FACILITIES[1] CORROSION IMPACTS ON OPERATIONS AND MISSION

By: Joseph C. Dean, P.E., for the Director, Corrosion Policy and Oversight (DASD) [Material Readiness]

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This Table highlights typical facility types, systems, and components and their response to corrosion that can result in premature degradation, reduced service life, and high sustainment costs if appropriate Corrosion Prevention and Control (CPC) features are not employed. The environmental effects on the facilities can be considerably intensified if the materials utilized are not selected to resist humidity, heat, and corrosive chemicals. For an explanation of ISO 9223 Environmental Severity[2] Classification and Zones and how it affects facility condition see the *CPC Source Environmental Severity Classification (ESC)*[3] page (http://www.wbdg.org/ffc/dod/cpc-source/environmental-severity-classification). See the Corrosion Science Knowledge page (http://www.wbdg.org/ffc/dod/cpc-source/corrosion-science-knowledge-area) for additional background on the science and types of corrosion. Corrosion Training can be found in the DoD Course Section of Continuing Education (http://www.wbdg.org/continuing-education?field_ed_sponsor_value_selective=DOD&field_topics_tid_selective=All) and in the CPC Source Training Page (http://www.wbdg.org/ffc/dod/cpc-source/training). The Table describes the deterioration, types, and mission impacts of corrosion on facilities. The Notes Section along with the Table provide insights on how to leverage ESC and understand why the selection of corrosion appropriate materials, construction practices and sustainment actions impact the safety, health, quality of life (QOL), environment, life cycle and operational readiness of a facility, and could be used to help in project documentation and justification.

FACILITY CATEGORY	CORROSION DETERIORATION DESCRIPTION	FACTORS CONTRIBUTING TO CORROSION[4]	OPERATIONS & MISSION IMPACTS
Pavements (http://www.wbdg.org/ffc/dod/cpc-source/cpc-source-pavements-knowledge-area)	Asphalt binder breakdown, loss of flexibility, cracking & pothole failure, base course & structural failure. Concrete mix permeability and contaminants. Concrete pavement reinforcing steel corrosion causing spalling and surface failure, alkali silica reaction.	Ultra-violet light radiation degradation. Corrosion of reinforcing steel (Concrete Pavements). Chemical impacts (salt & other chemicals). Heat impacts of jet blast. Freeze/thaw cycles.	For operational pavements such as airfields & critical road infrastructure, loss of mission capability. For roads & related pavements, inability to support designed functions creating delays, congestion, disruption. Access denial. Reduced safety.

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Bridges (Multiple Materials)	Corrosion of metals to include concrete reinforcing, structural steel, bridge deck corrosion/erosion, metallic connectors	Humidity, rain, chloride containing environments, salinity from deicing salts, structural loading, applied chemicals, erosive forces.	Access denial, structural failure. Inability to support designed functions creating delays, congestion, disruption. Reduced safety.
Waterfront & Coastal Structures (Drydocks, Wharves, Piers, Utilities, etc.) (http://www.wbdg.org/ffc/dod/cpc-source/waterfront-coastal-structures-knowledge-area)	Extreme corrosion exposure, high structural deterioration causing failure, sea level rise (fixed elevation exposure to high salinity impacts from gradual & dramatic variations in sea level).	Humidity, rain, chloride containing environments, salinity from deicing salts (esp. salt water, dramatic shifts in tides), structural loading, applied chemicals, erosive factors, temperature, moisture, water borne pollutants. Waterfront utilities are particularly susceptible to atmospheric & salinity.	Facility availability, high sustainment costs, reduced life cycle, structural degradation. Shoreline erosion, reduced capacity and berthing availability.
Aviation (e.g. Runways, Hangars, Engine Test, Corrosion Control, Maintenance, Wash Racks, AFFF (Fire Protection), Lighting (Landing & Approach))	When viewed as a system, all facilities must function together to ensure safe & ready operational environment. Other facilities such as pavements, POL, storage, airfield lighting, arresting gear, etc., react to corrosive environments, especially where deicing & salt laden air exposure occurs.	Humidity, rain, chloride containing environments, salinity from deicing salts, ultraviolet light exposure, condensation, structural, applied chemicals, microbiologically induced corrosion, internal environments (esp. pipelines, utilities, AST/UST), erosive forces, soil corrosivity, heat and freeze/thaw impacts on pavements.	Corrosion related operational impacts include any risk where one or more facility that is on the process of keeping an aircraft or the sustainment of that aircraft cannot meet required readiness levels. For example, runway integrity will be impaired by asphalt binder breakdown or concrete doweling corrosion that causes spalling and foreign object damage. Maintenance facility roof failure may affect health and safety (mold, mildew, HVAC air quality) or shop testing efficiency.
Below Ground Utilities & Buried Structures (http://www.wbdg.org/ffc/dod/cpc-source/utilities-	Facilities that are out of sight create a challenge for facility managers. Systems must be in place to inspect & assess the	Soil corrosivity, structural, erosive forces, soil corrosivity, inadequate or malfunctioning CP, internal corrosion (H_2S, H_2O, microbiologically	Buried facilities are essential for supplying power, waste removal, water supply, natural gas supply, etc. System failures in whole or in part can be hugely

