Corrosion
Temporary Fix?
Corrosion - A Natural Process

IRON OXIDE  +  REFINING  +  MILLING  =

IRON, STEEL, PCCP  +  CORROSION  =  IRON OXIDE
Corrosion Cell on Buried Piping (4 Prerequisites)

1) Anodic Area (-)
2) Cathodic Area (+)
3) Soil or Water
4) Metallic Path
Corrosion of Metallic Structure
Adverse Conditions for Metallic Pipe

- High Chlorides
- Low Soil/Water Resistivity
- High Sulfates
- Moisture
- Bimetallic Couplings
- Stray Current Interference
History of Iron Pipe

**Cast Iron**
- Introduced to North America during the 1800’s and installed till the 1970’s.
- Early on, statically cast process produced a thick walled, heavy pipe.
- No longer produced in North America.

**Ductile Iron**
- Introduced in 1955 as an improvement to cast iron.
- Centrifugal casting process produces a thinner walled, lighter pipe which is stronger and more ductile than cast iron.
Cast (Grey) Iron Failures

Graphitization leaves pipe brittle and weakened.
Ductile Iron

Pitting (concentrated) corrosion attack on ductile iron pipe.
Actual size of AWWA Specification Thickness Reductions for 36-inch Diameter Cast and Ductile Iron Pipe - 1908 to Present (150 PSI Operating pressure)
Water
(Electrolyte)

Anodic Area
(Corrodes)

Metallic Return Path

Cathodic Area
(Protected)

Tank Wall

Current Flow
History of Cathodic Protection

- 1824 Royal British Navy Protected the Copper Hulls of Warships by applying sacrificial anodes.

- 1940’s Internal Submerged Areas of Water Storage Tanks

- 1960’s Oil & Gas Buried Pipelines and Storage Tanks
Dissimilar Soils

Pavement

Sandy Loam

Clay

Sandy Loam

Cathode

Anode

Cathode

De-icing salts?

Fertilizers?

CORRPRO COMPANIES INC
Corrosion Caused by Differential Aeration

Aerated Soil
Pipe
Oxygen
Available (Cathode)
Low Oxygen (Anode)
Dissimilar Surface Conditions

Pipe (Cathode)

Threads Bright Metal (Anode)

Scratches (Anode)
# PRACTICAL GALVANIC SERIES

<table>
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<th>Potential*</th>
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* Potentials With Respect to Saturated Cu-CuSO₄ Electrode
Coupling to Dissimilar Metals

Copper service (Cathode) - 300mV

Iron pipe (Anode) - 500mV

Metallic Connection
Proper Handling & Installation of Polyethylene Ductile Iron Pipe
Polyethylene Encasement of Ductile Iron Pipe

- Follow DIPRA installation procedures
- Clean pipe before installing polywrap
- Repair tears or damage to encasement
- Engage an inspector to oversee installation
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* Potentials With Respect to Saturated Cu-CuSO₄ Electrode
Anode

Cathode (Protected)
Galvanic Anode

Magnesium Anode

Current Flow

Structure
Anode Installation

Augered hole

Galvanic anode

Connection to piping
Access to Pipe
Thermit Weld to Pipe
Break Records for Water Mains Cathodically Protected in 1988

1988 C.P. Totals
Length Protected = 12,780 feet
Break Records for Water Mains Cathodically Protected in 1993

1993 C.P. Totals
Length Protected = 55,360 feet

- 94 Breaks Prior to Cathodic Protection
- 1 Breaks After Cathodic Protection

Year
Number of Breaks
74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95
Temporary Fix?
Repair of Break Should Include Anode Installation
Water Leak Repair Kit

Includes:

- Installation instructions.
- One day onsite technical assistance.
- Cathodic protection components/connection materials suitable for 10 repairs.
Polyethylene Encasement

- Follow manufacturer's and AWWA recommendations to insure proper installation of polyethylene encasement.

