



FACILITY AND INFRASTRUCTURE CORROSION PREVENTION AND CONTROL

CONSTRUCTION AND QUALITY CONTROL

Training Objectives



Training Objectives

- Identify corrosion prevention and control (CPC) impacts and opportunities during construction activities
- Discuss aspects of Design-Build that may affect the selection and specification of corrosion prevention and control (CPC) materials and strategies
- Identify the importance of quality assurance and control on facility components which typically have high sustainment costs associated with corrosion
- Introduce key project and environmental factors that affect the rate of corrosion and component service life
- Identify design and construction pitfalls which can contribute to facility corrosion
- Identify resources and training opportunities for corrosion prevention and control (CPC)

Importance of Corrosion Prevention



- Corrosion

- Adds nearly \$2B in annual facility sustainment costs across the DoD and may be as much as 40% of an asset's life cycle cost
- Affects mission readiness – facility capacity and downtime, personnel productivity, and asset employment
- Affects safety, health, and quality of life

The DoD is required by law¹ and policy² to:

- *Prevent or mitigate corrosion during the design, construction, and sustainment of military equipment and **facilities***
- *Ensure corrosion prevention and mitigation technologies are fully considered during research and development and incorporated into all phases of the acquisition process*

¹ 10 USC Sec 2228 and the House Armed Service Committee Report accompanying H.R. 1540, The National Defense Authorization Act (NDAA) for Fiscal Year 2012 (H.R. Rep. No 112-78, p. 293)

² DoDI 5000.67, February 2010, Prevention and Mitigation of Corrosion on DoD Military Equipment and Infrastructure

Definition of Corrosion



CORROSION – 10 USC Sec. 2228

“The deterioration of a material or its properties due to a reaction of that material with its chemical environment.”

More than Rust!



Traditionally thought of as deterioration of metal (e.g., rusting of steel) but now expanded to include degradation of non-metallic materials as well.

Some nontraditional examples include rotting of wood, degradation of concrete (carbonation, alkali-silica reaction phenomena, degradation of composite materials, destruction of organics from mold and mildew, and material degradation due to erosion, stress induced cracking, embrittlement, biological processes, and solar exposure

Design-Build



Design-Build is the prevalent acquisition strategy for Military Construction Projects. Key elements of Design-Build:

- The **Request for Proposal (RFP)** identifies both the design and construction requirements.
- The **detailed design (plans and specifications)** is prepared after award of the construction contract by an Architect/Engineer (A/E) firm. The A/E firm is usually a subcontractor to the prime construction contractor. In some cases, the design will be developed in phases in order to begin construction activities as soon as possible.
- **Unified Facility Criteria (UFC)** are technical manuals which define design and performance requirements, guidance, and best practices. **Unified Facility Guide Specifications (UFGS)** are guide specifications which define material performance standards and in some cases, construction installation procedures. These documents are used in tandem to develop the design documentation (plans and specifications) and are required for all DoD facilities construction. **Policy Requirements – [Cursor over]**

Design-Build and Corrosion Prevention



Since design occurs after construction award, and in some cases in phases during construction, there are opportunities to ensure the appropriate corrosion prevention and control (CPC) features are incorporated into the design detailing and in the selection of materials and coatings.

- Ensure corrosion prevention is discussed at the design/construction kick-off meeting and implemented on the plans at each submittal stage
- Ensure the design component or assembly complies with the requirements from the RFP, including performance technical specifications, referenced UFC, and UFGS
- Ensure the design drawings and specifications address corrosion prevention and control through proper choice of materials and coatings

CAUTIONARY NOTE: Some areas of the UFGS are editable by the designer. As a result, there is often flexibility associated with selection of corrosion prevention materials and coatings. It is important to avoid the selection of poor performing materials and coatings which may be influenced only by low first costs.



Design Expectations

The DoD expects facilities to be designed such that they have low life cycle costs and can reach their intended service life:

- Select and specify materials and coatings that have low life cycle costs, are durable, and minimize the need for preventative and corrective maintenance. Initial investments in corrosion prevention are typically more LCC-effective than maintenance, repair, and replacement of prematurely degraded components.
- Design and specify components and assemblies to reach its intended service life, including the use of enhanced materials and coatings in severe corrosive environments. It is typical for many DoD facilities to be in service in excess of 50 years: Foundations, structural elements, utilities, piping, insulation, and other building components that are buried or located in walls, ceilings, crawl spaces, interstitial spaces, and duct banks should be designed to meet or exceed this service life.