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buried-structures-knowledge-area)	facility (e.g. CP, SCADA, etc.) including access points. Leaks & systems failures caused by corrosive soils, chemicals, de-icing, poor construction, dissimilar metal use & design geometrics creating a high probability of service interruptions.	induced corrosion), condensation, poor design geometrics, poor construction practices, dissimilar metal corrosion, water entrapment & intrusion.	disruptive to the mission & create environmental and health & safety concerns. Utility system reliability is critically important.
Above Ground Utilities & Structures (http://www.wbdg.org/ffc/dod/cpc-source/utilities-buried-structures-knowledge-area)	Above ground utilities are extensive & complex & create a major challenge for facilities professionals. Corrosion often occurs before it is noticed & can be anything from pitting, to uniform to galvanic across a broad range of exposures & environmental conditions. Vigilance & an effective SRM program along with good design & construction are essential for continuous system responsiveness.	Chloride containing environments, humidity, rain, salinity, structural loading, applied chemicals & contaminants, erosive forces, internal corrosion (H_2S, H_2O, microbiologically induced corrosion), condensation, poor design geometrics & construction practices, dissimilar metal corrosion, water entrapment & intrusion.	Above ground facilities are essential for supplying power, waste removal, water supply, natural gas supply, etc. System failures in whole or in part can be hugely disruptive to the mission & create environmental and health & safety concerns. Utility system reliability is critically important.
POL Distribution & Storage	System design, construction, & sustainment for POL distribution & storage is a carefully managed DoD program. Record system failures (fuel leaks & monitoring) & explosions have	Chloride containing environments, humidity, rain, salinity, structural loading, applied chemicals & contaminants, erosive forces, soil corrosivity, inadequate or malfunctioning Cathodic	Above & below ground POL distribution & storage facilities are essential for supplying fuel supplies to equipment, boilers, vehicles including back-up supplies for emergency generators, etc. System failures in whole or in part can be hugely

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	ensured that appropriate attention be paid to this mission critical area. Vigilance by planners, designers, engineers, SMEs, construction & sustainment personnel are required for system operation reliability.	Protection (CP), internal corrosion (H_2S, H_2O, microbiologically induced corrosion), condensation, poor design geometrics & construction practices, dissimilar metal corrosion, water entrapment & intrusion.	dangerous & disruptive to the mission & create environmental and health & safety concerns. POL system reliability is critically important.
Electrical Distribution Systems (Generators, support structures, lightening protection, switches, conductors, etc.) (http://www.wbdg.org/ffc/dod/cpc-source/utilities-buried-structures-knowledge-area)	Electrical distribution systems are extensive & complex & must be well managed by facilities professionals. Corrosion often occurs before it is noticed & can be anything from pitting, to uniform to galvanic across a broad range of exposures & environmental conditions. Vigilance & an effective SRM program along with good design & construction are essential for continuous electrical distribution system responsiveness.	Chloride containing environments, humidity, rain, salinity, structural loading, ultraviolet light exposure, applied chemicals & contaminants, erosive forces, soil corrosivity, inadequate or malfunctioning CP, internal corrosion (H_2S, H_2O, microbiologically induced corrosion), condensation, poor design geometrics & construction practices, dissimilar metal corrosion, water entrapment & intrusion.	Electrical distribution systems are essential in supplying power to facilities. Airfield lighting, shore power at dockside, security systems, control systems for waste removal, water supply, natural gas supply, etc. are affected by electrical power. System failures in whole or in part can be hugely disruptive to the mission & create health & safety concerns. Utility system reliability is critically important.
Wastewater & Water Treatment Plants[5]	Highly corrosive environment, catastrophic equipment failure, rust, mildew, CP related corrosion risks (see UFC 3-240-13FN).	Water borne corrosive pollutants, temperature, moisture, corrosive chemical reactions, abrasive, pitting, inadequate or malfunctioning CP, erosion, dissimilar metals, mold, mildew, organic growth & reactions.	Public health risks, environmental pollution, high cost repairs and recovery.