- In extremely corrosive areas, additional methods (bonding of joints, cathodic protection, may be required).
Pipe

Metallic Coupling

Lower Stress Area (Cathode)

Threaded Bolt
Higher Stress Area (Anode)

Stress Corrosion

Pipe

Metallic Coupling
Cathodic Protection of Metallic Fitting

- Metallic Coupling
- Anode Lead Wire Connection
- Galvanic Anode
Anode Installed on Metallic Fitting
Meter Vault Corrosion

Meter Vault with Anode
Stainless Steel Corrosion
Stray Current
Impressed Current CP System on Oil/Gas Lines can Create Stray Current Problem on Water Lines
Cathodic Protection

Gas Pipeline

Rectifier

Anode Groundbed

Gas Pipeline

(-)

Cathodic Protection Rectifier

(+)  

Anode Groundbed

Current Discharge (Corrosion)

Water Pipeline

Current Discharge (Corrosion)

Stray Current Due to Impressed Current Cathodic Protection System
Bonding Across a Bell and Spigot or Slip-joint

Thermite brazed connection coated with bitumous compound

Copper wire with direct burial insulation
Computerized Potential Logging Survey

- Test Station
- Backpack Computer Unit
- Chainer/Wire Dispenser & Counter
- Reference Cells
- Bonded Joints
- Pipeline
AC Mitigation
Pumping Stations
Depleted & Refurbished Cathodic Protection for Lift Stations

Depleted cathodic protection system allows corrosion to occur.

Effective cathodic protection system prevents corrosion and extends life of lift station.
For New or Refurbished Tanks
Horizontally Submerged Cathodic Protection System in Water Storage Tank
Vertically Suspended High Silicon Cast Iron Anode String
CP Benefits:  
- Triple life of coating  
- Reduce maintenance cost
Suspended Horizontal Anode System

Top View Diagram

- Steel anchors welded to side wall
- Polyester rope supports
- Platinized niobium wire anode or titanium rod with mixed precious metal oxide
- Permanent reference electrodes

Submerged Anode Support System

Automatic Potential Control Rectifier

Pressure Entrance Fitting
Corrosion of Clarifier Center Well
Annual Maintenance
Internal Corrosion of Force Mains....

Solids Buildup

H2S
Force Main Inspections
36” Above Ground Crossing

• Failure of force main at above ground crossing

• Crown of pipe attacked by hydrogen sulfide gas
Rehabilitation Options
Investigative Structure (Existing)

Corrosion Assessment
- Review of General Characteristics of Water System
  - Age
  - Material Type
  - Wall Thickness
  - Construction Practices
- Review Break / Leak History
- Field Survey
  - Soil Conditions (Resistivity, Moisture Content, Chemical Analysis)
  - Electrical Test
- Data Analysis & Risk Management
- Priority Index (Identification of Opportunities to Reduce Replacement / Repair Costs)
PHASE I

- Obtain drawings of proposed route
- Conduct independent field investigation:
  a) Soil resistivity study
  b) Identify foreign pipeline crossing
  d) Identify AC potential influence
  e) Collect soil samples (moisture content, chlorides, pH, sulfate ions concentration, conductivity)
- Stray current investigation
Corrosion Protection Design
Phase II

Prepare Bid Quality Specifications for:

- Coatings or Polyethylene Encasement
- Test Stations (Monitor Corrosion Rates)
- Bonded Joints
- Stray DC/AC Mitigation
- Cathodic Protection
- Combination of Multiple Items
- Review Submittals/Onsite Periodic Inspection
Reducing corrosion rates on existing water distribution piping will result in a reduction of the number of breaks and also extend the operational life.

Corrosion control measures should be considered during the design stage for any new metallic piping and storage tank installations.
Traffic Disruptions

Water Loss

Fire Protection

Legal & Environmental Claims

Damages
QUESTIONS?

James T Lary
Corrpro Companies, Inc.
1055 W Smith Rd.
Medina, Ohio 44256
330-241-6615
email jlary@corrpro.com
Impressed Current CP System on Oil/Gas Lines can Create Stray Current Problem on Water Lines
Internal & External Corrosion of Force Mains....