Corrosion Prevention Key Factors



When evaluating the design and construction activities for corrosion prevention, it is critical to understand:

- the **environmental severity** at the project site
- the **design characteristics** of components and systems that are at risk of corrosion



Navy and Marine Corps facilities, Guam

Cursor over for more information



Corrosive Environmental Severity

Environmental Severity must be considered when choosing materials and coatings and can vary significantly across an installation based on proximity to salt water, exposure to prevailing winds, and exposure to industrial pollutants. Localized corrosion effects can be more important and destructive than general attack.

Corrosive environmental factors:

- Airborne salinity
- Time of wetness
- Temperature
- Humidity
- Pollution
- Prevailing winds
- Insects & fungi (mold & mildew)
- Erosive forces – wind, wave action, fluid flow
- UV/Solar exposure
- Subsurface conditions
 - Submerged (e.g. water conditions)
 - Buried (e.g. soil PH and resistivity)

Example:

The **SSPC Painting Manual Vol. 2** contains useful tables to help select coatings and painting systems for different environmental zones and special service conditions.

<http://www.sspc.org>

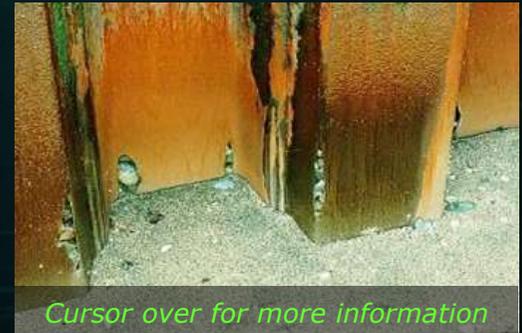
[Cursor over] for **International Organization for Standardization (ISO)** standards on the environmental corrosive effects on metals and alloys

High Sustainment Cost Systems and Components



A heightened level of quality assurance should be given during design and construction for the following components and systems which typically have high sustainment costs associated with corrosion:

- Building envelope - Exterior doors, windows, and roofing
- Exterior attachments - Stairways, gutters/down spouts, lighting fixtures, electrical panels, and mechanical louvers
- Interior spaces with high humidity, plumbing, and fixtures
- Interior spaces routinely open to the exterior and non-conditioned spaces that are vented
- HVAC systems
- Pavements
- Utilities and buried structures
- Waterfront and coastal structures
- Wastewater plants





Building Envelope

The building envelope is designed to control the transfer of heat, air, moisture, light/radiation, and noise. In order to prevent interior corrosion and molds, it is important to have the following elements which make up the building envelope, designed correctly, continuous, and sealed:

- Rain screen or water deflection layer
- Insulation or thermal barrier
- Air barrier
- Water drainage plane
- Waterproof barrier
- Fenestrations & penetrations (Doors, windows, vents, etc.)

Requirements are found in UFC 3-101-01 Architecture Chapter 3

http://www.wbdg.org/ccb/DOD/UFC/ufc_3_101_01.pdf

Design Characteristics and Defects



Improper material selection and poor design detailing will accelerate deterioration of building components and interfere with their protection by coatings. Review the design and construction submittals to avoid the following:

- Water Traps and Crevices *[Cursor over]*
- Rough and Sharp Surfaces *[Cursor over]*
- Incompatible Environments *[Cursor over]*
- Contact of Dissimilar Metals *[Cursor over]*
- Improper Coating Selection *[Next slide]*





Paints and Coatings Resources

Architectural Painting Specification Decision Tree

<http://www.wbdg.org/tools/apsdt.php?c=5>

UFC (Unified Facility Criteria) 3-190-06 Protective Coatings and Paints

http://www.wbdg.org/ccb/DOD/UFC/ufc_3_190_06.pdf

UFGS (Unified Facility Guide Specifications) *[Cursor over]*

http://www.wbdg.org/ccb/browse_cat.php?c=3

SSPC Painting Manual Volume 2 *[Cursor over]*

<http://www.sspc.org>



Cursor over for more information

Coating Condition Inspections and Testing Options:

- SSPC-PA 2 Procedures for Determining Conformance to dry coating thickness Requirements
- SSPC-VIS2 Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces
- ISO 4628-3 Evaluation of Degradation of Coatings
- ASTM D610 Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces
- Other ISO and ASTM Standards are available for evaluating Blistering, Cracking, Flaking, Chalking, and Delamination of Coatings
- Other tests include Cure Tests, Adhesion Tests, Low Voltage (Wet Sponge) Holiday Testing, and High Voltage Holiday Testing

Unified Facility Guide
Spec
UFGS 09 90 00
Paints & Coatings

MPI
Master
Painters
Institute

Decision
Tree

Approved
Products
List

Construction Impacts



Poor construction practices can easily negate the best design provisions taken to produce a durable and corrosion-resistant structure.



