Atmospheric Corrosion

Bryan Evans, Pond & Company

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About the Speaker

Bryan Evans, E.I.T.

Pond & Company – Executive Vice President | Energy

B.S. Civil Engineering Technology

- Certifications
  - Cathodic Protection Specialist – No. 9754
  - Sr. Corrosion Technologist – No. 9754
  - Internal Corrosion Technologist – No. 9754
  - Coating Inspector Level 1 – No. 21458
  - API 570 Piping Inspector – No. 80649
- 25+ years of experience in corrosion control, cathodic protection, pipeline integrity and AC mitigation both as a design consultant & installation contractor.

Atmospheric Corrosion Control

Code of Federal Regulations

Gas Lines:

- 192.479 General Atmospheric Corrosion Control
- 192.481 Monitoring of Atmospheric Corrosion Control

Liquid Lines:

- § 195.583 What must I do to monitor atmospheric corrosion control?

Atmospheric Corrosion Control

New Mega Rule Requirements 49 CFR 192, RIN2 August 24, 2022

Gas Transmission Lines: § 192.613 Continuing Surveillance - Inspections following extreme weather events within 72 hours

(c) Following an extreme weather event or natural disaster that has the likelihood of damage to pipeline facilities by the scouring or movement of the soil surrounding the pipeline or movement of the pipeline, such as a named tropical storm or hurricane; a flood that exceeds the river, shoreline,or creek high-water banks in the area of the pipeline; a landslide in the area of the pipeline; or an earthquake in the area of the pipeline, an operator must inspect all potentially affected onshore transmission pipeline facilities to detect conditions that could adversely affect the safe operation of that pipeline.

New Mega Rule Requirements 49 CFR 195, October 1, 2019

Hazardous Liquid Lines: § 195.414 Inspections of pipelines in areas affected by extreme weather and natural disasters.

(a) General. Following an extreme weather event or natural disaster that has the likelihood of damage to infrastructure by the scouring or movement of the soil surrounding the pipeline, such as a named tropical storm or hurricane; a flood that exceeds the river, shoreline, or creek high-water banks in the area of the pipeline; a landslide in the area of the pipeline; or an earthquake in the area of the pipeline, an operator must inspect all potentially affected pipeline facilities to detect conditions that could adversely affect the safe operation of that pipeline.

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Atmospheric Corrosion Control

49 CFR 192.479

Atmospheric Corrosion Control General

- Pipeline sections installed aboveground after 1971 must be cleaned and coated to prevent corrosion.
- The exception to this rule is if an operator can show that the line resided in a non-corrosive environment.

Atmospheric Corrosion Control

49 CFR 192.479

For Aboveground Pipeline Sections Installed before 1971, the Operator Shall:

- Determine areas of atmospheric corrosion
- Have these areas remediated by appropriate means
- Be cleaned and coated / jacketed to prevent further corrosion

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Atmospheric Corrosion Control

49 CFR 192.481

Monitoring Atmospheric Corrosion on Gas Lines

- Onshore pipelines must be re-evaluated every three (3) years
- Offshore pipelines must be re-evaluated once (1) annually
- No specifics noted in the regulations on evaluation criteria

Atmospheric Corrosion Control

LNG AND LIQUIDS

- 193.2627 – LNG
  - Components subject to atmospheric corrosion must either be constructed from corrosion resistant material or coated
- 195.416 – Hazardous Liquids
  - Components subject to atmospheric corrosion must either be constructed from corrosion resistant material or coated

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Atmospheric Corrosion Control Inspection Interval

- Onshore inspection requirements every *3 calendar years not to exceed 39 months*
- Offshore inspection requirements once *each calendar year not to exceed 15 months*

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Special Attention

- Part 192 TRANSPORTATION OF NATURAL AND OTHER GAS BY PIPELINE: MINIMUM FEDERAL SAFETY STANDARDS
  Subpart I Requirements for Corrosion Control

- § 192.481 Atmospheric corrosion control: Monitoring
- (a) Each operator must inspect each pipeline or portion of pipeline that is exposed to the atmosphere for evidence of atmospheric corrosion, as follows:

If the pipeline is located:	Then the frequency of inspection is:
Onshore	At least once every 3 calendar years, but with intervals not exceeding 39 months
Offshore	At least once each calendar year, but with intervals not exceeding 15 months

- (b) During inspections the operator must give particular attention to pipe at soil-to-air interfaces, under thermal insulation, under disbonded coatings, at pipe supports, in splash zones, at deck penetrations, and in spans over water.
- (c) If atmospheric corrosion is found during an inspection, the operator must provide protection against the corrosion as required by §192.479.

Special Attention

- Part 195 TRANSPORTATION OF HAZARDOUS LIQUIDS BY PIPELINE
  Subpart H Corrosion Control

- § 195.583 What must I do to monitor atmospheric corrosion control?
- You must inspect each pipeline or portion of pipeline that is exposed to the atmosphere for evidence of atmospheric corrosion, as follows:

If the pipeline is located:	Then the frequency of inspection is:
Onshore	At least once every 3 calendar years, but with intervals not exceeding 39 months.
Offshore	At least once each calendar year, but with intervals not exceeding 15 months.

- (b) During inspections you must give particular attention to pipe at soil-to-air interfaces, under thermal insulation, under disbonded coatings, at pipe supports, in splash zones, at deck penetrations, and in spans over water.

- (c) If you find atmospheric corrosion during an inspection, you must provide protection against the corrosion as required by §195.581.

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Special Attention

STATE OF FLORIDA

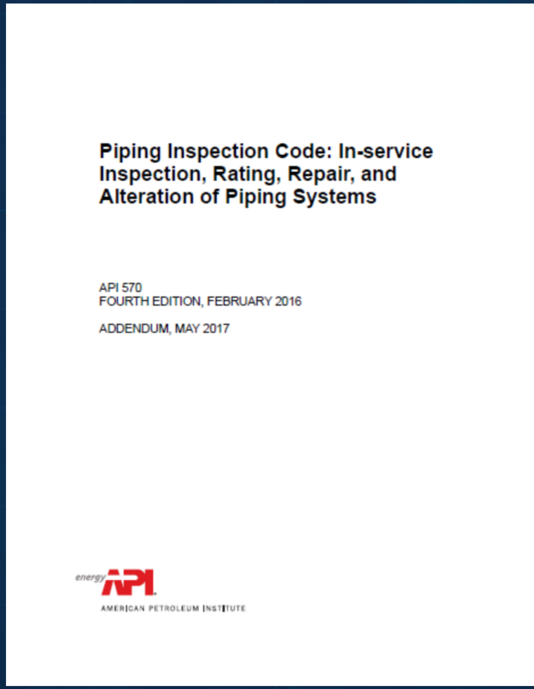
DEPARTMENT OF ENVIRONMENTAL PROTECTION

RULE NOS.: RULE TITLES:

62-762.201 Definitions Bulk Aboveground Storage Tank Farms

PURPOSE AND EFFECT: Revising language for clarification in certain Aboveground Storage Tank Systems rules.

