Corrosion Control
Part 192, Subpart I

- External
- Internal
- Atmospheric

Added To Part 192 By Amendment 4, 8/1/71
Definition of Corrosion

- The Deterioration of a Material, Usually a Metal, that Results from a Reaction with its Environment.

- Galvanic Corrosion of a Metal Occurs because of an Electrical Contact with a More Noble (Positive) Metal or Non-metallic Conductor in a Corrosive Electrolyte.
## Galvanic Series of Metals

### Practical Galvanic Series for Materials in Neutral Soils and Water

<table>
<thead>
<tr>
<th>Material</th>
<th>Potential Volts (CSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon, Graphite, Coke</td>
<td>+0.3</td>
</tr>
<tr>
<td>Platinum</td>
<td>0 to −0.1</td>
</tr>
<tr>
<td>Mill Scale on Steel</td>
<td>−0.2</td>
</tr>
<tr>
<td>High Silicon Cast Iron</td>
<td>−0.2</td>
</tr>
<tr>
<td>Copper, Brass, Bronze</td>
<td>−0.2</td>
</tr>
<tr>
<td>Mild Steel in Concrete</td>
<td>−0.2</td>
</tr>
<tr>
<td>Lead</td>
<td>−0.5</td>
</tr>
<tr>
<td>Cast Iron (Not Graphitized)</td>
<td>−0.5</td>
</tr>
<tr>
<td>Mild Steel (Rusted)</td>
<td>−0.2 to −0.5</td>
</tr>
<tr>
<td>Mild Steel (Clean and Shiny)</td>
<td>−0.5 to −0.8</td>
</tr>
<tr>
<td>Commercially Pure Aluminum</td>
<td>−0.8</td>
</tr>
<tr>
<td>Aluminum Alloy (5% Zinc)</td>
<td>−1.05</td>
</tr>
<tr>
<td>Zinc</td>
<td>−1.1</td>
</tr>
<tr>
<td>Magnesium Alloy (6% Al, 3% Zn, 0.15% Mn)</td>
<td>−1.6</td>
</tr>
<tr>
<td>Commercially Pure Magnesium</td>
<td>−1.75</td>
</tr>
</tbody>
</table>

*aTypical potential normally observed in neutral soils and water, measured with respect to copper sulfate reference electrode.*
Basic Corrosion Cell

Metallic Path

ANODE
CATHODE
ELECTROLYTE
METALLIC PATH
Pipe Corrosion

Metallic Path

Anodic Area

Cathodic Area
Corrosion on Pipelines

- Dissimilar Metals
- Dissimilar Soils
- Differential Aeration
- Mill Scale Corrosion
## Soil Resistivity vs. Corrosivity

<table>
<thead>
<tr>
<th>Soil Resistivity (ohm-cm)</th>
<th>Degree of Corrosivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 500</td>
<td>Very corrosive</td>
</tr>
<tr>
<td>500 – 1,000</td>
<td>Corrosive</td>
</tr>
<tr>
<td>1,000 – 2,000</td>
<td>Moderately corrosive</td>
</tr>
<tr>
<td>2,000 – 10,000</td>
<td>Mildly corrosive</td>
</tr>
<tr>
<td>Above 10,000</td>
<td>Minimally corrosive</td>
</tr>
</tbody>
</table>
Soil pH

ACIDIC
0 1 2 3 4 5 6 7

ALKALINE
8 9 10 11 12 13 14

CORROSIVE
Cathodic Protection

The Decrease of Corrosion of a Metal by Forcing Current to Flow to the Metal from a Solution (Electrolyte).
Cathodic Protection

- Galvanic Sacrificial Anodes
- Impressed Current Systems

* Properly Designed & Installed
Must be carried out by, or under the direction of, a person qualified in pipeline corrosion control methods.
Operator Qualification requires that an unqualified person must be under the direct observation of a qualified person.
Required System Information

- Date of Installation
- Transmission or Distribution
- Coated or Bare
CP Required

- Coated Metallic Pipelines Installed after 7/31/71 ~ §192.455 (a)

- Coated Transmission Lines (except station piping) Installed prior to 8/1/71 ~ §192.457 (a)
CP Required

Areas of Active Corrosion - Installed prior to 8/1/71 §192.457 (b)

- Bare or Ineffectively Coated Transmission Lines
- Station Piping (Bare or Coated)
- Bare or Coated Distribution Lines
CP Not Required

- Bare TEMPORARY lines installed after 7/31/71
  §192.455 (c)(2) &(d)

- Bare or ineffectively coated lines installed prior to 7/31/71 with no evidence of active corrosion
  §192.457 (b)
Active Corrosion

Continuing corrosion which, unless controlled, could result in a condition that is DETRIMENTAL to PUBLIC SAFETY

Per §192.3
**CP Not Required (cont.)**

- Electrically isolated metal alloy fittings in plastic pipeline systems §192.455 (f)

