Impressed Current Anode Systems

Period 4

Intermediate Corrosion Course 2017
Objectives of the Topic

• Provide Corrosion control methods by designing an impressed current cathodic protection system for underground structures

• Discuss the various parameters which must be considered in the design of an impressed current system
Discussion Topics

• Review of Impressed current system fundamentals

• Design and Applications
  – Deep well systems
  – Conventional systems
  – Distributed systems

• Calculations
Fundamentals

• Cathodic protection can be defined as the reduction or elimination of corrosion by making a metallic structure cathodic with respect to the electrolyte in which it is installed.
Fundamentals

• The impressed current cathodic protection system utilizes an external power source (normally AC to DC) to provide a potential difference between the anode(s) and the protected structure.

• Anodes are connected to the (+) positive terminal of the power source

• Structure is connected to the (-) negative terminal of the power source
Fundamentals

• The process used for the current to flow is called **conventional** current flow, where current flows from positive to negative

• Impressed current system
  – Current flows from the power source to the anodes
  – From the anodes (groundbed system) to the structure’s holiday areas through the electrolyte
Anode bed

Current Flow

Positive (+)

Negative (-)

Rectifier Unit

structure - Pipeline

(+)

Current Flow

(-)
Fundamentals

• Due to the fact of using an external power source, the systems can protect a very large body of pipeline in which requires a great magnitude of current than what can be provided economically by a galvanic anode system

• Most systems are equipped with an adjustable output setting of current and voltage (DC)
Fundamentals

• These systems can be design to protect bare (uncoated) structures, poorly coated, or well coated structures.

• As the amount of increased bare surface of the pipeline in need of protection, the total amount of current requirement increases, and the impressed current systems become the system of choice
Fundamentals

• Advantages
  – Can be designed for a variety of applications with a reasonable degree of flexibility
  – The ability to increase or decrease the current output
  – Pipe segments requiring large amounts of current for CP can be achieved at a lower cost in comparison to the galvanic systems

• Disadvantages
  – Possibility of contributing to stray current interference on neighboring structures
  – Locating areas of supplied AC power source
Designing

• Some key Factors to consider before embarking on the design
  – Pipe material type
  – Type of coating and the effectiveness
  – Pipe size and length
  – Pipe welded solid or are mechanical couplers used or any insulators installed
  – Obstacles (Residential location, other pipelines)
  – Power system nearby such as AC power lines
Designing

• Selection of groundbed site

• Selection of groundbed type
Designing

• Selection of groundbed site

• Selection of groundbed type
Designing

• Data collection needed for site selection
  – Soil resistivity & Soil moisture – Key factor in decision making
  – Accessibility for Maintenance and Testing (right of way clearing)
  – Vandalism (populated area?)
  – Interference with Foreign Structures
  – Availability of land (purchase or lease)
Designing

• Key factors in deciding on the site -
  – **Soil resistivity** – The lower the resistivity the better the anode current output, less anodes to use, this is considered a prime location for a groundbed site
  – **Soil moisture** – The soil resistivity will increase or decrease depending on the moisture content,
    • the higher the moisture the lower the soil resistivity
    • the lower the moisture the higher the soil resistivity
Design

• Testing
  – Current Requirement
  – Soil Resistivity testing
    • Four Pin Method
Field Testing

- Apply current to the pipe line
- Set up a temporary ground
  - Normally copper rods
- Connect a temporary power source such as portable rectifier
- Measure the current output to bring end points to cathodic protection criteria
Four Pin Method

Measure the resistance,

Calculate – \( S \times R \times 191.5 = \text{Ohms Cm} \)

\( S = \) Distance apart of the pins
\( R = \) Resistance measured
\( 191.5 = \) standard factor
Four Pin Method

Space between the pins represents the depth of the measurement.
Note: Near metallic structures will give a lower resistivity reading, keep the pins perpendicular from the structure at least 15 feet from the closest pin.
Designing

• Selection of groundbed site
• Selection of groundbed type
Designing

• Three most common used groundbed types
  – Deep Well anode groundbed
  – Conventional (Remote) groundbed
  – Distributed groundbed
Groundbed Type