Evaluation and testing of single-walled metallic bulk product and hydrant piping systems. Single-walled metallic bulk product and hydrant piping systems in contact with the soil, excluding those containing high viscosity products, shall be evaluated and the re-testing frequency established and implemented in accordance with API 570, 4th Edition, February 2016, includes Addendum 1 (2017), incorporated by reference in subsection 62-762.411(3), F.A.C. **Evaluations shall be certified by a professional engineer licensed in the State of Florida or by an API 570 certified inspector.** Non-destructive testing shall be performed by qualified personnel as specified in API 570, 4th Edition, February 2016, includes Addendum 1 (2017). All single-walled metallic bulk product and hydrant piping systems in contact with the soil shall be repaired in accordance with API 570, 4th Edition, February 2016, includes Addendum 1 (2017).


Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems

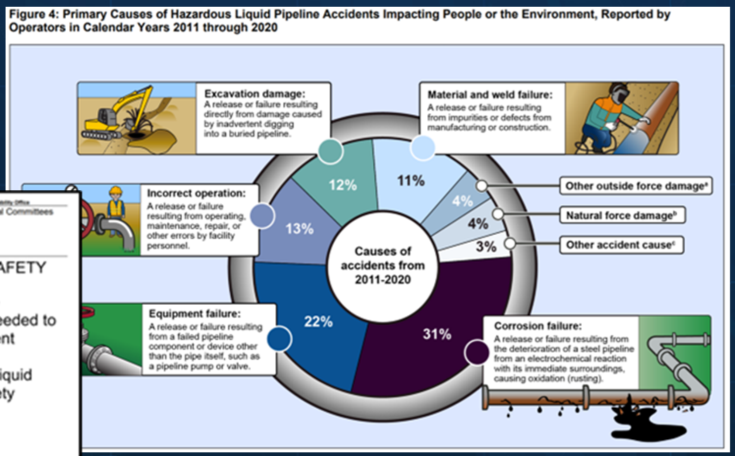
API 570
FOURTH EDITION, FEBRUARY 2016

ADDENDUM, MAY 2017

Special Attention

Pipeline failure rates from corrosion:

- *Transmission and gathering pipelines.* Historically, corrosion is one of the two most prevalent causes of pipeline failures, most often manifesting as leaks or seeps. For the 10-year period of 2011-2020, approximately 31% of reported incidents on hazardous liquid pipelines were caused by corrosion failures.



Above Ground Pipeline Integrity

1 Scope

1.1 General Application

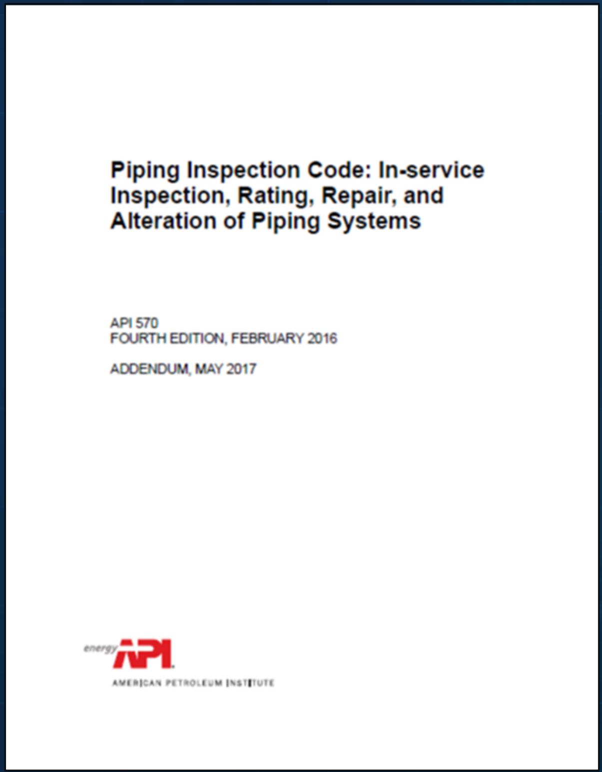
1.1.1 Coverage

API 570 covers inspection, rating, repair, and alteration procedures for metallic and fiberglass-reinforced plastic (FRP) piping systems and their associated pressure relieving devices that have been placed in service. This inspection Code applies to all hydrocarbon and chemical process piping covered in 1.2.1 that have been placed in service unless specifically designated as optional per 1.2.2. This publication does not cover inspection of specialty equipment including instrumentation, exchanger tubes and control valves. However, this piping Code could be used by owner/users in other industries and other services at their discretion.

Process piping systems that have been retired from service and abandoned in place are no longer covered by this “in service inspection” Code. However abandoned in place piping may still need some amount of inspection and/or risk mitigation to assure that it does not become a process safety hazard because of continuing deterioration. Process piping systems that are temporarily out of service but have been mothballed (preserved for potential future use) are still covered by this Code.

1.1.2 Intent

The intent of this Code is to specify the in-service inspection and condition-monitoring program as well as repair guidance that is needed to determine and maintain the on-going integrity of piping systems. That program should provide reasonably accurate and timely assessments to determine if any changes in the condition of piping could possibly compromise continued safe operation. It is also the intent of this Code that owner/users shall respond to any inspection results that require corrective actions to assure the continued integrity of piping consistent with appropriate risk analysis. API 570 is intended for use by organizations that maintain or have access to an authorized inspection agency, a repair organization, and technically qualified piping engineers, inspectors, and examiners, all as defined in Section 3.


Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems

API 570
FOURTH EDITION, FEBRUARY 2016

ADDENDUM, MAY 2017

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Above Ground Pipeline Integrity

1.2.1 Included Fluid Services

Except as provided in 1.2.2, API 570 applies to piping systems for process fluids, hydrocarbons, and similar flammable or toxic fluid services, such as the following:

a) raw, intermediate, and finished petroleum and chemical products;
b) catalyst lines;
c) hydrogen, natural gas, fuel gas, and flare systems;
d) sour water and hazardous waste streams;
e) hazardous fluid services;
f) cryogenic fluids such as: liquid N_2, H_2, O_2, and air;
g) high-pressure gases greater than 150 psig such as: gaseous He, H_2, O_2, and N_2.

1.2.2 Optional Piping Systems and Fluid Services

The fluid services and classes of piping systems listed below are optional with regard to the requirements of API 570:

a) hazardous fluid services below designated threshold limits, as defined by jurisdictional regulations;
b) water (including fire protection systems), steam, steam-condensate, boiler feed water, and Category D fluid services as defined in ASME B31.3;
c) other classes of piping that are exempted from the applicable process piping code.

Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems

API 570
FOURTH EDITION, FEBRUARY 2016

ADDENDUM, MAY 2017

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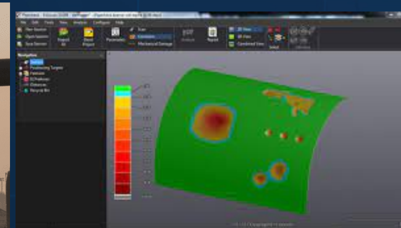
Above Ground Pipeline Integrity

Typical testing and evaluation methods:

- ❑ Visual Inspections
- ❑ Coating Evaluations
- ❑ Drones
- ❑ Snooper Trucks
- ❑ Pit Depth Measurements
- ❑ Ultrasonic Thickness (UT)
- ❑ Guided Wave Ultrasonics
- ❑ Eddy Current
- ❑ Radiography (RT)
- ❑ Magnetic Particle (MT)
- ❑ Liquid or Dye Penetrant (PT)



Atmospheric Corrosion Control

Typical Aboveground Facilities Areas
Requiring Atmospheric Inspection

- Tank Farms
- Bridge Span Crossings
- Docks
- Drilling Platforms
- Meter / Regulator Stations
- Valve Sites
- Piers
- Refineries
- Bulk Storage Facilities
- Soil to Air Interfaces
- Corrosiom\n Under Insulation

Atmospheric Corrosion Control

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Types / Causes of Atmospheric Corrosion

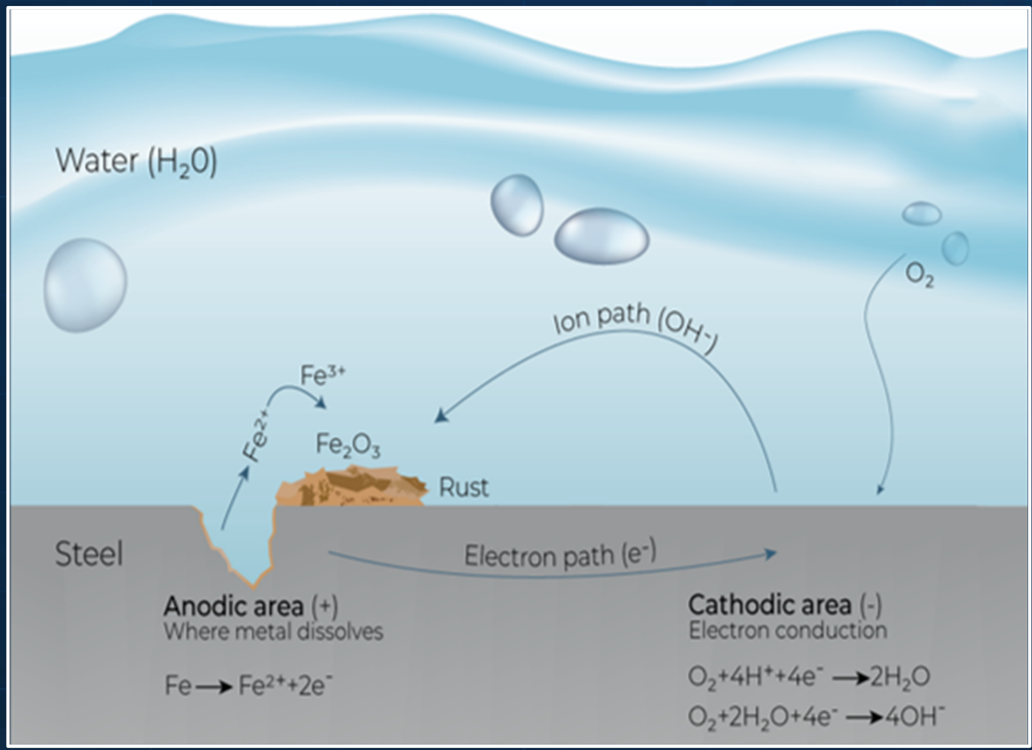
Corrosion Basics

Anode

Cathode

Metallic Path

Electrolyte



Factors Affecting Atmospheric Corrosion

- MOISTURE (ELECTROLYTE) – MOST IMPORTANT FACTOR
- TEMPERATURE EFFECTS
  - RELATIVE HUMIDITY / DEW POINT
  - TIME OF WETNESS
  - KINETICS OF CORROSION REACTIONS
- AIR POLLUTANTS
- FOREIGN MATTER ACCUMULATION

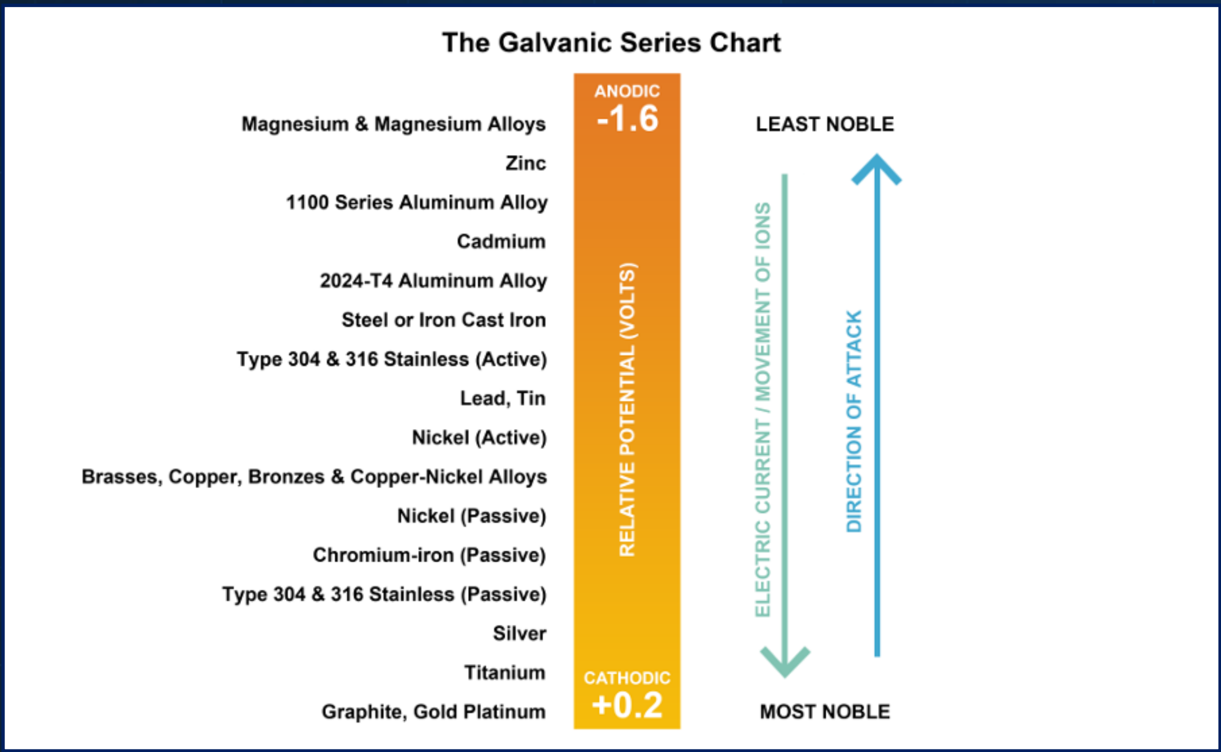
How is Aboveground Piping Different from Below Ground?