- Pipelines in NON-CORROSIVE environments §192.455 (b)
Non-Corrosive Environment
Tests Needed to Demonstrate:

- Soil Resistivity Measurements
- Corrosion Accelerating Bacteria
- Leak Frequency
- Soil Composition
- pH
- Bell Hole Examinations
- Internal Inspections

POST-INSTALLATION TESTS (< 6 MONTHS)
- Close Interval Potential
- Soil Resistivity
Cathodic Protection Criteria

§192.463 Requires Cathodic Protection to a Level that Complies with Appendix “D”
Cathodic Protection Criteria

- Negative 850 mV
- 100 mV Negative Polarization Decay
- Negative 300 mV Shift
- Net Protective Current
- $E \log I$ (Gas)
Components of IR Drop

Resistances
- Measuring Lead (+)
- Contact Lead (+)/Ref. Cell
- Reference Cell
- Contact Reference Cell to Electrolyte
- Electrolyte
- Polarization Structure
- Contact Test Lead/Structure
- Test Lead
- Contact Test/Measuring Lead
- Measuring Lead (-)
- Internal Meter

Diagram showing the components of IR Drop with a voltmeter, reference cell, electrolyte, and structure.
IR Drop Major Contributors

- Contact between the reference cell and the soil.
- Electrolyte (soil)
- Polarization at the pipe coating / soil interface
C. P. Criteria - 850 mV

- 850 mV
- Measured with Current Applied
- Consider IR Drop
- Cu/CuSO4 Reference Electrode
- - 800 mV - Ag/Ag Cl (Silver/Silver Chloride) for sea water
Cathodic Protection Criteria

(-850 mV)

Protected Levels Considering IR Drop

P/S

Protection Level

Instant Off Potential
Cathodic Protection Criteria

100 mV Polarization Decay

- Current Interruption
- Cu/CuSO4 Reference Electrode
100 mV Polarization Decay

Adequate Protection Demonstrated

Polarized Potential

De-polarized Potential

Instant off

Time in Hrs

P/S

550 600 650 700 750 800 850

0 6 18 30 42
C. P. Criteria - 300 mV Shift

Does **NOT** Apply to Structures with Different Anodic Potentials
Cathodic Protection Criteria

Net Protective Current

- Current Flow from Electrolyte to Structure
- At Predetermined Anodic Areas
Cathodic Protection Criteria

E Log I

- Tafel Slope
- Cu/CuSO₄ Reference
Monitoring §192.465 (a) & (c)

- Cathodically Protected Zones
- Isolated Sections less than 100 ft. (Gas Mains or Transmission) 10% Sampling Per Yr.
- Non-Critical Bonds

Once Each Calendar Year Not to Exceed 15 Months
Monitoring §192.465 (b)&(c)

- Rectifiers
- Critical Bonds
- Reverse Current Switches
- Diodes

6 Times Each Calendar Year not to Exceed 2 1/2 Months
Monitoring §192.465 (c)
Monitoring §192.465 (c)
Monitoring ~ §192.465 (e)

- Re-evaluation of Unprotected Lines
  - Every 3 Years not to exceed 39 Months

- Determine Areas of Active Corrosion
  - Electrical Survey (Where Practical)
  - Corrosion and Leak History
  - Leak Survey
  - Exposed Pipe Inspection Records
  - Pipeline Environment
Detrimental to Public Safety Considerations

- Pipeline Location
- Population Density
- Road Crossings
- Pressures
- Corrosion Rate (3 Year Intervals)
Electrical Survey

Definition ~ (Per §192.3)

A series of closely-spaced pipe-to-soil readings over a pipeline that are subsequently analyzed to identify locations where a corrosive current is leaving the pipeline.
Electrical Surveys

What’s Impractical

- Wall to Wall Paving
- Common Trench
- "Stray Current" Areas
- Pipeline Cover In and Out of Paving
Pipeline Environment

- Soil Resistivity (High or Low)
- Soil Moisture (Wet or Dry)
- Soil Contaminants
- Other Known Conditions
Exposed Pipelines

- Investigate to determine whether corrosion or coating deterioration exists
- If corrosion found, investigate beyond exposed area (visual or other means)
- Repair any problems
- Keep records
Remedial Actions §192.465 (d)

“Within Monitoring Period”

“Prompt”

Consider:

- Population Density
- Environmental Concerns
- Rate of Corrosion
- Climatic Conditions
- Availability of Materials
Electrical Isolation ~ §192.467

- From Other Underground Structures
- From Casings
- Effective Insulation
- Protection From Arcing
Shorted Casings

- P/S reading ESSENTIALLY the Same as Casing reading

Other Tests May be Necessary to Demonstrate Isolation
Remedial Measures

(1) Clear the Short

(2) Fill Annular Space with Dielectric

(3) If 1 or 2 Impractical, Monitor with Gas Detection Equipment at Intervals Specified in §192.705 & §192.721, or Smart Pig