- Deep Well anode groundbed
- Conventional (Remote) groundbed
- Distributed groundbed

- **Deep Well anode groundbed**
  - Utilizes anodes installed electrically remote from the structure in a vertical hole drilled to a minimum depth of 50 feet and in some cases, as deep as 1000 feet
  - Deep anode groundbeds are usually effective when high surface soil resistivity exist over deeper low-resistivity areas where the anodes are installed.
  - Requires less of right of way area
Groundbed Type

- **Deep Well** anode groundbed
- **Conventional (Remote)** groundbed
- **Distributed** groundbed

**Deep Well** anode groundbed

- Placement of anodes depends on area of lowest soil resistivity readings
- PVC casing normally used in the first 25 - 100 feet for unconsolidated soils, prevent cave in’s
- Vent line used to displace the corrosion product gases to prevent causing high resistivity barriers around the anodes, if not placed, could shut down system over time
Coke Breeze in Deep well Systems

• The Coke breeze is pumped into the well
  – It must first be mixed with water to form a slurry solution
  – Then pumped into the well starting from the bottom to the top
  – Covering all anodes in the well uniformly
Pumping Hose connected, and rods placed to the bottom of the well to pump the coke breeze from the bottom to the top of the anodes.
Coke breeze is mixed with water to form a slurry solution to pumped into the well around the anodes.
Tub used for water and mineral products collected from the well as being drilled out. Use a Vac truck to suck out the products in to a storage vessel for hauling off.
Bentonite is used in the mud solution with water to help prevent cave ins of the well.

- Need sufficient clearance for the drilling rig, normally 20 to 40 feet height.
- Run off occur, which causes tremendous amount of clean up, recommend to use vac truck.

February 21-23, 2017
Testing The Resistance in the Well

• Find the areas of the least resistance for anode placement
• Perform a current requirement test
• Measure the voltage and current
• Use ohms law to determine the resistance
• Document on a graph paper
• When finish, place anodes in the areas of the least resistance according to the graph created based on the measurements taken
• Ask the driller of the material being encountered, and at what drilling depth
Testing wires connected on drilling rig, using the drill bit as the ground source.

Testing equipment used for measuring the resistance as the drill bit moves down the well.
Portable Rectifier used for the current to be supplied to the temporary groundbed
Apply current,

Use ohms law to calculate resistance

\[ R = \frac{E}{I} \]
Amperes measured

Voltage measured

Ohms law –

\[ R = \frac{E}{I} \]

\[ 13.73\text{v} / 2.12\text{ A} = 6.5 \text{ ohms} \]
Space your anodes according to the measurements of the areas of the lowest resistance in the drill hole.
Ventralizer’s

Attach the Ventralizer to the vent pipe and to the anode.
The Ventralizer's dual function is to centralize the anode in the hole, and at the same time, provide 1" of separation between the anode and the vent pipe.

A common practice is to "tape" the anodes to the vent pipe - feeding a single assembly down the hole. However, this can result in the anode being too close to the vent pipe to allow the backfill to fill around the entire anode surface during pumping operations. To make matters worse, the non-conductive vent pipe can serve to shield portions of the anode in contact with it - resulting in uneven current discharge of the anode.
Small slits are cut to allow the gases in the well to vent out but too small for the coke breeze to enter.
Designing

• Groundbed Type
  – Deep Well anode groundbed
  – Conventional (Remote) groundbed
  – Distributed groundbed

• Conventional (remote) groundbed
  • Normally used to distribute current over a broad area
  • The first anode may be more than 300 feet away
  • Anode normally installed on 15 to 30 foot spacing
  • Can be installed parallel, preferable install perpendicular to reduce the gradient effect on the pipeline
• Groundbed Type
  – Deep Well anode groundbed
  – Conventional (Remote) groundbed
  – Distributed groundbed

• **Groundbed Type**
  – **Conventional (remote) groundbed**

• The term “remote”, in association to this type of groundbed design, means that the pipeline is outside of the anodic gradient of the groundbed caused by the discharge of the current from the anodes to the surrounding soil.
Anodic Gradient field surrounding groundbed

Rectifier Unit

Cathodic protection current

Protected pipeline
Horizontal Installation

Vertical Installation

Figure 7.1 Typical vertical anode installation.
The industry standard cable for direct burial is a stranded copper conductor covered with an insulation of high molecular weight polyethylene (HMWPE). The thick insulation provides both electric isolation and mechanical protection. During installation, this cable can withstand considerable mechanical abuse without compromising the conductor. The HMWPE insulation is chemically resistant and protects against most organic and inorganic substances.