- Cathodic protection is not possible.
- Easy visual inspection
- Aesthetics become very important
- Weathering conditions are much different.

Atmospheric Corrosion Control

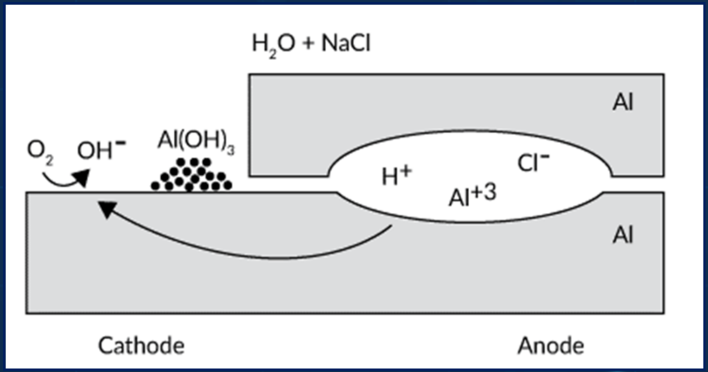
UNIFORM CORROSION

Atmospheric Corrosion Control



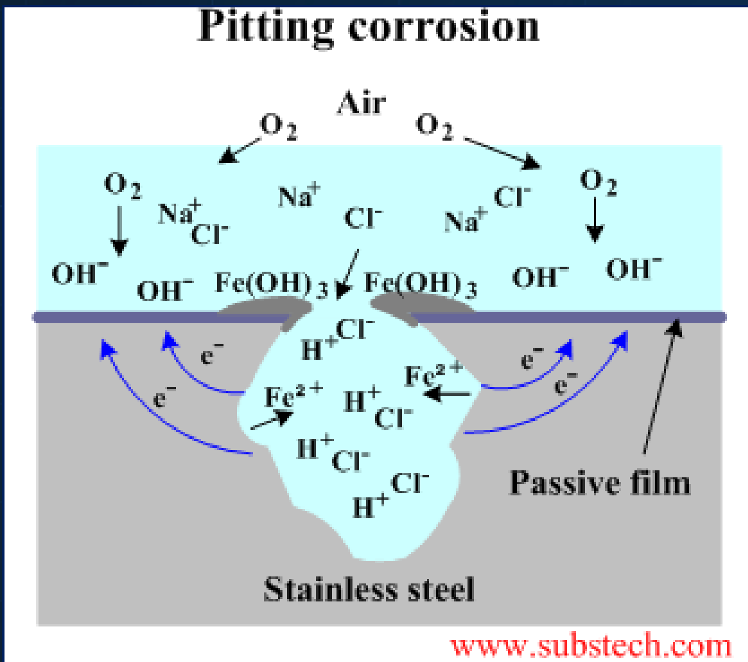
DISSIMILAR METAL CORROSION

Atmospheric Corrosion Control



CREVICE CORROSION

Atmospheric Corrosion Control



PITTING CORROSION

Atmospheric Corrosion Control

Two (2) Special Cases for Further Discussion

- Soil to Air Interface (S/A)
- Corrosion Under Insulation (CUI)

What is Soil-to-Air Interface Corrosion?

- API RP-574 *Inspection Practices for Pipeline Systems Components*
- Definition 3.1.34 Soil-to-air interface:
  - An area in which external corrosion may occur or be accelerated on partially buried pipe or buried pipe where it egresses from the soil.
  - NOTE: The zone of the corrosion will vary depending on factors such as moisture, oxygen content of the soil and the operating temperature. The zone generally is considered to be from 12 in. (30 cm) below to 6 in. (15 cm) above the soil surface. Pipe running parallel with the soil surface that contacts the soil is included.

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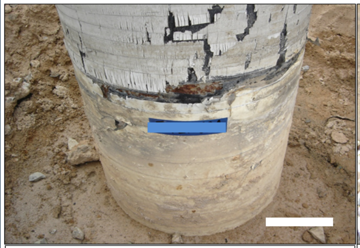
Examples of Soil-to-Air Interfaces

What Factors Affect Soil-to-Air Interface Corrosion?

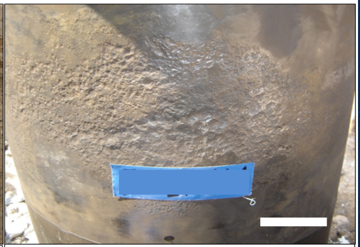
- Soil Oxygen Content
- Soil Moisture Level
- Soil pH
- Operating Temperature
- Presence of Sulfate Reducing Bacteria (SRB) / Acid Producing Bacteria (APB)
- Soil Stresses / Pipe Movement

Soil to Air Interface

Example of Soil-to-air Interface Inspection for Underground Piping



Inspection of Soil-to-air Interface by digging 12 in. below the soil surface. Wrapping damage and Corrosion product found.



After remove wrapping and clean the surface, Localized Corrosion was detected in the area of wrapping damage.

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Soil to Air Interface - Mechanism of the Problem

- Variation in moisture content of soils closer to the surface (drying effects) tend to provide higher resistance to cathodic current, reducing protection. Soil stress
- Seasonal freeze / thaw cycles can block cathodic current while at same time having a higher moisture content in the surface soils

