Introduction to Corrosion Control and Coatings

Fundamentals of Corrosion Control

Topics

• Corrosion control by selecting materials
• Corrosion control by design
• Corrosion control by coatings
• Corrosion control by barrier and inhibitive pigment protection
Corrosion Control by Selecting Materials

Selecting Materials

- Vital step of the design process
- Materials and design must be considered together
- Materials may be selected that are resistant to the types of corrosion that can result in system failure
- Not an afterthought
Corrosion Resistant Materials

- Titanium
- Aluminum alloys
- Composites
- Stainless Steels
- Nickel alloys
- Copper alloys

Titanium

- High strength-to-weight ratio
- Resistant to many severe environments
  - Seawater
  - Hypochlorites
  - Nitric acid
- Used in high temperature areas
- Readily forms a strong and stable oxide film - “passive film”
**Aluminum and Aluminum Alloys**

- Very high strength-to-weight
- Aluminum oxidizes quickly
  - Results in aluminum oxide “passive film” which resists further corrosion
- Aluminum alloys are more prone to certain types of corrosion than pure aluminum

**Composites**

- Excellent strength-to-weight and stiffness-to-weight ratios
- Offer excellent resistance to corrosion, chemical attack, and outdoor weathering
- Some chemicals are damaging to composites (e.g. coating stripper)
Stainless Steels

- Produced almost exclusively for their corrosion resistance
- Should contain at least 11% chromium
- Stainless steels are more corrosive to aluminum than other materials despite having less galvanic potential
  - Parts are cadmium-plated and primed if attached to aluminum or alloy steel parts
- Main concern with stainless steel is its weight

Nickel Alloys

- Strong passive film formers
- Very resistant to pitting, crevice corrosion, stress corrosion cracking, and erosion-corrosion
- Used in immersion, high temperature service, and for resistance to attack by hydrochloric acid
- Extensively used in electroplating
- Tend to be costly
Copper Alloys

- Alloys such as 90-10 and 70-30 widely used in seawater handling systems
- Corrosion resistance due to the formation of a complex surface film on contact with seawater
- Resistant to pitting, crevice corrosion, and stress corrosion cracking
- Inherently resistant to biofouling
- May be susceptible to erosion-corrosion
- Should not be coupled to aluminum alloys

Corrosion Control by Design
Corrosion Control by Design

- Corrosion should not be ignored during initial design, modifications, and repair
- Design details can significantly impact corrosion performance of a system

Corrosion Control by Design - Galvanic Corrosion

- Whenever two or more dissimilar metals are used in a system
- Corrosion products from one surface can bleed onto another surface and cause rapid attack
  - Copper corrosion products are aggressive towards aluminum, steel, and stainless steel
  - Iron corrosion products can accelerate corrosion of aluminum and stainless steels
- Can be mitigated by correct design such as electrical isolation
Geometric Considerations

- Water traps
- Crevices
- Edges
- Inaccessible areas

Water Traps

- Moisture accelerates corrosion
- Avoid geometric features that trap and hold water
- Use of drain holes helps avoid accumulation of moisture
  - Inspect effectiveness of drain holes
Crevices

- Corrosion is more severe in systems with crevices
- May cause accelerated attack by:
  - Concentration cell corrosion
  - Retaining wetness
  - Contaminates
- Virtually impossible to protect effectively with coatings

Edges

- Difficult to obtain a uniform coating thickness on edges and corners
- Proper preparation of edges is necessary for good coating adhesion
Inaccessible Areas and Difficult to Coat Areas

- Interior corners are difficult to clean and keep clean
- Small amounts of contaminates can interfere with proper bonding of coatings
- Coatings tend to be thicker than desired on interior corners
  - Interferes with proper curing
    - Excessive shrinkage
    - Coating adhesion
- Surface defects interfere with effectiveness of surface preparation
  - Pits
  - Cracks
  - Gouges
  - Weld spatter

Corrosion Control by Protective Coatings
Corrosion Control by Coatings

- Protective coatings:
  - Isolate the metal from the electrolyte – “Barrier Protection”
  - May contain inhibitive pigments (e.g. chromates) that reduce corrosion rates

Barrier Protection

- Coating forms a barrier between the metal and the electrolytes in the environment
- Length of time the coating provides barrier protection depends upon:
  - Inherent permeability of the resin
  - Level and type of pigments and additives
  - Film thickness
  - Quality of coating formulation
  - Cleaning of the substrate prior to coating
  - Adhesion of the film to the substrate
  - Severity of the environment
Inhibitive Pigment Protection

- Common inhibitive pigments
  - Chromates
  - Phosphates
  - Molybdates
- Inhibit chemical reactions at the interface between the substrate and the coating and/or contribute to the barrier properties of the coating

![Diagrams of films pigmented with isometric and nonisometric particles.]

Protective Coating System Stackup

- Usually consists of two or more individual coatings
- Each coat may provide corrosion control by one or more of the mechanisms
- Each coat of the system is usually tinted differently so it is easier to determine imperfections
Protective Coating System Stackup

- Pre-treatment
  - May provide corrosion protection
  - Promotes adhesion
- Primer
  - Must adhere well to the substrate
  - Provides a base for good adhesion of additional coats
  - Contains corrosion inhibitor
  - Provide greater thickness for barrier protection
- Topcoat
  - Provides additional barrier protection
  - Provides desired color, gloss, and texture
  - Protection from weathering

Corrosion Preventative Compounds (CPCs)

- Water-displacing soft films
  - Low viscosity product that wicks into crevices
  - Displaces water and delivers corrosion inhibitor
- Hard films (water displacing and non-water displacing)
  - Delivers corrosion inhibitor
  - Forms additional barrier coating
- Vapor phase CPC’s
  - Evaporate or sublimate to release inhibitor molecules which settle in thin film on surface to be protected
  - Usually used in enclosed spaces
Sealants

- Effectively eliminates the potential for crevice corrosion
- Choose the correct sealant for a specific area or situation
- Apply according to manufacturer's product data sheet

Corrosion Control by Cathodic Protection

- Electrochemical means of corrosion control
- Protected structure becomes a cathode in an electrochemical cell
- Cathodic protection substantially reduces the rate of corrosion by reducing the rate of the anodic reaction responsible for corrosion
- Done by either sacrificial anode or ICCP (Impressed Current CP)
- Steel hulled ships and underground pipelines are common structures that are cathodically protected using ICCP
- Sacrificial anodes are used in many places including home hot water heaters and on outboard motors (the zinc tab)
- Care required to avoid causing hydrogen embrittlement of the structure being protected and damage to the coating system
Corrosion Control by Altering the Environment

- Dehumidification
  - Removes moisture from the air in enclosed spaces to reduce its humidity, while depressing the dew point significantly below the surface temperature
- Sheltering
  - Protects from exposure of sunlight and outdoor elements

Corrosion Control by Cleaning

- First step in preventing early corrosion
- Removes dirt, salt deposits, and other contaminants
- Clean water rinses must be preformed according to parent service organization's requirements
Fundamentals of Corrosion Control

Summary

- Corrosion of system is greatly affected by its design.
- Proper selection of coatings and materials is extremely important in the design process.
- There are a variety of ways to mitigate corrosion after the design has been set.

Agenda

- Corrosion Basics
- Fundamentals of Corrosion Control
- **Surface Preparation for Coatings**
- Coatings and Coating Types
- Coating Application and Safety
- Coating Defects and Inspection