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Fencing (http://www.wbdg.org/ffc/dod/cpc-source/fencing-knowledge-area)	Material selection inconsistent with the ESC Zone directly impacting the system life cycle; corrosion caused appearance degradation can be visible very quickly; sustainment costs can be significant.	Chloride containing environments, humidity, rain, dissimilar metals causing galvanic corrosion, water entrapment, highly corrosive soils, salinity, structural loading, airborne chemicals & contaminants, erosive forces, condensation	Physical security & appearance degradation, reduction in access denial capabilities.
Building Envelopes[5]	In highly corrosive environment, exterior equipment and system failure (e.g. roof, windows, doors), rust, mildew, weather affects and related corrosion risks.	Humidity, rain, wind, temperature, moisture, corrosive chemical reactions, efflorescence, abrasive, pitting, dissimilar metals causing galvanic corrosion, mold, mildew, air borne corrosive pollutants.	Structural integrity, morale, safety, high sustainment cost impacts, reduced life cycle.
Doors (http://www.wbdg.org/ffc/dod/cpc-source/doors-knowledge-area)	In highly corrosive environments, poor performing doors (including weather stripping, etc.) increase exposure of equipment and building interior risking component system failure & increase the appearance of rust, mildew, weather affects & related corrosion risks.	Humidity, rain, chloride containing environments, structural loading, airborne and applied chemicals & contaminants, erosive forces, dissimilar metals & materials.	Doors are one of the most important building envelope barriers to the elements; repetitive use causes deterioration in hardware & weather-stripping allowing water & wind intrusion resulting in barrier efficiency & effectiveness.
Roofs & Roofing Systems	Asphalt binder breakdown, loss of flexibility, cracking of roofing materials.	Humidity, rain, condensation, biological, erosive forces, ultra-violet exposure, heat.	Barrier failure endangering structural integrity & interior safety (e.g. mold, mildew, etc.).
Interior spaces with high humidity,	Enclosed spaces that utilize & store corrosive chemicals	Chloride containing environments, humidity, temperature, leaks, poor	Negative impacts to health, morale, safety, maintenance

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plumbing & fixtures (e.g. chemical storage, swimming pool enclosures, chemical treatment areas, research labs, etc.)[5]	must be designed with materials & components that are appropriately corrosion resistant. The cheaper alternative never works. In that many chemicals are dangerous (e.g. chlorine) storage & utilization must be appropriate. All surfaces are impacted such as doors, valves, & structures. Control systems when exposed to moisture, heat & corrosive chemicals deteriorate quickly affecting systems operation.	air circulation, air borne corrosive pollutants, structural, applied chemicals & contaminants, inadequate or malfunctioning CP, internal corrosion (H_2S, H_2O, microbiologically induced corrosion), poor design geometrics & construction practices, dissimilar metals causing galvanic corrosion, water entrapment & intrusion.	costs, disruption of services to supported systems.

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Heating Ventilation and Air Conditioning (HVAC) Systems[5]	Exterior components & interior components exposed to outside ventilation. Air borne corrosive pollutants, condensation, leaks, temperature, moisture, and poor humidity control, corrosive chemical reactions, abrasive, pitting, galvanic corrosion, mold, mildew, dissimilar metals, corrosion soils affecting buried chilled water lines. Temperature differentials of air, liquid, and or gas in ducts & conduits and surrounding the environment.	Condensation, humidity, airborne contaminants, chloride containing environments, poor air quality, dissimilar metals, microbiologically induced corrosion, mold, mildew.	Negative impacts to health, structural integrity, safety, sustainment costs, life cycle, & interrupted operations that require HVAC. Because humidity & temperature control are so important to building integrity & health, a well-managed & balanced HVAC system is essential to sustainment, life cycle & balanced costs. HVAC affects every aspect of the building envelope.
Fire Protection System	Component malfunction due to corrosion (e.g. sprinkler heads, valves, control systems, etc.) impacting system operation & availability, with associated risk to structure and life safety (See UFC 3-600-01).	Moisture, salt water/air, inadequate coatings, dissimilar metals.	Denial of facility availability, safety, asset protection, high cost of facility replacement, potential loss of life.