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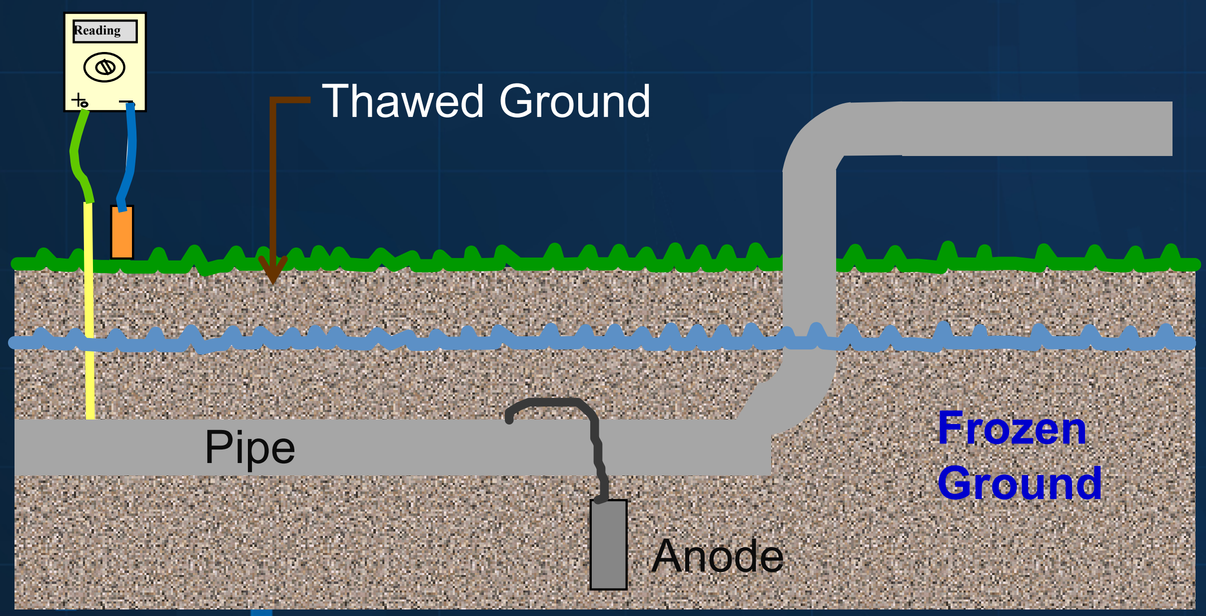
Soil to Air Interface - Spring "Thaw"



Soil to Air Interface - Mechanism of the Problem

- Grinding action of soils
  - Freeze / Thaw
  - Drought
- Limited cathodic protection
- Location that is hidden from immediate visual inspection
- Differential surface conditions

Soil to Air Interface - Best Practices

- Ensure cathodic protection is designed appropriately
- Provide more robust coating protection in the soil to air interface
- Visually inspect and perform regular maintenance

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Corrosion Under Insulation (CUI)

Corrosion Under Insulation (CUI)

From API 570 Code

5.8 Corrosion Under Insulation Inspection

Inspection for CUI shall be considered for externally-insulated carbon and low alloy piping operating between 10 °F (–12 °C) and 350 °F (175 °C). CUI inspections may be conducted as part of the external inspection. If CUI damage is found during spot checks, the inspector should inspect other susceptible areas on the piping. API 583 on CUI has much more detailed information on CUI and should be used in conjunction with piping CUI inspection programs.

Although external insulation may appear to be in good condition, CUI damage may still be occurring. Non-intrusive techniques such as real time radiography can help to determine if any scale is present behind the insulation without removal. Other techniques such as profile radiography, Pulsed Eddy Current and Guided Wave Examination can help to locate damage. Removal of scale on live equipment and removal of insulation where leaks are suspected can pose a significant safety risk. CUI damage is often quite insidious in that it can occur in areas where it seems unlikely.

Considerations for insulation removal include but are not limited to:

a) history of CUI for the specific piping system or comparable piping systems;
b) visual condition of the external covering and insulation; rust stains, biological growth and bulged weather jacketing;
c) evidence of fluid leakage (e.g. drips or vapors);
d) whether the piping systems are in intermittent service;
e) condition/age of the external coating, if known;
f) evidence of areas with wet insulation;
g) potential for the type of insulation to absorb/hold more water (e.g. calcium silicate versus cellular glass);
h) low points of sagging lines;
i) bottom of vertical pipe;
j) proximity to equipment that could increase the local humidity, (e.g. cooling towers);
k) areas where temperature regimes are moving into and out of the CUI temperature range.

Atmospheric Corrosion Control Options

Atmospheric Corrosion Control System Design

- Full system compatibility
- Eliminate galvanic couples
- Appropriate coating system
- Inspection and maintenance

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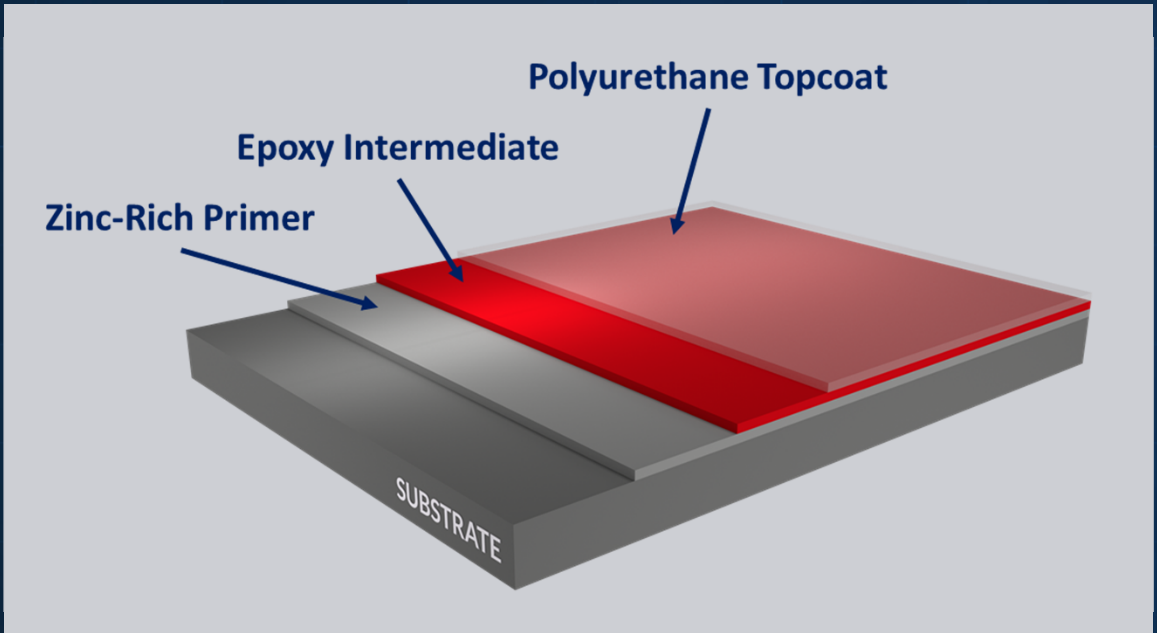
Coatings are the Most Common Corrosion Control Method for Aboveground Areas

Coatings

- System Selection
- Surface Preparation
- Application
- Application Inspection (QA/QC)
- Handling and Transportation

