FACILITIES[1] CORROSION IMPACTS ON OPERATIONS AND MISSION

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This Table highlights typical facility types, systems, corrosion categories, and components and their response to corrosion and the impacts on Operations and Mission. The health and safety effects on facilities can be considerably intensified if the materials utilized are not selected to resist humidity, heat, and corrosive chemicals consistent with the ESC Zone as identified in the applicable UFC and UFGS criteria. 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 and UFC 1-200-01 *DoD Building Code*. See the *Corrosion Science Knowledge Area* for additional background on the science and ten types of corrosion. Corrosion Training can be found in the DoD Course Section of Continuing Education and in the CPC Source *Facilities Corrosion Knowledge Proficiency Track Summary* Table.

The *Facilities Corrosion Impacts on Operations and Mission Table* describes the Facility Risk Category, Corrosion Deterioration Description, Factors Contributing to Corrosion, and Operations and Mission Impacts. These descriptors might be helpful in creating the wording for the “Requirement, Current Situation, and or Impact if not Provided” paragraphs to justify projects (MILCON, Special Projects, etc.) on the Form DD1391 FY__ Military Construction Program Project Documentation.

The Notes Section below provides additional insights into CPC and ESC zone requirements.

FACILITY OR RISK CATEGORY	CORROSION DETERIORATION DESCRIPTION	FACTORS CONTRIBUTING TO CORROSION[4]	OPERATIONS & MISSION IMPACTS
Asphalt Concrete & Portland Cement Concrete Pavements	Asphalt binder breakdown due to Ultra-violet (Uv) degradation, loss of flexibility, cracking & pothole failure, base course & structural failure. For PCC the nemesis is water & salt getting to reinforcing steel	Uv light radiation degradation. Corrosion of reinforcing steel (Concrete Pavements). Chemical impacts (salt & other contaminants). Heat impacts of jet blast & road & ramp surfaces. Freeze/thaw cycles. POL spills. Alkali silica reaction.	For operational pavements such as airfields & critical road infrastructure, loss of mission capability. Foreign Object Damage (FOD) from pavement failure can lead to debris on the flight line. Jet engines can suffer major damage from even small objects being pulled into the engine intake.

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	causing cracking, spalling, & structural failure. Lack of durability, poor mix design, permeability & contaminants affect both AC & PCC. For PCC alkali silica reaction is also an issue. Freeze-thaw actions resulting in heaving pavements. Temperature impacts may result in surface expansion causing cracks, failure, heaving.		Inability to support designed functions creating delays, congestion, disruption. Access denial. Reduced safety. The cost to defer essential repairs increases over time.
Bridges (Multiple Materials – steel, concrete, timber)	Corrosion is a long-term threat to bridge integrity. Corrosion of metals including concrete reinforcing, structural steel, bridge deck corrosion/erosion, & metallic connectors. Paint failure, cathodic conditions. Leaking bridge joints allowing water, salts, & debris to fall to bridge components below. General uniform thickness loss or concentrated pitting. Stress corrosion cracks leading to fatigue growth & fracture. For timber bridges, bacteria, fungi, insects, mollusks, weathering, wetting, drying,	Risk categories include temperature, airborne & deicing salt, moisture/humidity, rain, ultra-violet radiation, oxygen, chloride containing environments, salinity from deicing salts, structural loading, applied chemicals, biologics, insects, & erosive forces. Both macro & micro bridge environments. Loss of strength due to bridge system component failure.	Access denial, structural failure. Inability to support designed functions creating delays, congestion, disruption. Reduced safety. Catastrophic failure. Replacing a bridge, especially if it is of any length & height becomes a formidable & expensive endeavor. Temporary bridges may or may not be a feasible interim solution. Often a bridge provides the only access to a location.

