CORROSION PREVENTION AND CONTROL PLANNING GUIDEBOOK

SPIRAL 3

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Introduction

I.1 Purpose

This document provides program and project managers with guidance for developing and implementing a corrosion prevention and control program for DoD weapon systems and infrastructure. It includes corrosion-related policy; management planning; and technical and design considerations that should be addressed for a viable design. This guidance is in accordance with the DoD *Corrosion Prevention and Control* policy letter, signed by the Acting Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]), 12 November 2003 (see Attachment 1), and the *Facility Corrosion Prevention and Control* memorandum, signed by the Deputy Under Secretary of Defense for Installations and Environment, 10 March 2005 (Appendix F to Volume III).

Program and project managers—perhaps more than any other group—greatly influence DoD's corrosion-related cost, safety, and reliability impacts during the acquisition of systems and infrastructure. That is why Volumes I and III of the *Corrosion Prevention and Control Planning Guidebook* are targeted to them. The volumes identify the materials, processes, techniques, and tasks required to develop and integrate an effective corrosion prevention and control program during all phases of DoD weapon system and infrastructure development. The objective is to minimize the effects of corrosion on life-cycle costs, readiness, reliability, supportability, safety, and structural integrity.

Volume II of this guidebook focuses on equipment sustainment and includes information on life-cycle logistics and the development of sustainment corrosion programs for weapon systems.

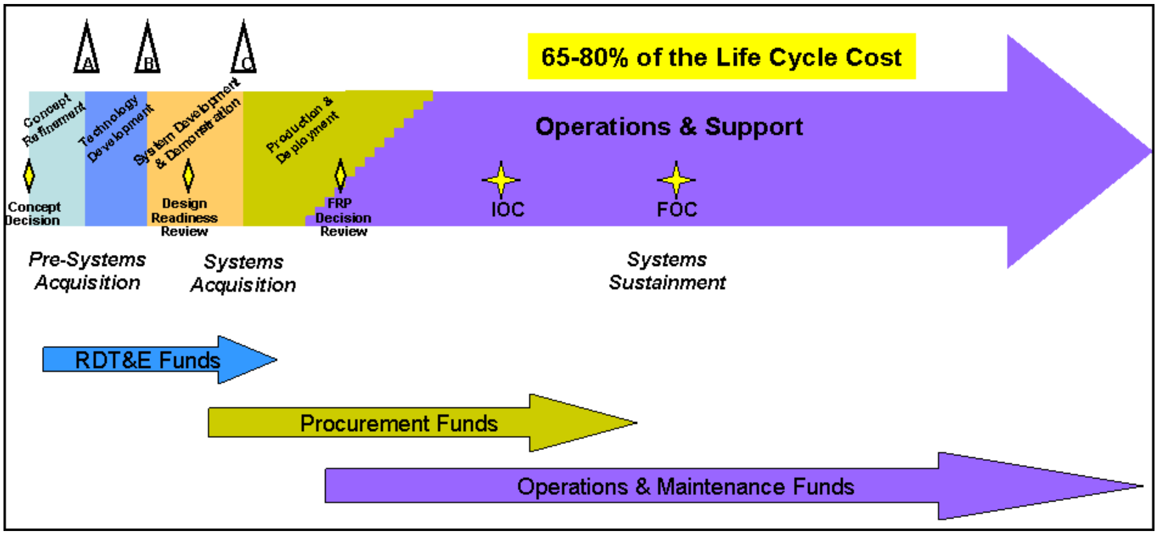
Following the guidance in this document in conjunction with applicable program and technical documentation will result in the best possible balance between acquisition and life-cycle costs for DoD systems.

I.2 Requirement

10 U.S.C. 2228 requires DoD to develop and implement a long-term strategy to address the corrosion of its equipment and infrastructure. A key element of this strategy is programmatic and technical guidance provided in this guidebook. Spiral 3 adds a volume on sustainment and refines the previous acquisition guidance based on corrosion surveys, lessons-learned from program office reviews, and Government Accountability Office audits. For example, GAO-07-618 evaluated the extent to which DoD has incorporated corrosion prevention planning in weapon system acquisition. It should be noted that corrosion prevention and control (CPC) planning is now required for all acquisition programs requiring an acquisition plan in the Defense Federal Acquisition Regulation Supplement (DFARS). While sustainment has been included since the inception of the congressionally directed OSD Corrosion Program, it has not been the focus of the program nor has it been separately addressed in the *Corrosion Prevention and Control Planning Guidebook*—until now.