Modifications and Substitutions



- Ensure that any modifications to the original design and specifications do not reduce the corrosion prevention features of the building component including:
 - material substitutions – type, grade, thickness, and coatings
 - design detail changes to the component or assembly
- Ensure deviations, substitutions, and field modifications are approved by the designer of record

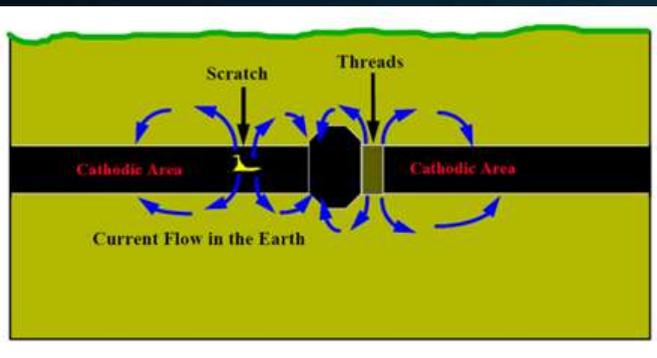
NOTE:

Avoid trade-offs of corrosion prevention technologies and features (such as cathodic protection) or elimination of the **Operation and Maintenance Support Information (OMSI)** in order to obtain project betterments or to offset shortfalls in the construction budget.

Material Handling and Storage



- Ensure proper storage and handling of materials. Materials degrade at a higher rate once rust forms and chemical deterioration of the material begins.
- Avoid damage to coatings and surfaces. Even the most minuscule break in a coating can be a starting point for corrosion. A marred or scratched surface becomes anodic to the surrounding metallic surface.



Typical corrosion cell of a buried utility with a surface that is irregular, marred, or scratched

[Cursor over] for more information

Field Cuts and Welds



Field cuts and **field welding** of materials that will be exposed to a corrosive environment should be avoided. Both damage the shop-applied coatings and may alter the material properties. A field-applied touch-up coating is usually less effective than shop-applied, for preventing corrosion due to variances in quality control and coating thickness.



Cut Edge Corrosion

[Cursor over for more information]

Weldments can experience all the classical forms of corrosion (galvanic, pitting, stress corrosion, inter-granular, and hydrogen cracking). Although shop welding can induce flaws affecting weldment corrosion such as moisture contamination, weld slag and spatter, incomplete weld penetration/fusion, porosity, crevices, high residual stresses, and improper choice of filler metal -- it is more likely that field welding will result in lower quality weldments.

Building Envelope Quality Assurance



In addition to energy loss, openings in the building envelope can result in interior corrosion and mold. Chronic moisture intrusion and high humidity levels (greater than 60%) can lead to indoor air quality issues and mold growth both visible and hidden. The following quality assurance activities will help prevent these unwanted conditions:

- Protect building materials from the elements. Ensure the materials are dry and undamaged before installation.
- Inspect all elements which make up the building envelope as they are installed. Ensure they are continuous and sealed. Special attention should be given to components which penetrate the envelope such as masonry ties and joint reinforcement, structural steel supports, and hangers for panels and curtain walls. *[Cursor over] for building envelope testing options*
- Ensure proper flashing is installed. *[Cursor over] for more information*

Building Interior



In addition to building envelope leakage, other causes of corrosion (including mold) of interior building components are:



- Inadequate ventilation during construction
- Improper insulation and leakage of HVAC ducts and utility piping
- Poor design of humid areas such as bathrooms, locker rooms, pools, and mechanical rooms
- Omission of corrosion prevention of interior spaces exposed to the exterior environment such as **aircraft hangars** *[Cursor over]* and vented mechanical rooms
- Inadequate commissioning, testing, and balancing of HVAC systems.
- Water damage from a severe weather event or internal building system rupture or discharge during construction.
[Cursor over] for remediation information

Concrete Construction



The quality of concrete and its ability to prevent corrosion is highly dependent on the quality of the mix design and construction activities associated with its placement.