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	chemical exposure & atmospheric contaminants.		
Waterfront & Coastal Structures (Drydocks, Wharves, Piers, Utilities, etc.) & Piers & Wharves	Waterfront zone exposure causes high structural & system corrosion deterioration resulting in reduced support capabilities. Sea level rise (fixed elevation exposure to high salinity impacts from gradual & dramatic variations in sea level) worsens risk levels. Wood destroying organisms (marine borers, insects, & fungi) cause damage & deterioration of marine timber structures. Corrosion can have a significant effect on operational systems which are then more prone to failure leading to structural collapse & leakage of hazardous or flammable materials.	Salt water is an excellent electrolyte contributing to an aggressive corrosive environment. Hydrostatic forces, wind, salt spray, currents, tides, waves, & ice all contribute to corrosion & erosion of waterfront systems & structures. Waterfront operations & industrial activities (pollution, fuels, hazardous materials, & stray currents) often add to the corrosion severity. Humidity, rain, salinity from deicing salts, structural loading, applied chemicals, erosive factors, & temperature, moisture impact waterfront systems. Utilities are particularly susceptible to corrosive forces. Failures are often not visible until the facility is in extremis. Failure to provide good design, quality construction, & SRM places waterfront systems in extremis.	Corrosion negatively impacts facility availability & increases structural degradation, accompanied by high sustainment costs, & reduced life cycle. Corrosion of waterfront systems result in reduced capacity & availability. Repairs are costly since access to structural components can be difficult. Loss of ship berthing affects readiness especially if the ship is preparing to deploy. Environmental contamination from leaking fuel & hazardous material poses a significant concern causing fleet operation reduction & work arounds. The cost to handle fuel & hazardous materials that leak from corroded facilities usually exceeds the costs associated with the control of the corrosion responsible for the leak. In some cases, the products of corrosion themselves are hazardous & corrosion must be controlled to prevent direct environmental damage.
Aviation Facilities & Support	Note, when viewed as a system, facilities on an aviation	Humidity, rain, chloride containing environments, salinity	Corrosion related operational impacts include any risk where one

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Structures (Runways, Hangars, Engine Test, Corrosion Control, Maintenance, Wash Racks, AFFF (Fire Protection), Lighting (Landing & Approach))	installation must function together to ensure a safe & ready operational environment. Facilities such as pavements, POL, storage, airfield lighting & pavements, arresting gear, & utilities, react to corrosive factors (deicing salt, coastal salt laden air, moisture, Uv exposure, ESC Zones 3 thru 5 conditions) causing degradation in facilities comprising the aviation system.	from deicing salts, Uv exposure, condensation, structural, applied chemicals, microbiologically induced corrosion, mold/mildew, utility deterioration, erosive forces, soil corrosivity, heat & freeze/thaw impacts on pavements.	or more facility that supports an aircraft including maintenance activities cannot meet required readiness levels. For example, runway integrity will be impaired by asphalt binder breakdown or concrete doweling corrosion that causes spalling & foreign object damage. Aircraft maintenance hangar roof failure may affect operations & testing ability. A corrosion driven failure in a POL & Storage system affects timely delivery of fuel to aircraft.
Below Ground Utilities & Buried Structures	Below ground facilities create a challenge for facility managers. Systems such as cathodic protection must be in place and maintained to protect the facility. Leaks & systems failures caused by corrosive soils, chemicals, de-icing salts, poor construction, dissimilar metal use & poor design geometrics create a high probability of service interruptions.	Soil corrosivity, erosive forces, inadequate or malfunctioning Cathodic Protection systems, internal corrosion (H_2S, H_2O, microbiologically induced corrosion), condensation, poor design geometrics & construction practices, dissimilar metal corrosion, water entrapment & intrusion.	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 disruptive to the mission & create environmental & health & safety concerns. Utility system reliability is critically important.
Above Ground & Related Structures	Corrosion often occurs before it is noticed & can be in the form of pitting, uniform and galvanic	Chloride containing environments, humidity, rain, salinity, structural loading stresses exposing cracking &	Above ground facilities are essential for supplying power, waste removal, water supply, natural gas supply, etc. System