The importance of both acquisition and sustainment is depicted in the graphic below. Sixty-five to 80 percent of a system's life-cycle costs occur in the sustainment phase. However, most of the decisions (e.g., materiel selection, component reliability, designed maintainability) are determined during the acquisition phase.

Figure 1. Acquisition and Sustainment Phases



I.3 Background

The Department of Defense acquires, operates, and maintains a vast array of physical assets, ranging from aircraft, ships, ground combat vehicles, and other materiel to wharves, buildings, and other infrastructure. These assets are subject to degradation due to corrosion, with specific effects in the following areas:

- *Safety*. A number of weapon system and infrastructure mishaps have been attributed to the effects of corrosion. For example, corroded electrical contacts on F-16s caused "uncommanded" fuel valve closures (with subsequent loss of aircraft), and corrosion-related cracking of F/A-18 landing gears resulted in failures (collapses) during carrier operations.
- *Readiness*. Weapon systems and infrastructure support activities are routinely out of commission due to corrosion deficiencies. For example, corrosion has been identified as the reason for more than 50 percent of the maintenance needed on KC-135 aircraft. Also, corrosion of a fuel pipeline resulted in a leak of hazardous petroleum, oil, and lubricants (POL) material into the environment endangering area water aquifers. Until it was repaired, the loss of the pipeline also affected the ability to transfer fuel, hampering the ability to perform the mission, detrimentally affecting readiness.
- *Financial*. The cost of corrosion to the DoD is estimated to be between $10 billion and $20 billion annually.[1]

[1] United States General Accounting Office, *Opportunities to Reduce Corrosion Costs and Increase Readiness*, GAO-03-753, July 2003, p. 3.

DoD has a long history of corrosion prevention and control. The Department has been a leader in many areas of research (ranging from understanding the fundamentals of corrosion to applying advanced materials, coatings, inhibitors, and cathodic protection for corrosion control); however, it also has very special corrosion-related challenges:

- DoD's assets are getting older in both relative and absolute terms. The current expected—although often not planned—service lives of some aircraft, missiles, ships, and infrastructure are much longer than any comparable commercial assets.
- In order to perform its mission, the Department must train, fight, and sustain infrastructure in all environments, some of which are among the most corrosively aggressive on Earth.
- DoD has unique corrosion-related issues. For example, many coatings used on vehicles and other assets are formulated to perform a special function, such as resistance to chemical agents or maintaining low signature. Corrosion is, at best, a secondary consideration.

Corrosion costs DoD an estimated $10 billion–$20 billion annually. In an attempt to minimize these costs, Congress enacted 10 U.S.C. 2228, which emphasizes DoD management and technical awareness of corrosion prevention and control. Corrosion is a long-term issue that usually affects system operation some time after the system is procured; but the best time to combat the effects of corrosion is early in system development.

According to DoD Directive 5000.1, *The Defense Acquisition System*, corrosion prevention, control, and mitigation will be considered during life-cycle cost tradeoffs. Consideration of operational and logistics capabilities (such as readiness, reliability, sustainability, and safety) is critical to ensure the effectiveness of a weapon system, and is usually accomplished during conceptual design, when the effects of corrosion on these capabilities should be addressed as well. Corrosion is often "out of sight" and, therefore, "out of mind" until a failure occurs; and there is a false perception that corrosion prevention and mitigation can be reverse-engineered later in a system's operational life cycle. The fact is, corrosion can have a significant impact on operational readiness and safety (both by itself and in conjunction with other damage phenomena), and its interactions with these factors should be considered during the conceptual design phase.

National priorities dictate the need for extended service lives for DoD systems and infrastructure. History indicates the effects of corrosion increase with system age, which only amplifies the need to consider corrosion prevention as a primary design parameter. As a consequence, the original designs of weapon systems should include the best materials and manufacturing processes. The only way to ensure an effective, across-the-board response to prevention or a dramatic reduction of corrosion and its effects is to establish a standard DoD corrosion control philosophy and methodology. With a clearly defined methodology, acquisition program managers and infrastructure project managers can initiate and execute plans and actions to employ satisfactory materials and processes.

I.4 Document Structure

This guidebook is structured into three volumes—Equipment Acquisition; Equipment Sustainment; and Facilities Acquisition/Sustainment—as outlined below.