Anodic Area

H2S

Solids Buildup
36” Above Ground Crossing

- Failure of force main at above ground crossing
- Crown of pipe attacked by hydrogen sulfide gas
24” Ductile Iron Force Main

- Internal failure following loss of internal mortar lining
- Failure was along top of pipe due to formation of hydrogen sulfide gas
Computerized Potential Logging Survey

- Test Station
- Backpack Computer Unit
- Chainer/Wire Dispenser & Counter
- Reference Cells
- Bonded Joints
- Polywrap
- Pipeline
Dual 26” Force Mains

- Internal failures at bottom of pipe
- Failure following loss of internal mortar lining
- Failures concentrated at low areas (dips) in pipeline alignment
- Cause is corrosion under accumulated solids
Break Records for Water Mains Cathodically Protected in 1993

1993 C.P. Totals
Length Protected = 55,360 feet
Design Decision Model

For Ductile Iron Pipe
Insituform
Cathodic Protection of Metallic Fitting

Anode Lead Wire Connection

Galvanic Anode

Metallic Coupling
Corrosion of Metallic Structure
Design Decision Model

For Ductile Iron Pipe
ABOVEGROUND STORAGE TANK

CATHODIC PROTECTION

Test/Access Station

Aboveground Storage Tank

Grade

3”Ø PVC 20% Exposure

10’ Typical

Anode Material

Anode Tube

ABOVEGROUND STORAGE TANK
CATHODIC PROTECTION
The estimated annual cost to repair water piping breaks in North America alone is estimated to be*: $1.5 Billion

based on 250,000 breaks at a repair cost of $5,875.00 U.S.D. each
Budget Estimate for Complete Cathodic Protection System for 1MMG Water Tank

$12,000
Pipe

Metallic Coupling

Lower Stress Area (Cathode)

Threaded Bolt
Higher Stress Area (Anode)

Stress Corrosion

Metallic Coupling
Yard Piping Deep Anode Groundbed
Impressed Current System
Factory Installed Cathodic Protection Systems
Bi-Metallic Corrosion Between Carbon Steel Tank & Stainless Steel Ladder
Corrosion Control for Water System Piping Results in Reduction of Water Loss

Presented By:

James T Lary
Corrpro Companies, Inc
1090 Enterprise Dr.
Medina, OH 44256
Tel. 330-723-5082 (x1215)
email: jlary@corrpro.com
http://www.corrpro.com
Repair of Break Should Include Anode Installation

Incomplete

Complete
Annual Cathodic Protection Survey
Corrosion Control for Water & Wastewater Systems

Presented By:

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Corrosion is the leading contributor to cast and ductile iron water system breaks!
Bolt & Nut Corrosion
Inspection of CP System
Basic Corrosion Cell

1) Anode
2) Cathode
3) Electrolyte
4) Electrical Connection
Structures

- Piping (Distribution/Transmission)
- Metallic Fittings
- Water Storage Tanks
- Clarifier Units
- Lift Stations
Corrosion Can be Defined as Either:

- **Practical**
  
  Tendency of a Metal to Revert to its Native State

- **Scientific**
  
  Electrochemical Degradation of Metal as a Result of a Reaction with its Environment
Copper Service Connections
Anode Installation Prevents Corrosion on Copper Service Line

Non metallic or Polyethylene Encased Ductile Iron Main

Anode Connection to Line

Anode
Stainless Steel Bowl Shaft

Bronze Shaft Spacers (Cathode)

Mild Steel Column Pipe (Anode - Corrodes)

Bowl Shaft (Stainless Steel) Cathode

Crown (Steel) Anode

Crown Bearing (Bronze) Cathode

Impeller (Bronze) Cathode

Discharge Case (Cast Iron) Anode

Bowls (Cast Iron) Anode

Suction Case (Cast Iron) Anode
Water Wells
History of Iron Pipe

**Cast Iron**
- Introduced to North America during the 1800’s and installed till the 1970’s.
- Early on, statically cast process produced a thick walled, heavy pipe.
- No longer produced in North America.

**Ductile Iron**
- Introduced in 1955 as an improvement to cast iron.
- Centrifugal casting process produces a thinner walled, lighter pipe which is stronger and more ductile than cast iron.
Dissimilar Soils

- Pavement
- Sandy Loam
- Clay
- Sandy Loam
- De-icing salts?
- Fertilizers?
Corrosion of iron when coupled to copper service line.
Corrosion Pitting
Dissimilar Surface Conditions

Pipe (Cathode)

Threads Bright Metal (Anode)

Scratches (Anode)
Corrosion Caused by Differential Aeration

Aerated Soil

Pipe

Oxygen Available (Cathode)