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	corrosion across a broad range of exposures & environmental conditions. Exterior corrosion can be found on supports & distribution lines. Poorly maintained systems such as cathodic protection reduces facility protection. Leaks & systems failures caused by corrosive soils, chemicals, de-icing salts, poor construction, dissimilar metal use & poor design geometrics create a high probability of service interruptions.	uncoated area corrosion, 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.	failures in whole or in part can be hugely disruptive to the mission & create environmental & health & safety concerns. Utility system reliability is critically important. The absence of an effective SRM program ensures that corrosion failures will go unnoticed until the utility & the mission it supports is in extremis.
POL Storage Distribution Systems	Past system failures & explosions have ensured that appropriate attention be paid to this mission critical area. POL Facilities affected by corrosion include petroleum tanks (above & underground ground storage tanks (AST) & (UST)), POL pipelines, & associated structures such as valves, pumps, & fasteners. Corrosion of POL pipelines & storage tanks can occur on the exterior due to atmospheric effects &	Chloride containing environments, humidity, rain, salinity, structural loading, applied chemicals & contaminants, erosive forces, soil corrosivity, inadequate or malfunctioning Cathodic Protection (CP), microbiologically induced corrosion), condensation, poor design geometrics & construction practices, dissimilar metal corrosion, water entrapment & intrusion. Atmospheric effects & submerged conditions such as soil corrosivity. External corrosion such	System design, construction, & sustainment for POL distribution & storage is a carefully managed DoD program. 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 dangerous & disruptive to the mission & create environmental & health & safety concerns. POL system reliability is critically important. Vigilance by planners,

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	soil corrosivity as well as internal corrosion. As a result, corrosion effects often remain unseen or unnoticed until they are inspected by various non-destructive examination methods are in a failure mode.	as pitting, & surface erosion can occur due to the external environment. Internal corrosion can occur because of a variety of sources including condensation, hydrogen sulfide (H2S) evolution, the water dropping out of the fuel & sitting on the tank bottom for a long duration, & biological activity. Fuels such as biodiesel, low-sulfur diesel, & fuel containing high levels of ethanol can be corrosive.	designers, engineers, SMEs, construction & sustainment personnel are required for system operation reliability.
Electrical Distribution Systems (Generators, support structures, lightening protection, switches, conductors)	Given the vast utility infrastructure, corrosion may occur before it is noticed. The components of an electrical distribution system are at risk (wood, concrete & steel poles, transformers, switches, supports, connectors, etc.). Corrosion types can be anything from pitting, to uniform to galvanic across a broad range of exposures & environmental conditions.	Chloride containing environments, humidity, rain, salinity, structural loading, Uv 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. Wood deterioration.	Electrical distribution systems are essential to supplying power to DoD 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, mold/mildew, CP related corrosion	Water borne corrosive pollutants, temperature, moisture, corrosive chemical reactions, abrasive, pitting, H_2S, inadequate or	Public health risks, environmental pollution, high-cost repairs & recovery.

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	risks (see UFC 3-240-13FN *Industrial Water Treatment Operation and Maintenance*).	malfunctioning CP, erosion, dissimilar metals, mold, mildew, organic growth & reactions.	
Fencing (Gates, posts, wire fabric, extension arms, locks, turn stiles, turnbuckles, connectors, fasteners, dead man support, concrete base)	Material selection inconsistent with the ESC Zone directly impacts 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, coating failure.	Physical security impacts & appearance degradation, reduction in access denial capabilities. Risk to mission through loss of s secure operating environment.
Building Envelopes[5]	Loss of envelope integrity includes the flowing factors: water damage, air infiltration, unreliable structure (cracks, leaks, condensation), roofing system failure, windows & doors allowing air & moisture infiltration, poor HVAC system performance, plumbing system leaks. Failure in any of these components increases the risk of moisture, mold, condensation, corrosion.	Humidity, rain, wind, temperature, moisture, corrosive chemical reactions, condensation from unregulated air flow, efflorescence, dissimilar metals causing galvanic corrosion, mold, mildew, air borne corrosive pollutants.	Structural integrity, morale, safety, high sustainment cost impacts, reduced life cycle, reduced air quality. See other facility areas for more complete descriptions of building system corrosion (Mold, Mildew, Roofs).
Doors	In highly corrosive environments, poor performing door systems increase air infiltration, moisture intrusion, increasing risk of rust, mildew, weather affects &	Humidity, rain, chloride containing environments, structural failure around doorway, airborne & applied chemicals & contaminants, erosive	Doors are one of the most important building envelope barriers against the elements; repetitive use causes deterioration in hardware & weather-stripping allowing water & wind intrusion resulting in