Atmospheric: Most Common Coating System



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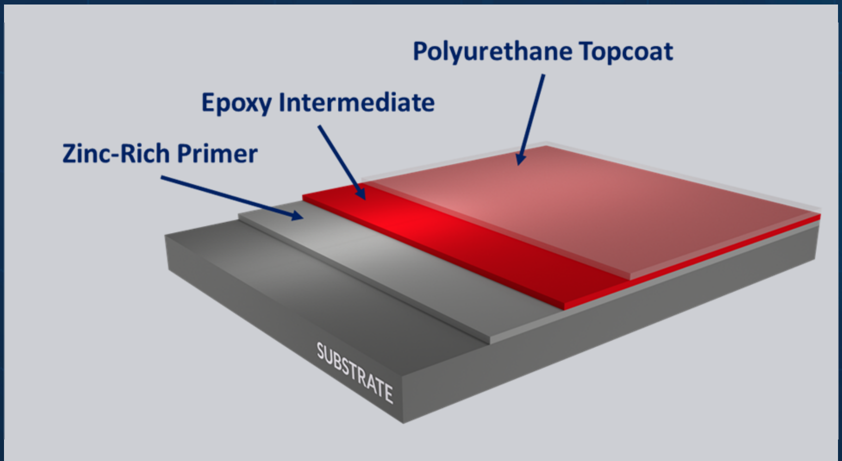
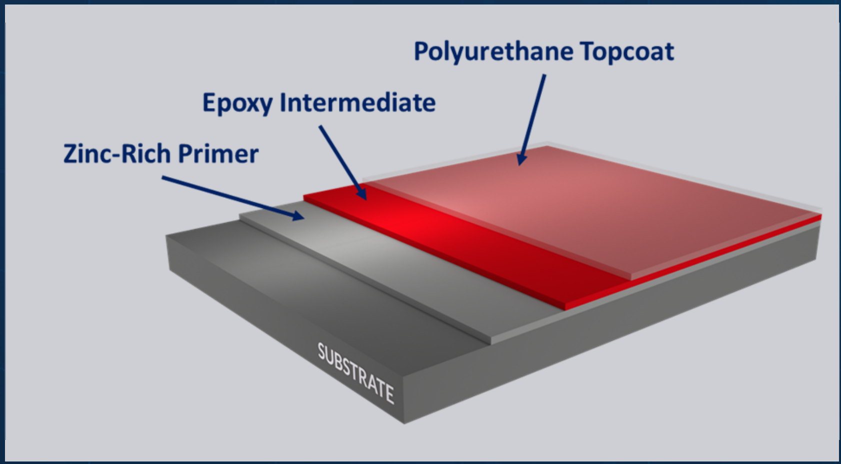
Three – Coat System

- Zinc-Rich Primer
  - Zinc provides sacrificial corrosion protection
  - Acts as an inhibitor
  - Bonds coating to substrate
  - Can be organic (polymer based) or inorganic (silicate based)



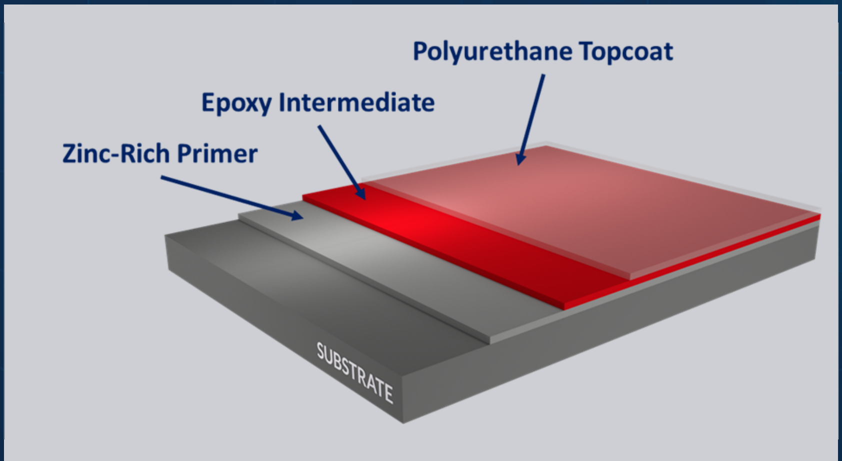
Three – Coat System

- Epoxy Intermediate Coat
  - Barrier Protection
  - Chemical/Solvent/Moisture Resistance
  - Coating Thickness
  - Susceptible to UV degradation



Three – Coat System

- Polyurethane Top-Coat
  - High UV resistance (sunblock)
  - Weatherability
  - Moisture Resistance
  - Glossy surface texture – provides aesthetics



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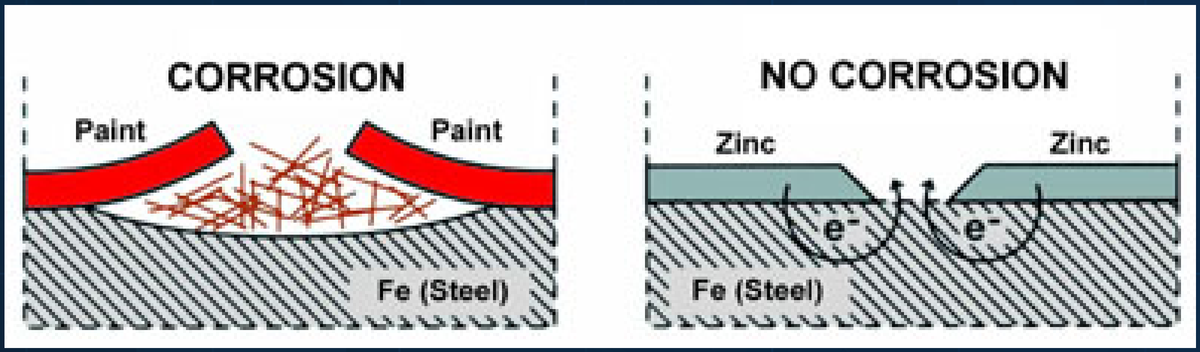
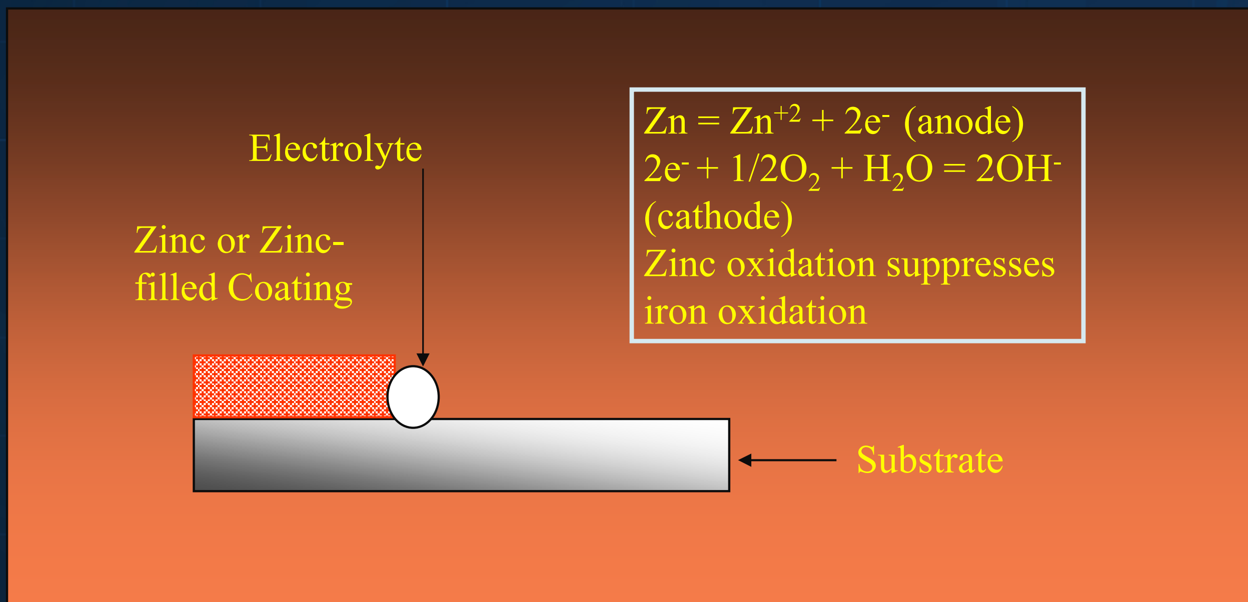
Other Coating Systems