Main Factors:

- Reduce **concrete permeability**
 - Decrease the water to cement ratio. Avoid adding additional water on site to improve workability
 - Add pozzolans/fly ash/polymers to the mix as designed
 - Control and reduce concrete cracking and surface imperfections
[Cursor here] for more information
 - Consolidate concrete and eliminate voids through proper vibration and placement techniques
 - Ensure proper curing and avoid premature removal of formwork
- Ensure the proper **placement of reinforcement bars and tendons** and that the appropriate minimum **concrete cover** is achieved

Corrosion of Buried Utilities and Structures -- Soil Conditions



Generally, buried utilities, tanks, and structures suffer from corrosion because of one or more of the following soil conditions:

- Low Resistivity values and high moisture content *[Cursor over]*
- Low pH values (Acidity) *[Cursor over]*
- Presence of chlorides, sulphides, and bacteria *[Cursor over]*
- Differences in soil composition *[Cursor over]*

Soil Type	Resistivity ($\Omega \cdot \text{cm}$) (ohm \cdot cm)
Gravel	20,000 to 400,000
Sand	10,000 to 500,000
Loam	3,000 to 20,000
Silt	1,000 to 2,000
Clay	500 to 2,000

Corrosivity	Resistivity ($\Omega \cdot \text{cm}$)
Not likely	Over 30,000
Mild	10,000 to 30,000
Moderate	2,000 to 10,000
Severe	0 to 2,000

Cursor over graph for more information

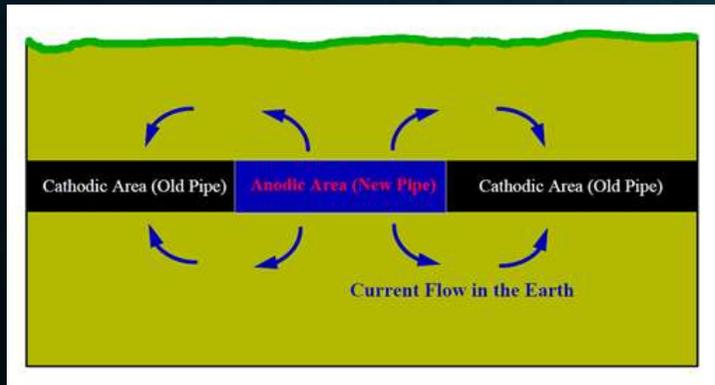
Corrosion of Buried Utilities and Structures



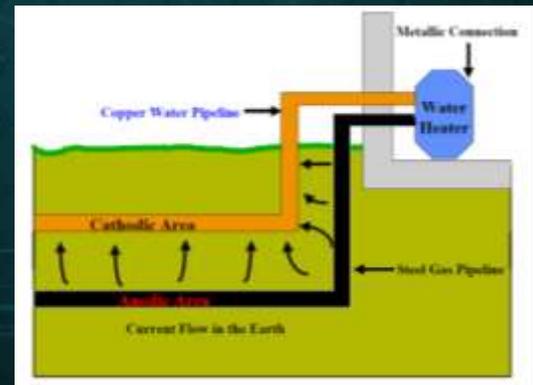
In addition to poor soil properties, the corrosion potential of buried structures can be increased due to:

- Dissimilar materials, including new and old adjacent materials. *[Cursor over] for more information*
- Surface scratches and irregularities
- Presence of stray currents *[Cursor over] for more information*
- Poor weldments, split seams and joints, separation at collars, buried flanges, and threaded pipes

Old-to-New Syndrome



Dissimilar Metal Corrosion Cell



Cathodic Protection



Cathodic protection is an electrochemical method used to prevent or control corrosion of buried or submerged metallic structures. Cathodic protection systems are active systems that rely on the application of electric current to control corrosion.

Systems that usually require both cathodic protection and protective coatings regardless of soil or water corrosivity include:

- Natural gas piping
- Liquid fuel piping
- Oxygen piping
- Underground storage tank (UST) systems
- Elevated and ground level tanks
- Underground fire protection piping
- Ductile iron pressurized piping under floor (slab on grade)
- Underground heat distribution and chill water piping in metallic conduit
- Systems with hazardous products

[Cursor over] for Cathodic Protection criteria and resources



Importance of Facility Data

More than 90% of the facility data required to support Public Works' facility lifecycle maintenance mission is generated during design and construction.



For older facilities, it can be challenging and time consuming to locate and update facility data.