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	related corrosion risk to equipment & building interior surfaces & components.	forces, dissimilar metals & materials.	reduced barrier efficiency & effectiveness.
Roofs & Roofing Systems	Asphalt binder breakdown, loss of flexibility, cracking of roofing materials. Saltwater effects on materials & structures (depending on the proximity of the roof to saltwater & the coastal environment). Soiling of roofing materials reduces the solar reflectance of reflecting materials causing the roof to become a sunlight absorber accelerating materials degradation. Wind can cause vibrations in roofing materials resulting in material fatigue & cracking.	Humidity, rain, condensation, biological, erosive forces, ultra-violet exposure, heat, snow loads, freeze thaw actions, hail damage, friction & material interactions, dissimilar metals & incompatible materials, ponding risks affecting materials, interior spaces, & structural integrity. Design geometry causing corrosive situations (e.g., roof valley failures allowing water access to building interiors, parapet walls & internal downspouts preventing water drainage), inadequate barriers & insulation between corrosive materials).	Barrier failure endangering structural integrity & interior safety including mold, mildew, water damage, flooding. Compromising of the building envelope, encouraging loss of HVAC efficiency & moisture management.
Interior spaces with high humidity, mechanical equipment & plumbing fixtures (e.g., hazardous chemical storage, swimming pool enclosures, chemical treatment areas, research labs,	Enclosed spaces that utilize & store corrosive chemicals must be designed with materials & components that are corrosion resistant. Many hazardous chemicals (chlorine) require specialized corrosion resistant storage. All surfaces are impacted such as doors, valves, &	Chloride containing environments, humidity, temperature, leaks, poor 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 &	Negative impacts to health, morale, safety, maintenance costs, disruption of services to supported systems.

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micro-environments)[5]	structures. Control systems when exposed to moisture, heat & corrosive chemicals deteriorate quickly affecting systems operation.	construction practices, dissimilar metals causing galvanic corrosion, water entrapment & intrusion.	
Heating Ventilation & Air Conditioning (HVAC) Systems[5]	Exterior & interior components exposed to corrosive air borne chemicals. Air borne corrosive pollutants, condensation, leaks, temperature, moisture, & poor humidity control, corrosive chemical reactions, abrasive, pitting, galvanic corrosion, mold, mildew, dissimilar metals, corrosion soils affecting buried chilled water lines. Unmanaged temperature differentials of air, liquid, & or gas in ducts & conduits & surrounding the environment.	Condensation, humidity, airborne contaminants, chloride containing environments, poor air quality, dissimilar metals, mold, mildew, microbiologically induced corrosion. Comprised air barrier, improperly balanced air flow/ducting, inadequate humidity management, failed seals around windows & doors allowing air infiltration. Effects of micro-environment corrosion.	Negative impacts to health, air quality, structural integrity, mold/mildew damage, 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 inside of the building envelope.
Fungi, Mold & Mildew	Condensation, leaks, temperature, moisture, & poor humidity control, mold, mildew, temperature differentials of air, liquid, & gas in ducts & conduits, surfaces, & surrounding the environment increase risk levels. Mold & mildew grow on wood products, ceiling tiles,	Humidity, temperature, leaks, poor air circulation, air borne spores, internal corrosion (H_2S, H_2O, microbiologically induced corrosion), poor design geometrics & construction practices, water entrapment & intrusion. Often molds occur in unseen areas, infrequently accessed, or inaccessible areas	Negative effects to health, morale, safety, maintenance costs, disruption of services to supported systems, sustainment costs, life cycle, & interrupted operations that require well-functioning HVAC & moisture/humidity control. Once mold & mildew have been identified, facility quarantine may be necessary to remove &