Where Chlorine gases may be generated due to groundbed operation or severe chemical environment are encountered, a protective jacket such as a KYNAR or HALAR should be used.
One of the major causes of deep anode failures is the failure of cable insulation. This is especially evident in areas where blackish water is present in the ground. In this environment, anodes generate reactive gases such as chlorine and nascent oxygen. These gases cause rapid deterioration of conventional HMWPE insulation. Cathodic protection cable insulated with HALAR fluoropolymer, is especially suited for deep anode lead wires. HALAR fluoropolymer is inert to reactive compounds and has an outstanding ability to prevent the passage of gases.

The material is also resistant to water intrusion and is not affected by most organic or inorganic substances. The inner or primary insulation is composed of HALAR, a fluoropolymer. This insulating material demonstrates exceptional chemical resistance. In the presence of chlorine, hydrochloric acid, sulfuric acid, or other strong oxidizing agents the material remains stable.
<table>
<thead>
<tr>
<th>Size</th>
<th>No. of Strands</th>
<th>Circular Mils</th>
<th>AWG Diameter</th>
<th>Insulation Thickness</th>
<th>Nominal Diameter</th>
<th>Weight Lbs per 1000 ft</th>
<th>DC Ohms per Mft at 20 C</th>
</tr>
</thead>
<tbody>
<tr>
<td>#14</td>
<td>7</td>
<td>4,110</td>
<td>.0726</td>
<td>.110</td>
<td>.293</td>
<td>38</td>
<td>2.57</td>
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<tr>
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<td>6,530</td>
<td>.0915</td>
<td>.110</td>
<td>.311</td>
<td>48</td>
<td>1.62</td>
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<tr>
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<td>7</td>
<td>10,380</td>
<td>.116</td>
<td>.110</td>
<td>.340</td>
<td>62</td>
<td>1.02</td>
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<tr>
<td>#8</td>
<td>7</td>
<td>16,510</td>
<td>.142</td>
<td>.110</td>
<td>.370</td>
<td>87</td>
<td>.652</td>
</tr>
<tr>
<td>#6</td>
<td>7</td>
<td>26,240</td>
<td>.179</td>
<td>.110</td>
<td>.40</td>
<td>122</td>
<td>.411</td>
</tr>
<tr>
<td>#4</td>
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<td>41,740</td>
<td>.225</td>
<td>.110</td>
<td>.45</td>
<td>175</td>
<td>.258</td>
</tr>
<tr>
<td>#2</td>
<td>7</td>
<td>66,360</td>
<td>.283</td>
<td>.110</td>
<td>.510</td>
<td>260</td>
<td>.162</td>
</tr>
<tr>
<td>#1</td>
<td>19</td>
<td>83,690</td>
<td>.322</td>
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<td>.580</td>
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<td>.129</td>
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<tr>
<td>#1/0</td>
<td>19</td>
<td>105,600</td>
<td>.362</td>
<td>.125</td>
<td>.620</td>
<td>401</td>
<td>.102</td>
</tr>
<tr>
<td>#2/0</td>
<td>19</td>
<td>133,100</td>
<td>.406</td>
<td>.125</td>
<td>.660</td>
<td>492</td>
<td>.081</td>
</tr>
<tr>
<td>#4/0</td>
<td>19</td>
<td>211,600</td>
<td>.512</td>
<td>.125</td>
<td>.770</td>
<td>750</td>
<td>.051</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Size</th>
<th>No. of Strands</th>
<th>Circular Mils</th>
<th>AWG Diameter</th>
<th>HALAR Thickness</th>
<th>HMWPE Thickness</th>
<th>Nomin Diameter</th>
<th>Weight Lbs per 1000 ft</th>
<th>DC Ohms per Mft at 20 C</th>
</tr>
</thead>
<tbody>
<tr>
<td>#8</td>
<td>7</td>
<td>16,510</td>
<td>.142</td>
<td>.020</td>
<td>.065</td>
<td>.32</td>
<td>81</td>
<td>.652</td>
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<td>26,240</td>
<td>.179</td>
<td>.020</td>
<td>.065</td>
<td>.36</td>
<td>116</td>
<td>.411</td>
</tr>
<tr>
<td>#4</td>
<td>7</td>
<td>41,740</td>
<td>.225</td>
<td>.020</td>
<td>.065</td>
<td>.41</td>
<td>170</td>
<td>.258</td>
</tr>
<tr>
<td>#2</td>
<td>7</td>
<td>66,360</td>
<td>.283</td>
<td>.020</td>
<td>.065</td>
<td>.46</td>
<td>254</td>
<td>.162</td>
</tr>
</tbody>
</table>
The resin cures in approximately 30 minutes to provide a moisture-tight seal and electrically insulated splice.

