cutback areas.
3. Pipe stacked on shared R.O.W. with HVAC line shall not exceed 10 joints in each stack, the number of layers is limited to two (2).
Temporary Grounding Detail for Welding Strings of Pipe

- HVAC Line
- No. 2 welding cables
- Ground Rods
- 3' (TYP)
- Coating Cut Back

Dimensions:
- 500' between towers
- 2000' Max length
- 500' between sections
Notes:
1. 2" Mesh can be chain ink fence.
2. Both 3/8" x 3/4" brass and steel bolts will be installed with lock washers and nuts.
3. Distance "Z" shall be X/2 - 2", "Z" shall not exceed 2-1/2 ft., if distance "X" in in excess of 5-1/3 ft., additional 3/8" x 3/4" steel bolts shall be installed.
4. The ground mat shall extend a minimum of three (3) feet beyond work area in all directions.
• AC Corrosion
Factors that influence AC corrosion potential.
- Open circuit AC voltage on pipe
  - Entry or exodus of power line ROW
  - Discontinuity in power lines
- Localized Soil resistivity
- Holiday size
- Condition of pipeline coating
  - FBE lines – high coating resistance – low attenuation
  - Coal tar and asphalt lines – lossy

Equation to determine the AC current density at a pipeline coating holiday:

\[ i_{AC} = \frac{8V_{AC}}{\rho \pi d} \]

\[ i_{AC} \text{ – AC current density (amp/m}^2\text{)} \]
\[ d \text{ – diameter of holiday (meters)} \]
\[ V_{AC} \text{ – AC voltage of the pipeline} \]
\[ \rho \text{ – soil resistivity (ohm-m)} \]
– Does not occur or is negligible at AC current densities of less than 20 A/m^2
– Is possible at AC current densities of 20 – 100 A/m^2
– Is anticipated at AC current densities of greater than 100 A/m^2 even with high levels of cathodic polarization
– Coating holidays having an area of 1 cm^2 represent a worst-case risk.
Recently found corrosion example
- New pipeline, installed 2002, 42” FBE Coated
- Pigged 2006
• 4 years created 30% metal loss.
• Actual conditions:
  – 8 Vac on pipeline
  – 1200 ohm-cm soil conditions
  – Assume 1 cm^2 holiday
  – Calculates to 169 A/m^2

• Not always high voltage areas.
PROPOSED 12-INCH FBE COATED PIPELINE

SWAMP OR WETLAND

COGENERATION ELECTRICAL POWER PLANT

OVER HEAD 230KV POWERLINES

3.75 MILES 12-INCH FBE EXTERNALLY COATED PIPE

TRANSMISSION MAIN LINES PROTECTED BY IMPRESSED CURRENT CATHODIC PROTECTION.

N.T.S.
• Our Approach to AC Mitigation

  – Found that modeling of AC corridor is difficult and is only as good as the data input
    • Can be expensive for sometimes questionable benefit.
      – Power company may charge for detailed data
      – Must capture sometimes rapidly changing soil res data
      – Need very accurate pipe to power line geometry

  – Walking / riding route has worked
    • Can get a handle on particulars such as:
      – Low resistance areas
      – Changes in power line or pipeline geometry
      – Allows for collection of soil resistivity data at many points based on judgment
      – AC voltages at test stations
• **AC CIS**
  • Jury Out
    - Twisted pair w/ shield
      - Grounded
    - Looking Promising
    - Have to interpolate for
      AC accumulated test on wire.
• Mitigation Measures
  – Install decoupling device (PCR) approximately every 1000 to 2000 feet along line focusing on low resistance areas for making connections to the pipeline.
    • Allow AC off pipeline while preventing DC from entering pipeline from grounding anode

– Grounding Anodes
  • 1/0 bare stranded copper cable with and without coke breeze
  • Matcor Mitigator #2 bare copper in coke breeze sleeve
  • Galvanic Anodes. Prepackaged magnesium bags
  • Road Casings – be careful to ensure vent is under 15 Vac step and touch limit after hooking to pipeline
• Matcor’s Mitigator
  – Similar to linear anode. Speeds up installation in ditch when coke breeze is required
• Typical PCR installation.
• Bare copper as grounding anode
• Coated 1/0 to Pipeline
• Yellow to stationary reference cell to beside pipeline for near IR free reading
• Car vs. PCR
• Installation Considerations
  – Install grounding anode on side of pipeline facing power corridor
  – Typical offset of grounding anode is 5 to 10 feet off side of pipeline. Distance may depend on land rights.
  – Connect to both ends of casing if possible
    • Check casing for electrical isolation from pipeline.
    • If shorted, can still use for AC mitigation but will need to keep separate from other grounding structure.
  – Ensure that decoupling devices are located at bounds of shared power corridor and at discontinuities within
• Time to see how well the system is working.
  – Chart before AC and DC reads along with current being discharged

<table>
<thead>
<tr>
<th></th>
<th>Overall Mitigation System off A/C</th>
<th>Overall Mitigation System off D/C</th>
<th>Pipe with only Casing</th>
<th>Pipe with only Mitigator</th>
<th>Pipe with only Bare Cable</th>
<th>Current</th>
<th>Overall Mitigation System on A/C Volts</th>
<th>Overall Mitigation System on D/C Volts</th>
<th>Overall Mitigation System on Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>D/S BOWDEN RD.</td>
<td>15.51V AC</td>
<td>-1.35V DC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.21V AC</td>
<td>-1.39V DC</td>
<td>7.45A</td>
</tr>
<tr>
<td>PIPE</td>
<td>2.21V AC</td>
<td>4.31V AC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CASING</td>
<td>19.06A</td>
<td>14.33A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MITIGATOR</td>
<td>6.18V AC</td>
<td>2.75V AC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BARE Cable</td>
<td>5.18V AC</td>
<td>12.75A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
• Check expected current density with local soil resistivity (12,000 ohm-cm) and assumed holiday of 1 cm^2
• Vac before = 15.51
• Vac after = 3.21
• Iac before = 32.9 A/m^2 – possible AC corrosion (in 20 to 100 A/m^2 range)
• Iac after = 6.81 A/m^2 – unlikely or negligible AC corrosion
• Also brought step and touch potential to below 15 Vac
• From results slide, DC potential rose on the pipeline. This is common when AC potential is removed.

• Went from -1.35 to -1.39 CSE
  – Very common to see 50 to 500 mV increase to on CP reads
• Not a perfect science.
• Common to perform follow up work with additional grounding cable in some areas based on in-service testing.

• Thanks! Questions?