- SACRIFICIAL COATINGS
  - Zinc-rich (inorganic zinc primers)
  - Pure-metal (galvanizing, metallizing, plating)

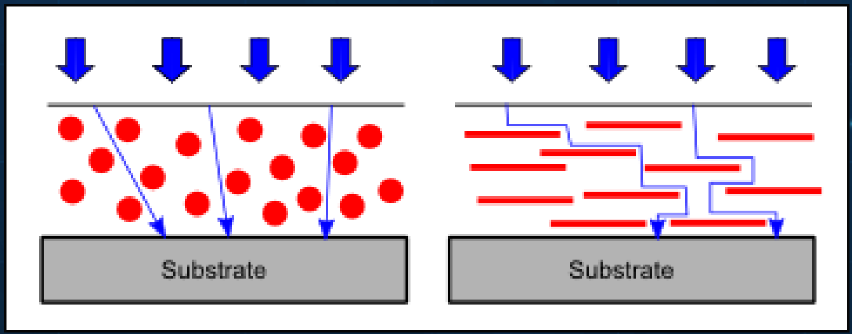


Sacrificial Coatings



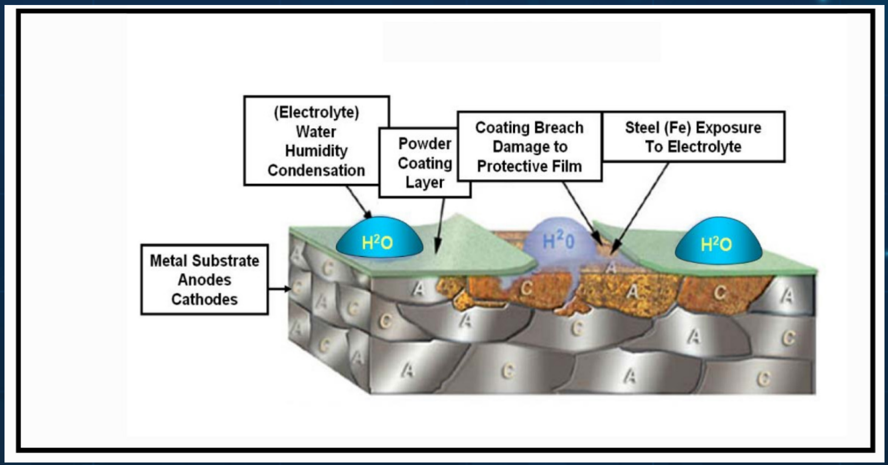
Other Coating Systems

- Barrier Coatings
  - Separate the electrolyte (environment) and the metal
  - Impede O2 & H2O diffusion
  - Restrict access of aggressive anions (chlorides, sulfates)
  - Withstand deterioration during prolonged exposure
  - May use a filler (MIO or aluminum flakes)



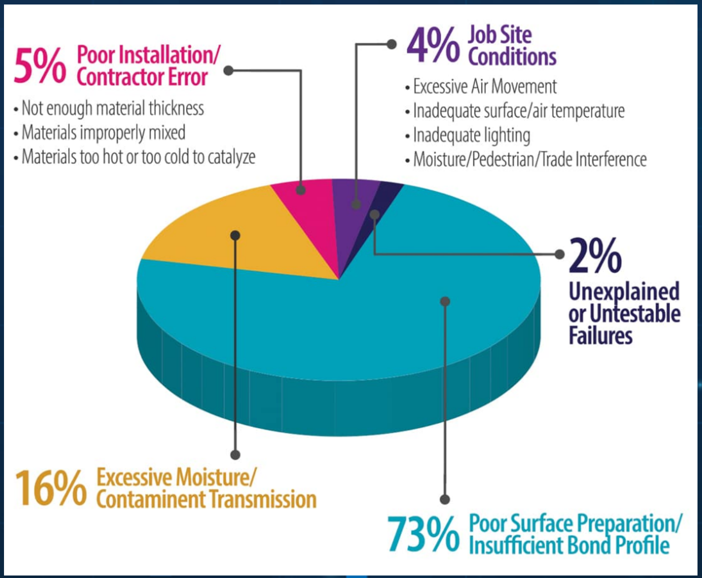
Barrier Coating Weakness

- All coatings are permeable
- No coating is flaw free
- Incompatibility with coating materials and substrate
- Difficult to apply successfully
- Surface preparation is essential



Surface Prep

- MOST IMPORTANT PART OF COATING APPLICATION PROCESS
- PURPOSE:
  - REMOVE SURFACE CONTAMINATION
  - CREATE AN ANCHOR PATTERN
- THE EXTENT OF CLEANLINESS IS DIRECTLY PROPORTIONAL TO LIFETIME OF COATING SYSTEM



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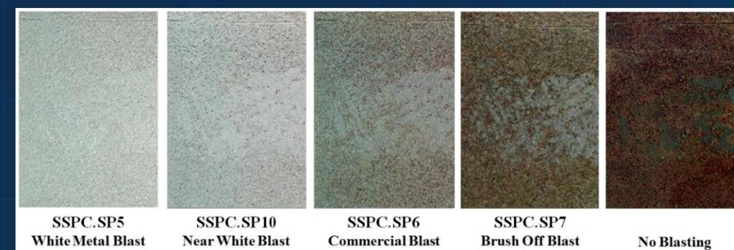
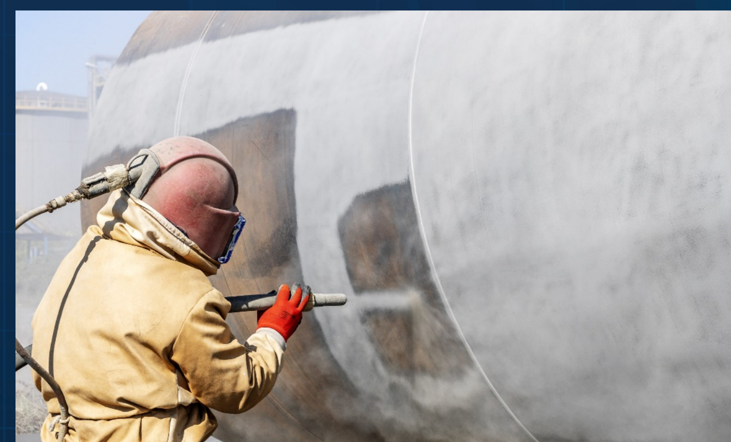
Surface Prep