Low Oxygen (Anode)
Traffic Disruptions
Water Loss
Fire Protection
Legal & Environmental Claims
Damages
Corrosion on damaged polyethylene encased pipe.
Corrosion of pre-stressed concrete cylinder pipe (P.C.C.P.).
Suspended Vertical Anode System

Support System Bolted to Roof for Bowl Anodes and Reference Electrodes

Automatic Potential Control Rectifier

Top View Diagram:
- Platinized Niobium Wire Anode or Titanium Rod with Mixed Precious Metal Oxide
- Permanent Reference Electrodes
PCCP Failure

WARNING

This pipeline has the potential to rupture in an explosive manner without warning. Keep away.
Stray Current by DC Operated Transit Systems

Power Station

Current exit (Anode)  Current entrance (Cathode)

Pipeline
Pre-stressed Concrete Cylinder Pipe (PCCP)
Give Me a Break
Fundamentals of Pipeline Corrosion

Presented By:
James T Lary
Corrpro
1090 Enterprise Dr.
Medina, OH 44256
Tel. 330-723-5082 (x1215)
email: jlary@corrpro.com
http://www.corrpro.com
Coating Flaws (Holidays)
Inspector name: ___________  Date: ___________  Address of pipeline inspection: ________________  Leak?  Yes: ___________  No: ___________

File Number: _______________

1) Type of Pipe:  cast iron: _______  ductile iron: _______  carbon steel: _______  copper: _______  carbon steel: _______  non metallic: _______  other: _______

2) Diameter of pipe: ___”  Pipeline Name: ___________  Service Type:  Water: _______  Wastewater: _______  Estimated date of pipe installation: _______  Depth of pipe: _______

3) Type of Pipe:  Distribution: _______  Transmission: _______  Service: _______  Hydrant: _______  Mechanical joint: _______  Fasteners: _______  Other: _______  Unknown: _______

4) Type of Coating:  Polyethylene Encased: _______  Shop applied coating: _______  No Coating: _______  Tape Wrap: _______  Unable to determine: _______

5) External Pipe Condition:  Very Good: _______  Good: _______  Poor: _______  comments: ________________

6) Is corrosion pitting evident?  Yes: _______  No: _______  Number of Pits: _______  Typical Size of Pits: _______  Quantity of pits: _______

7) Is graphitization evident (longitudinal or circumferential breaks)?  Yes: _______  No: _______

8) Is the pipe installed in (check off appropriate items):  Industrial area: _______  Residential area: _______  Rural area: _______  Near street or road: _______
    Near creek or waterway: _______  In reclaimed land: _______  Near oil or gas pipelines: _______  Near high voltage lines: _______

8) Describe soil conditions where inspection occurred:  wet: _______  dry: _______  clay soil: _______  rocky soil: _______  cinders: _______  other: ________________

9) Where soil samples obtained, sealed and analyzed for chlorides, moisture content, pH, sulfides, resistivity?  If yes results were: ________________

10) Were previous repairs made on the pipeline (leak clamps, etc) Yes: _______  No: _______.  Was new pipe installed: _______  Yes: _______  No: _______

11) Was a repair clamp installed on the pipe during inspection: Yes: _______  No: _______

12) Was a galvanic anode installed as part of the inspection process?  Yes: _______  No: ________, if yes size and quantity _______

13) Please relay additional comments: ________________

14) Plan of Action: ________________

15) Insert digital photos below:

Pipeline Inspection Report
CIS Survey

Close Interval Data
Interrupted Survey

Close Interval Data
PG/WFA Survey
Actual size of AWWA Specification Thickness Reductions for 36-inch Diameter Cast and Ductile Iron Pipe - 1908 to Present (150 PSI Operating pressure)
Dissimilar Surface Conditions

- Pipe (Cathode)
- Threads Bright Metal (Anode)
- Scratches (Anode)
Corrosion Caused by Differential Aeration

Aerated Soil

Pipe

Oxygen Available (Cathode)

Low Oxygen (Anode)
Coating Flaws (Holidays)
Meter Vaults

(Keep dry if possible)
Galvanic Anode on Polyethylene Encased Ductile Iron Pipe
Corrosion Can be Defined as Either:

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- **Scientific**
  Electrochemical Degradation of Metal as a Result of a Reaction with its Environment