These kits may be used for above ground or direct buried applications.
Designing

- **Groundbed Type**
  - Deep Well anode groundbed
  - Conventional (Remote) groundbed
  - Distributed groundbed

- **Distributed groundbed**
  - Used to protect a limited area of the pipeline
  - Anodes are generally installed close to the structure
  - Reduce influence on neighboring structures
  - Great for bare or ineffectively coated pipelines
  - Great for areas of congested facilities that could result in electrical shielding
Junction Boxes

Anode Terminal Box

• Terminals for individual anodes
• Shunts for anode current reading
• Resistors for anode current control

Order .001 ohm shunts to give a 1 to 1 ratio

Anode Terminal Box
Model ATB-M

• Terminals for individual anodes
• Meter with switch to monitor individual anode current
• Resistors available
Shunts used for the current measurements of the anodes - 1 to 1 ratio (.001 ohms)
Connect anodes individually for better performance in replacement to the cramp fittings and splice kits

**Advantages** -

Read anodes current output individually from measuring the voltage across the shunt (gives individual anode performance)

Any break in the anode lead wire, loss will be minimum, only one anode in comparison to the gathering wire of losing more than half or entire groundbed system
Impressed Current Groundbed Anode Types

- Graphite
- HSC – (High Silicon Cast Iron anodes)
- Mixed Metal Oxide
### Composition, ASTM A518 Grade 3

<table>
<thead>
<tr>
<th>Element</th>
<th>Content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.70 - 1.10</td>
</tr>
<tr>
<td>Mn</td>
<td>1.50 Max</td>
</tr>
<tr>
<td>Si</td>
<td>14.20 - 14.75</td>
</tr>
<tr>
<td>Cr</td>
<td>3.25 - 5.00</td>
</tr>
<tr>
<td>Mo</td>
<td>0.20 Max</td>
</tr>
<tr>
<td>Cu</td>
<td>0.50 Max</td>
</tr>
<tr>
<td>Iron</td>
<td>Remainder</td>
</tr>
</tbody>
</table>

- **Silicon**: 14.20 - 14.75%
- **Chromium**: 3.25 - 5.00%
- **Manganese**: 1.50% max
- **Carbon**: 0.70 - 1.10%
- **Copper**: 0.50% max
- **Molybdenum**: 0.20% max

High Silicon Cast Iron Anodes
### Graphite Anodes

<table>
<thead>
<tr>
<th>Size</th>
<th>Untreated Weight</th>
<th>Treated Weight</th>
<th>Area (ft²)</th>
<th>Recommended Max Amps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Backfill</td>
</tr>
<tr>
<td>3&quot; x 60&quot;</td>
<td>27 #</td>
<td>30 #</td>
<td>4.0</td>
<td>1.5 - 2.0</td>
</tr>
<tr>
<td>4&quot; x 80&quot;</td>
<td>65 #</td>
<td>72 #</td>
<td>7.0</td>
<td>2.0 - 4.0</td>
</tr>
</tbody>
</table>

### Chemical Composition

<table>
<thead>
<tr>
<th>Element</th>
<th>Content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.80</td>
</tr>
<tr>
<td>Ash</td>
<td>0.20</td>
</tr>
</tbody>
</table>
Mixed Metal Oxide Anodes

Tubular

Anodes are 4 ft., but they may be custom cut to virtually any length.