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	cardboard, wallpaper, carpets, drywall, fabric, plants, foods, insulation, decaying leaves & other organic materials.	with poor ventilation, exposed to high moisture. Mold spores waft through the indoor & outdoor air continually. When mold spores land on a damp spot indoors, they may begin growing & digesting whatever they are growing on to survive. Molds gradually destroy the things they grow on.	clean contaminated surfaces & materials. Area may require industrial hygiene air quality & surface readiness clearances. Building enclosure integrity affects every aspect of the building envelope. Water, waste, ducting conduits all must be appropriately designed & functioning allowing for the prevention of moisture & air infiltration, removal of condensate & overflow to avoid mold & mildew growth conditions.
Fire Protection & Water Distribution Systems	Component malfunction due to corrosion (sprinkler heads, valves, control systems, etc.) impacting system operation & availability, with associated risk to structure & life safety (See UFC 3-600-01 *Fire Protection Engineering for Facilities*).	Moisture, salt water/air, inadequate coatings, dissimilar metals.	Denial of facility availability, safety, asset protection, high cost of facility replacement, potential loss of life & facility due to loss of a functioning fire protection system.

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 *Joint Engineer Operations*). 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 the Appendix for *Facilities Environmental Severity Classifications (ESC) for DoD Locations in* UFC 1-200-01 *DoD Building Code* *and* the *Environmental Severity Classification Web Page*) to view initial ESC "C" calculations for DoD Installations. To calculate ESC classification, see the Corrosion Toolbox.
4. Factors Contributing to Corrosion:
    a. Atmospheric corrosion factors (Temperature, Time of Wetness (TOW), 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. In areas where condensation may occur at regular intervals such as in cooling pipes and contributes to surface wetness
    d. Stresses on structural materials or components due to strain, compression, elasticity, tensile forces, repetitive actions, and/or high temperatures causing stress corrosion cracking
    e. Corrosive soils
    f. Seawater and other natural waters, such as brackish and river waters, is saturated with dissolved oxygen creating a biofilm promoting the cathodic corrosion reaction.
    g. 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)
    h. Biological (Insects, Bacteria, and Fungi (mold & mildew))
    i. Internal Environments (Pipelines and Tanks)
    j. Erosive Forces (Wind, Rain, Wave Action, Fluid Flow)
5. Locations where micro-environmental factors (for example, prevailing winds, ventilation, waterfront environments, industrial emissions, deicing salt application, possible chemical splash and spillage, adverse weather events such as flooding or wind-driven rain, and penetrations of the building envelope) exist may create a locally corrosive environment regardless of ESC. See the *Environmental Severity Classification Web Page* and UFC 1-200-01 *DoD Building Code* for more

information. Micro-environments with differing environmental severity can occur within a given environment or zone. A good example of a micro-environment is an aquatics area where chlorine or other corrosive chemicals are used; the outside area might be an ESC Zone 2, but the interior of the structure might be a Zone 4 or 5. The cost of management and associated impacts of the “micro-environment” are generally high and are a significant cost of the total project.

6. The *CPC Checklists Tool* contains checklists for assisting in creating and evaluating a CPC Program, accomplishing project development, creating an RFP, establishing a Design Review, performing Quality Assurance, Contractor Quality Control, and Commissioning Programs to best align the facilities program with operational and mission requirements.