(3) May Not be Applicable in HCA Areas

See PHMSA Guidelines for Integrity Assessment of Cased Pipe for Gas Transmission Pipelines in HCA’s
Test Stations/Test Leads

§192.469 & §192.471

Must Have SUFFICIENT Test Stations or Other Contact Points to Determine the Adequacy of Protection.
Test Leads ~ §192.471

- Attach to Minimize Stresses on Pipe
- Coat the Bared Wire/Pipe Connection
- Maintain Mechanically Secure & Electrically Conductive
Internal Corrosion Control

§192.475

- Corrosive Product Transported
  - Test to Determine Effect on Pipeline
  - Take Steps to Minimize Effect

- Whenever a Segment is Removed
  - Inspect Internal Surfaces
  - Replace if Required By Remedial Measures
Internal Corrosion Control

§192.476

Design and Construction

New or Replacement Line Pipe, Valves, Fittings, or other Components **Must** be Designed and Constructed to Reduce the Risk of Internal Corrosion

Configure to Reduce Risk of Liquid Collection

Have Effective Liquid Removal Features Wherever Liquids Might Collect
Design and Construction

Allow use of Monitoring Devices where Significant Internal Corrosion Potential Exists

Exceptions (Does Not Apply To)

Offshore Pipelines

Pipelines or Components Installed or Replaced Before 05/23/2007
Internal Corrosion Control

§192.476

Design and Construction

Change to an Existing Transmission Line

Must Evaluate the Impact of Change to Internal Corrosion Risk for Downstream Portions of Existing Transmission Line

Must Maintain Records to Demonstrate Compliance with this section

Written Procedures Supported by As-Built Drawings or other Construction Records
Internal Corrosion Control Monitoring ~ §192.477

When Corrosive Product is Transported

Must Be Monitored For Internal Corrosion

Twice Each Calendar Year Not to Exceed 7 ½ mos.

Coupons

Water Analysis

Microbiological Analysis

Inhibitors
Pipeline Exposed to Atmosphere
- Cleaned
- Coated (Suitable Material)

Unless Non-Corrosive Environment or Only “Light Surface Oxide”
Atmospheric Corrosion Control

§192.479

Non-Corrosive Environment and Light Surface Oxide Not Applicable to Offshore Splash Zones or Soil-to-Air Interfaces
Atmospheric Corrosion Control

Monitoring §192.481

Onshore

Every 3 Calendar Years at Intervals Not Exceeding 39 Months
Atmospheric Corrosion Control Monitoring §192.481

Offshore

Once Each Calendar Year with Intervals not Exceeding 15 Months
Atmospheric Corrosion Control
Monitoring §192.481

Inspections Must Include Pipe:

- At Soil-to-Air Interfaces
- Under Thermal Insulation
- Under Disbonded Coatings
- At Pipe Supports
- In Splash Zones
- At Deck Penetrations
- In Spans Over Water
Pipe that Replaces Pipe because of External Corrosion must be:

- Cleaned
- Coated
- Cathodically Protected
Remedial Measures

Transmission §192.485

- General Corrosion
  - Replace
  - Lower MAOP / MOP
  - Repair

- Localized Corrosion
  - Replace
  - Repair
  - Reduce Operating Pressure
Remedial Measures
Transmission §192.485

- General Corrosion
  - Closely Grouped Pitting Affecting Overall Strength of the Pipe

- Localized Corrosion Pitting

Guides: GPTC & RSTRENG
Remedial Measures
Gas Distribution §192.487
(Except for Cast & Ductile Iron)

- General Corrosion or Less Than 30% Remaining Wall Thickness
  - Replace
  - Repair

- Localized Corrosion
  - Repair
  - Replace
Remedial Measures
Cast & Ductile Iron §192.489

- General Graphitization
  - If Fracture May Result – Replace

- Localized -
  - If Leakage Might Result
    - Repair
    - Replace
    - Seal Internally
Corrosion Control Records

§192.491 (a)

Records or Maps

- Location of Protected Piping
- Cathodic Protection Facilities
- Galvanic Anodes
- Bonds to Other Structures
Corrosion Control Records

§192.491 (b)

Records or Maps Required by §192.491(a)

Retain for as Long as the Pipeline Remains in Service
Corrosion Control Records
§192.491 (c)

Tests, Surveys, or Inspections
- Required by Subpart I
- Retain for at least 5 Years
- Specified Exceptions
- Check with Attorneys
Corrosion Control Records

§192.491 (c)

Exceptions/Retain for Service Life
- Annual P/S Surveys ~ §192.465(a)
- 3-Year Reevaluations ~ §192.465(e)
- Inspections for Internal Corrosion ~ §192.475(b)
Corrosion Control

The