Rods
### Mixed Metal Oxide

**Solid Rod Anode**

![Diagram of a Mixed Metal Oxide Solid Rod Anode]

#### Standard Dimensions and Shipping Weights

<table>
<thead>
<tr>
<th>ANODE TYPE</th>
<th>NOMINAL DIMENSIONS</th>
<th>NOMINAL WEIGHT</th>
<th>CURRENT RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ø (mm)</td>
<td>l (mm)</td>
<td>BARE WT oz/ft</td>
</tr>
<tr>
<td>M 84</td>
<td>0.125</td>
<td>(3.175)</td>
<td>4 (101.6)</td>
</tr>
<tr>
<td>M 88</td>
<td>0.125</td>
<td>(3.175)</td>
<td>8 (203.2)</td>
</tr>
<tr>
<td>M 44</td>
<td>0.25</td>
<td>(6.350)</td>
<td>4 (101.6)</td>
</tr>
<tr>
<td>M 48</td>
<td>0.25</td>
<td>(6.350)</td>
<td>8 (203.2)</td>
</tr>
<tr>
<td>M 24</td>
<td>0.50</td>
<td>(12.7)</td>
<td>4 (101.6)</td>
</tr>
<tr>
<td>M 28</td>
<td>0.50</td>
<td>(12.7)</td>
<td>8 (203.2)</td>
</tr>
</tbody>
</table>

*Based on 15 year design life and XE coating in saltwater*
Tubular MMO

<table>
<thead>
<tr>
<th>Anode</th>
<th>Nominal Rated Current (amps)</th>
<th>Weight (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 yrs.</td>
<td>15 yrs.</td>
</tr>
<tr>
<td>1'' X 45''</td>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td>1'' X 60''</td>
<td>6.6</td>
<td>5.3</td>
</tr>
<tr>
<td>1'' X 90''</td>
<td>9.9</td>
<td>7.9</td>
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</table>
### Table: Anode Current Output

<table>
<thead>
<tr>
<th>Application</th>
<th>Anode Dia. (inches)</th>
<th>Design Life (years)</th>
<th>Rated Current Output (Amps per linear inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater</td>
<td>0.125</td>
<td>10</td>
<td>0.067</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>10</td>
<td>0.134</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>10</td>
<td>0.268</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>10</td>
<td>0.400</td>
</tr>
<tr>
<td>Seawater</td>
<td>0.125</td>
<td>10</td>
<td>0.140</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>10</td>
<td>0.280</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>10</td>
<td>0.570</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>10</td>
<td>0.840</td>
</tr>
<tr>
<td>Coke</td>
<td>0.125</td>
<td>10</td>
<td>0.052</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>10</td>
<td>0.103</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>10</td>
<td>0.210</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>10</td>
<td>0.310</td>
</tr>
<tr>
<td>Sand</td>
<td>0.125</td>
<td>15</td>
<td>0.0167</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>15</td>
<td>0.0033</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>15</td>
<td>0.0067</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>15</td>
<td>0.0100</td>
</tr>
</tbody>
</table>

**For a 20 year life of \( \frac{1}{4} \times 48” \) MMO rod anode = 3.3 amp output**

### Graph: LIDA Rod Anodes in Coke

- **Current (amps per linear inch)**
- **Design Life (years)**

### Equation:

\[ \text{Current} = \frac{\text{Rated Current Output}}{\text{Anode Dia.}} \]

\[ \text{For a 20 year life of } \frac{1}{4} \times 48” \text{ MMO rod anode} = 3.3 \text{ amp output} \]