Electronic Facility Data



DoD agencies responsible for facility design, construction, and sustainment are transitioning to a more integrated electronic facility data approach.

Goals include:

- Utilizing **Building Information Management and Modeling (BIM)** compiled during design and construction
- Requiring **Electronic Operation and Maintenance Support Information (eOMSI)** which connects and integrates the design, construction, and public works data streams
- **Collaboration** between eOMSI information stake holders (Designers/Contractors/Public Works/Facility Managers)

This approach has the potential to reduce duplicated efforts, increase the accuracy and completeness of information, improve information retrieval, and ultimately, reduce total ownership cost.

eOMSI and Corrosion Prevention Data



eOMSI includes:

- Operation and maintenance data
- Product & equipment submittal data including warranty information
- Record as-built drawings
- Facility system & subsystem data

This data is critical for facility sustainment and future corrosion mitigation.

- Ensure the Contractor is putting together the required electronic data packages as construction progresses and at progress submittals
- Ensure product and equipment data include material type, grade, finish, and coating information
- Ensure components and systems are documented before being covered up/enclosed in walls, foundation, and backfill -- include photographic documentation if possible
- Ensure eOMSI package is included as a key element for facility turn-over

eOMSI and Cathodic Protection



Systems employing cathodic protection require periodic inspection, testing, and maintenance. Ensure the following information is included as part of the eOMSI data package:

- System design parameters should be recorded and kept with the system drawings in order to properly monitor and maintain the cathodic protection system. Specifically:
 - The **design potentials**. In some cases, different criteria may be used to establish minimum protective potentials at different locations of the same structure
 - The **design current outputs** of the rectifiers or sacrificial anodes in the system
 - The **initial system settings and potential readings**
 - **Rectifier instructions**
- As-built drawings showing the configuration of the cathodic protection system and the structure being protected. The drawings should include, at a minimum, the location and configuration of all test stations, the location and type of all anodes and rectifiers, and the location of all connections and insulating joints.
- As-built drawings of other structures in the area which might cause interference problems

Resources – DoD Subject Matter Experts



DoD Subject Matter Experts:

- CorrDefense <https://www.corrdefense.org>
- US Army Corps of Engineers, Engineer Research Development Center (ERDC)
<http://www.erdcenter.usace.army.mil/>
 - Construction Engineering Research Lab (CERL), Champaign, IL
<http://www.erdcenter.usace.army.mil/Locations/ConstructionEngineeringResearchLaboratory.aspx>
 - Geotechnical and Structures Laboratory (GSL), Vicksburg, MS
<http://www.erdcenter.usace.army.mil/Locations/GeotechnicalandStructuresLaboratory.aspx>
- Naval Facilities Engineering Command
 - Engineering and Expeditionary Warfare Center (EXWC) Port Hueneme, CA
https://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/capital_improvements.html
 - Engineering Criteria and Programs Office. NAVFAC Atlantic, Norfolk, VA
- US Air Force Civil Engineering Center (AFCEC), Operations Directorate, Engineering Division
<http://www.afcec.af.mil/facilityengineering/index.asp>

Other Resources



DoD Facility Criteria - Whole Building Design Guide <http://www.wbdg.org>

- CPC Source Page <http://www.wbdg.org/resources/cpcsource.php>
- Unified Facility Criteria http://www.wbdg.org/ccb/browse_cat.php?c=4
- Unified Facility Guide Specifications http://www.wbdg.org/ccb/browse_cat.php?c=3
- NAVFAC Design-Build Performance Technical Specifications (PTS) <http://ndbm.wbdg.org/system/html/6/>
- Engineering and Construction Bulletins (ECB) http://www.wbdg.org/ccb/browse_cat.php?c=268

Industry:

- Master Painters Institute (MPI) <http://www.mpi.net/>
- NACE International (The Corrosion Society) <http://www.nace.org>
(Training and Certification) <http://www.nace.org/Training-Education/>
- SSPC (The Society for Protective Coatings) <http://www.sspc.org>
(Training and Certification) [http://www.sspc.org/training/SSPC Training Programs from A Z/](http://www.sspc.org/training/SSPC_Training_Programs_from_A_Z/)
- STI (Steel Tank Institute) <http://www.steeltank.com>
(Training and Certification)
<http://www.steeltank.com/Education/EducationandTraining/tabid/481/Default.aspx>

Training Sponsor



This training is provided by the



Office of the Under Secretary of Defense (AT&L),
Corrosion Policy and Oversight