Notes:

1. Facilities Definition - A “facility” is a real property entity consisting of one or more of the following: a building, a structure, a utility system, pavement, and underlying land (in accordance with JP 3-34). Facilities include buildings, structures, airfields, port facilities, surface and subterranean utility systems, heating and cooling systems, fuel tanks, pavements, and bridges. Inclusive of both vertical (buildings, bridges, etc.) and horizontal

(roads, utility systems, etc.) structures. The term facilities is inclusive of “infrastructure” and structures described in this paragraph.

2. Environmental severity is defined as the corrosivity of the local environment of a given location or region. Environmental severity contributes directly to the occurrence and rate of corrosion. The effects of corrosion and the rate at which they occur are consequences of the corrosion system, which is comprised of a material or physical system, the environment, and operational conditions. Recent changes to UFC 1-200-01 *DoD Building Code* and several UFCs and UFGSs require ESC evaluations and considerations in the design of facilities which should help in the planning, RFP development and design justification for more CPC resistant designs where ESC Zones C3 through C5 are encountered.
3. The ISO Corrosivity Classification method is contained in ISO 9223:2012. This method consists of corrosivity categories defined by first-year corrosion effects on standard specimens as specified in ISO 9226. ISO Corrosivity Categories can be assessed in terms of the most significant atmospheric factors that influence the corrosion of metals and alloys. In this sense, ISO Corrosivity Categories characterize the corrosivity of the atmospheric environment and can provide a basis for the selection of materials and systems that are subject to the demands of the specific application and its required service life. See *Appendix B Facilities Environmental Severity Classifications (ESC) for DoD Locations (http://www.wbdg.org/FFC/DOD/UFC/ufc_1_200_01_2016_c2.pdf) and* the *Environmental Severity Classification Web Page* (http://www.wbdg.org/ffc/dod/cpc-source/environmental-severity-classification) to view initial ESC “C” calculations for DoD Installations.
4. Factors Contributing to Corrosion (See http://www.wbdg.org/continuing-education/dod-courses/dod01):
    a. Atmospheric corrosion factors (Temperature, Time of Wetness (TOW), Atmospheric contaminants, Solar radiation); abrasive stresses such as erosion from wind due to presence of particulates such as sand; Hydro-dynamic - abrasive stresses in water from solid debris or flow/current affecting waterfront and/or immersed structures and components
    b. Salinity and associated negative impacts due to areas where deicing salt is used
    c. Condensation - in areas where condensation may occur at regular intervals such as in cooling pipes and contributes to surface wetness
    d. Structural - stresses on structural materials or components due to strain, compression, elasticity, tensile forces, repetitive actions, etc. and/or high temperatures causing stress corrosion cracking
    e. Corrosive soils
    f. Applied chemicals and contaminants (including pesticides), immersed corrosion factors (soil water); increased presence of corrosive atmospheric contaminants due to facility type/use (i.e. pollutants derived from operation of a facility generating pollutants)
    g. Biological (Insects, Bacteria, and Fungi (mold & mildew))
    h. Internal Environments (Pipelines and Tanks)
    i. Erosive Forces (Wind, Rain, Wave Action, Fluid Flow)
5. *Micro-environments* - The actual environment that affects a specific material or system correlates directly to the conditions of the "micro-environment" that it experiences (the "local environment" that occurs on the surface of the material or system), which can vary

even over small distances. Micro-environments with differing environmental severity can occur within a given environment or zone.

a. Heating Ventilation and Air Conditioning (HVAC) - Temperature differentials of air, liquid, gas in ductwork or conduits, and surrounding environment; in areas of high humidity or industrial pollutants, the HVAC must be designed to address the "micro environment" impacts on the facility.
b. The cost of management and associated impacts of the "micro environment" are generally high and are a significant cost of the total project.
c. Addressing micro-environment impacts and corrosion in general in initial estimates along with high-level documentation in the DD Form 1391 Fiscal Year XX Military Construction Project Data will ensure that the system and components are adequately funded and constructed once approved. See "*The Importance of Including Corrosion in the Planning Process*"*(http://www.wbdg.org/ffc/dod/cpc-source/importance-including-corrosion-planning-process)* page for more information.