### Note:

- \( 0.25 = 0.069 \) amp per linear inch
• Flexibility of anode selection (Graphite, Cast Iron, or Mixed Metal Oxide)
• 26 gauge close seam spiral galvanized steel canisters (10" and above use 24 gauge)
• 3/4 inch plywood end caps
• Top end cap is recessed for coiled lead wire protection during shipment
• Anodes are centered while the coke breeze is carefully vibration tamped to insure good compaction and proper coverage
• Coke breeze is high quality metallurgical grade backfill or petroleum coke backfill

Canister anodes
Linear Anodes
Linear Anodes
Back Fill Material

• Lowers anode-to-soil resistance
• Eliminates gas blocking (when vented) - maintains low resistance
• Permits use of higher operating currents per anode
• Eliminates high drain points and resulting selective attack on anodes
• Greatly extends life of groundbed
Back Fill Material

• Coke breeze increases the anode size which lowers the groundbed resistance

• Bears the consumption of the current discharge

• Needs to be tamped properly

• Resistance should not exceed 50 Ohms Cm
### Table 8.7 Chemical Composition of Petroleum and Metallurgical Coke Backfill

<table>
<thead>
<tr>
<th>Element</th>
<th>Content %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Petroleum Coke Backfill</strong></td>
<td></td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>99.77</td>
</tr>
<tr>
<td>Ash</td>
<td>0.1</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.0</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>0.0</td>
</tr>
</tbody>
</table>

| **Metallurgical Grade** |           |
| Fixed Carbon           | 85.89     |
| Ash                    | 8–10      |
| Moisture               | 6–9       |
| Sulfur                 | 0.8       |
| Volatile Matter        | 0.5       |

### Table 8.8 Weights of Carbonaceous Backfill

<table>
<thead>
<tr>
<th>Material</th>
<th>Lb/ Ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal coke breeze</td>
<td>40 to 50</td>
</tr>
<tr>
<td>Calcined petroleum coke breeze</td>
<td>45 to 70</td>
</tr>
<tr>
<td>Natural graphite particles</td>
<td>70 to 80</td>
</tr>
<tr>
<td>Crushed man-made graphite</td>
<td>70</td>
</tr>
</tbody>
</table>
Carbonaceous coke breeze is the material most commonly used for this purpose. This material lowers anode-to-earth resistance, provides a uniform environment for current discharge, and extends the anodes design life.

<table>
<thead>
<tr>
<th>Hole Diameter</th>
<th>Backfill Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 in</td>
<td>9 lbs/ft</td>
</tr>
<tr>
<td>8 in</td>
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<tr>
<td>16 in</td>
<td>67 lbs/ft</td>
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Dry Volume of Loresco Type SC-3 Required Versus Hole Size

<table>
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<tr>
<th>Hole Size</th>
<th>Ft³/Linear Ft</th>
<th>Lbs./Linear Ft</th>
<th>Lineal Ft/100 Pounds</th>
<th>Lbs./100' of Hole</th>
</tr>
</thead>
<tbody>
<tr>
<td>4&quot;</td>
<td>.087</td>
<td>6.4</td>
<td>15.70</td>
<td>640</td>
</tr>
<tr>
<td>6&quot;</td>
<td>.196</td>
<td>14.3</td>
<td>6.99</td>
<td>1430</td>
</tr>
<tr>
<td>8&quot;</td>
<td>.349</td>
<td>25.5</td>
<td>3.93</td>
<td>2550</td>
</tr>
<tr>
<td>10&quot;</td>
<td>.545</td>
<td>39.8</td>
<td>2.51</td>
<td>3980</td>
</tr>
<tr>
<td>12&quot;</td>
<td>.784</td>
<td>57.2</td>
<td>1.75</td>
<td>5720</td>
</tr>
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</table>
Carbonaceous coke breeze is the material most commonly used for this purpose. This material lowers anode-to-earth resistance, provides a uniform environment for current discharge, and extends the anodes design life.

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Select diameter of well

Multiply factor x depth of the well

Dry Volume of Loresco Type SC-3 Required Versus Hole Size
Permeable Back Fill

• 24 hours after coke breeze back filled
• Prevents surface water run off contaminating the well
• Recommend to place the permeable back fill to a min. 25 feet depth of the inactive portion of the well
99% Bentonite
Any Questions?

Thank You