METHODS OF SURFACE PREPARATION:

MORE CLEANLINESS

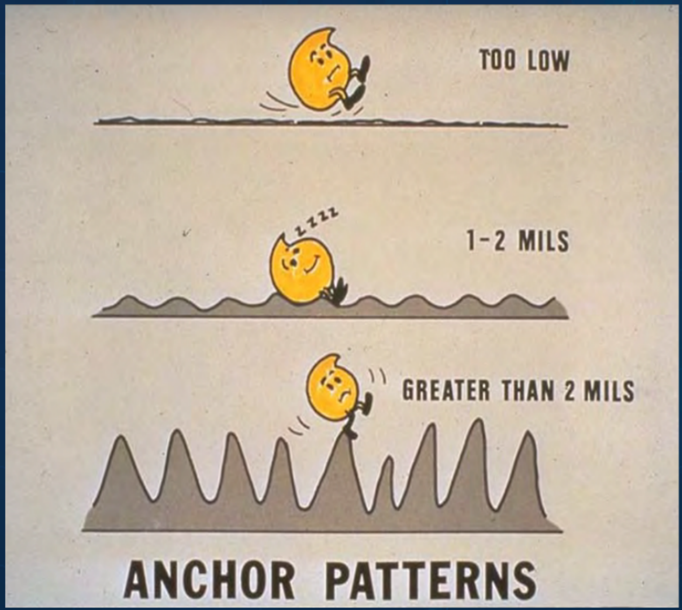
- ABRASIVE BLAST (DRY OR WET)
  - WHITE METAL
  - NEAR WHITE
  - COMMERCIAL BLAST
  - BRUSH BLAST
- WATER BLAST
- WATER JETTING
- POWER TOOL CLEANING
- HAND TOOL CLEANING
- SOLVENT CLEANING





Anchor Profile

- Provides surface area for the coating to grab on to
- Dependent on manufacturer or specifier
- Too shallow will not provide enough adhesion
- Too deep can cause holidays



Surface Prep

Surface Prep

Coatings

PIPELINE COATINGS	ATMOSPHERIC COATINGS
• Thick (physical damage) • Supplemented by CP • Repairs difficult and costly	• Thin (no physical damage) • No CP • Repairs relatively simple

Coatings Specs

- GENERAL
  - SCOPE OF WORK
  - QC / QA
  - CONTRACTOR QUALIFICATIONS
- MATERIALS
  - SYSTEM COMPATIBILITY
  - JOINT SEALANT
  - ABRASIVE MATERIALS
- EXECUTION
  - SURFACE PREPARATION
  - APPLICATION
  - INSPECTION

Application Inspection

Coating Inspection during application is very important:

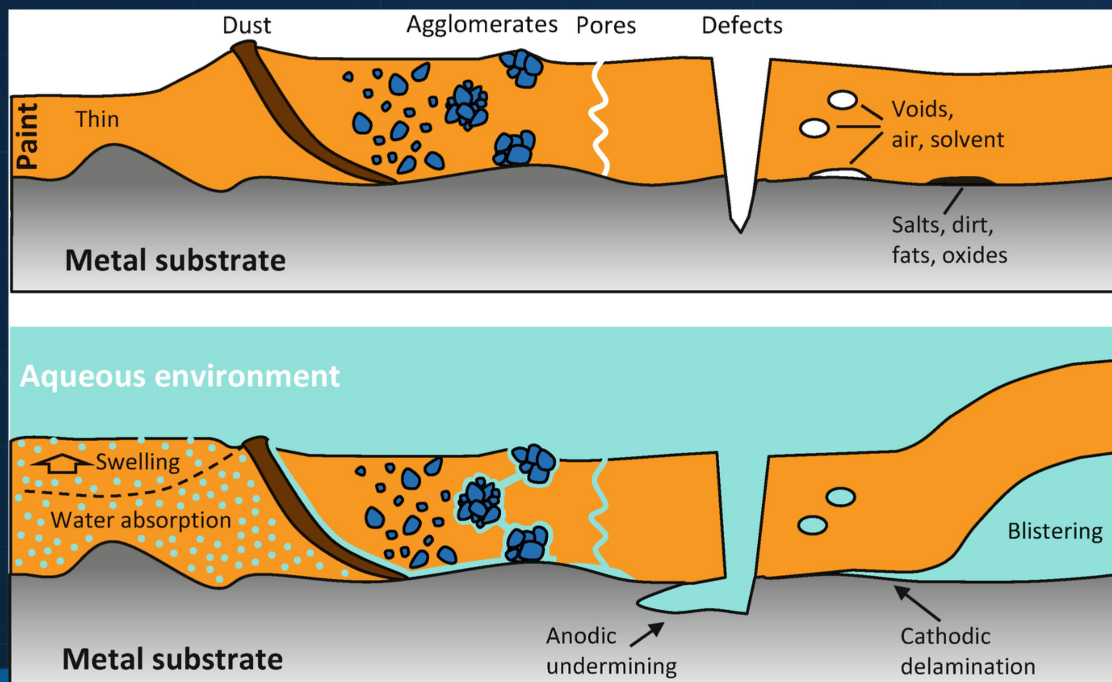
- Ensures that specifications are being met
- Conduct tests
- Keep records
- Approximately 10% of total painting project cost
- Good inspection pays for itself in improved coating life expectancy

Coatings

NO COATING LASTS FOREVER

MAINTENANCE AND EVENTUAL REPLACEMENT WILL BE NEEDED

No Coating Is Flawless



Coatings

Reasons for Coating Maintenance:

- A good coating if properly maintained should last 10 to 15 years before requiring a major recoating.
- Periodic visual coating inspection and minor repairs are necessary to identify areas of coating failure to avoid catastrophic results.
- Repair on a routine basis prolongs the life of the coating and postpones the need for a full recoat.

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Summary

- Above ground corrosion control is very different from below grade control.
- Proper selection, application inspection and maintenance of organic coatings is the most cost-effective way to control corrosion in most cases.
- Change or design and use of alternative materials is sometimes appropriate.

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Questions

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