Cathodic Protection Use
On Tank Bottoms
& Underground Piping
In Power Generation Plants

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San Francisco
January 18, 2007
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• Corrosion process for tanks and piping
• Principles of cathodic protection
• Effects of coatings
• Cathodic protection design requirements
• Selecting the proper system
• Construction implementation issues
• Compliance testing
• Continued monitoring and maintenance
Fe° \rightarrow Fe^{++} + 2e^{-}

H_2O + 1/2O_2 + 2e^- \rightarrow 2OH^-
Rate of Corrosion

• Soil Corrosivity
  – Resistivity
  – pH
  – Salts
• Bi-metallic effect
• Mixed soils
• Differences in oxygen
Corrosion Current

Copper ground
-200 mV

Bare steel pipe
-500 mV

Corrosion
• API recommends against the use of asphalt and concrete tank pads.
Corrosion Losses

- Will occur in all plants
- Rate of loss dependent on soil and materials used
- Coatings alone do not stop soil corrosion
- Care during construction can significantly reduce losses
Corrosion Control

- Material selection
- Bedding
- Coatings
- Cathodic Protection
- Reduces amount of exposed metal
- Coatings are not perfect
Cathodic Protection

\[ \text{H}_2\text{O} + \frac{1}{2}\text{O}_2 + 2e^- \rightarrow 2\text{OH}^- \]
Cathodic Protection

• Galvanic

• Impressed Current
Galvanic Anode

Exothermic weld

Pipe

-500 mV

Magnesium anode

-1700 mV
Galvanic Cathodic Protection

- Galvanic anodes have a limited current output, 10 to 30 milliamperes per anode.
- Due to the limited current output, the use of galvanic anodes is limited to coated and electrically isolated underground piping and underground tanks.
Galvanic Cathodic Protection

- Dielectric flange
- Coating
- Coating damage
- Pipe
- Magnesium anode
Galvanic anode

Bare steel tank bottom

Protects only outer floor
Impressed Current

AC Power

Rectifier

Anode

Structure

(+)

(-)
Impressed Current

Anode

Unit 1

Unit 2

Unit 3

Rectifier
Impressed Current

Rectifier — Tank — Anode

20'
Impressed Current

• Anodes produce high amounts of current, 1000 to 5000 milliamperes per anode.
• High current output allows protection of bare steel structures.
• Structures do not necessarily need to be electrically isolated.
New Power Plant Design

- Involve corrosion engineer from the start
- Obtain site soil resistivity data
- Select piping materials
- Select coating types and quality control procedures
- Decide which structures require cathodic protection
Cathodic Protection Design - Piping

- Soil resistivity data
- Clearly identify piping to receive cathodic protection
- Yard plan showing piping layout, isometric drawings are difficult to use
- Location of all risers
- Type of coating
- Responsibility of isolation gaskets
- Desired service life
Cathodic Protection Design - Tanks

- Site soil resistivity data
- Tank diameters and layout
- Equipment access
- Type of foundation
- Containment
- Monitoring capability
- Desired service life
Design Options

- Design documents issued in construction plans
- Contract responsible for cathodic design
Design Submittal

• Qualifications of person responsible for design, supervision during installation and testing
  – Can not mail order
• Detailed calculations for each tank and pipeline showing current required, number of anodes, circuit resistance and life
• Material list providing descriptions, models and quantities
• Product data sheets
• Detailed installation plans – not diagrams
Implementation

- The cathodic design submittals must be approved before construction of structures
- A site meeting must be held to discuss how the cathodic protection system will be installed, and special concerns during construction
- Mechanical and electrical foremen should be involved in cathodic discussions
Avoid Costly Mistakes

- Grounding cables must be at least 12 inches from underground pipes
- Temporary pipe supports must be removed
- Piping must be inspected for coating quality and separation from grounding before burial
Grounded Pipeline

Pipe

Ground wire

Anode
Completed Before Testing

- All pipe flanges connected and isolated
- Pipes back filled and cathodic protection is complete
- AC power to rectifier unit
- Storage tanks contain product
- Schedule for testing and training issued
Compliance Testing - Specialist

- Inspect cathodic systems to ensure they are properly installed
- Test each dielectric flange for isolation
- Obtain native potentials on pipes and tanks
- Connect galvanic anodes at test stations and/or energize rectifier(s)
- Cathodic protection systems on isolated coated structures should operate at least 4 hours before testing
- Cathodic protection systems on bare steel or grounded structures must operate between 12 hours and 7 days before testing
Soil

Set to DC volts

Reference cell

Pipe

Soil

6"
Galvanic Anode Current

Set to DC millivolts

Shunt
Impressed Current Rectifier Unit

Breaker

Volts

Amps

Transformer adjustments

Meters

Shunt

Output lug

(-)  (+)
Impressed anode Voltage gradient Cell Potential plus gradient Potential of steel Meter Voltage gradient
$E_{\text{measured}} = P_{\text{tank}} + I \cdot R$

- If the current is momentarily interrupted, $I=0$, then;
  $E_{\text{measured}} = P_{\text{tank}} + (O) \cdot (R)$

- “Instant Off” potential
Cathodic Protection Criteria

• Galvanic anodes
  – -850mV or more negative with anodes connected

• Impressed current
  – -850mV or more negative “instant-off”
    -or-
  – 100mV polarization shift
100mV Polarization Criteria

-525 “Native”

-1104 “On”

“Instant off” -692

Polarization 167
Compliance Report

- Tabulated Data
- Narrative analysis of the data
- Compliance statement
- Calculated anode life
- Test procedures and instrumentation
- As-built drawings
- O&M Manual
O&M Manual

- Test Procedures
- Instrument requirements
- Qualification requirements
- Frequency
- Criteria
- Trouble shooting
- Spare parts
- Wiring diagrams
Conclusions

- Cathodic protection is viable and necessary to preserve power plant structures
- Proper planning and coordination are essential throughout the design and construction phases, to ensure cathodic protection systems work properly
- Properly implemented and monitored cathodic protection will extend the service life of storage tanks and yard piping more than 30 years
Owner Monitoring & Maintenance

- Record rectifier output levels monthly and compare output to target values
- Repair inoperable rectifiers within 30 days
- Inspect test stations and dielectric flanges every six (6) months for damage and removal
- Instruct maintenance staff to replace and test removed dielectric gaskets
- Annually, obtain potential measurements and ensure effective cathodic protection levels