- Volume I, Equipment Acquisition
  - Chapter 1, General Acquisition Program Management
  - Chapter 2, Program Management Corrosion Prevention and Control Planning
  - Chapter 3, Technical and Design Considerations
  - Appendix A, DoD Acquisition Process
  - Appendix B, Example of Charter for Corrosion Prevention Action Team
  - Appendix C, Example for Corrosion Prevention and Control Plan for Systems and Equipment
  - Appendix D, Aerospace Systems Guidelines
  - Appendix E, Navy Ships and Submarines Guidelines
  - Appendix F, FAQs about Corrosion Prevention and Control Planning
- Volume II, Equipment Sustainment
  - Chapter 1, Life-Cycle Logistics
  - Chapter 2, Corrosion Programs for Weapon System Sustainment
  - Appendix A, Equipment Cost-of-Corrosion Baseline Studies
- Volume III, Infrastructure
  - Chapter 1, General Project Management Requirements
  - Chapter 2, Project Management Corrosion Prevention and Control Planning
  - Chapter 3, Technical and Design Considerations
  - Appendix A, DoD Construction Process
  - Appendix B, Example of Charter for Corrosion Prevention Advisory Team
  - Appendix C, Example of Corrosion Prevention and Control Plan for Facilities
  - Appendix D, Facilities and Infrastructure Design Guidance
  - Appendix E, Facilities Cost of Corrosion Results
  - Appendix F, Facility Corrosion Prevention and Control Memorandum
- Attachments (to all volumes)
  - Attachment 1, Corrosion Prevention and Control Memorandum
  - Attachment 2, Acronyms
  - Attachment 3, Principal Integrated Logistics Support Element Definitions
  - Attachment 4, Corrosion Points of Contact—Organization and Personnel
  - Attachment 5, CPC Policy, Regulations, and Directives
  - Attachment 6, Scales, Tables, and Elements

Equipment Acquisition

Volume I Equipment Acquisition
Table of Contents

Figures

1. General Acquisition Program Management Requirements

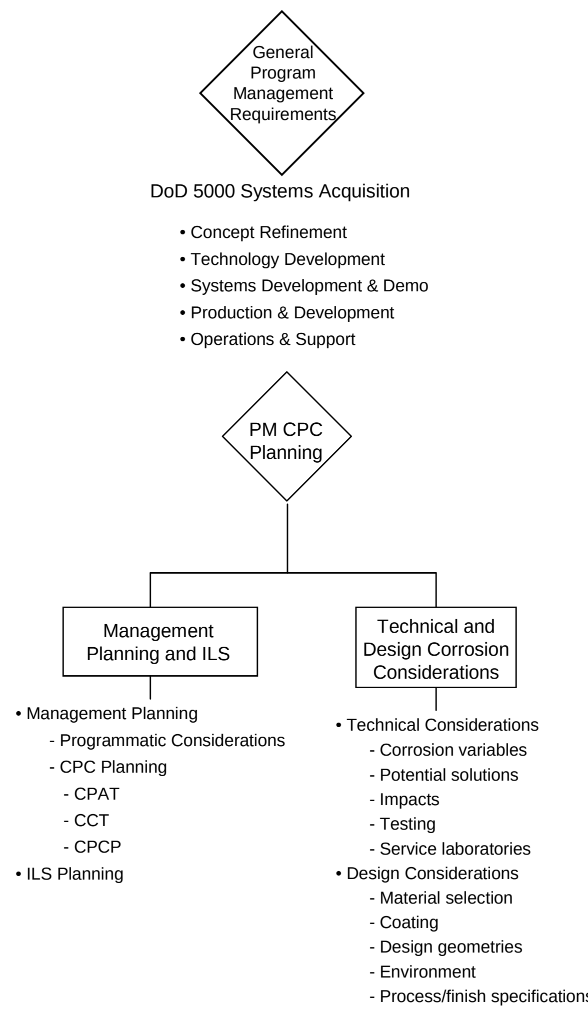
> It is simply good sense and good management to prevent corrosion through better design and selection of materials, and to reduce treatment costs by detecting corrosion earlier and more precisely. Fighting corrosion is just one of the things that we need to constantly do so that we are always ready to perform the fundamental mission of the Department, which is to maintain our national security.[1]
>
> —DoD Corrosion Executive

1.1 Introduction

Program managers—perhaps more than any other group—greatly influence DoD's corrosion-related costs, safety, and reliability issues, regardless of whether it is in the acquisition of new systems or during the sustainment of existing systems. That is why this volume of the *Corrosion Prevention and Control Planning Guidebook* is targeted to them. It identifies the materials, processes, techniques, and tasks required to integrate an effective corrosion prevention and control program during all phases of DoD weapon system and infrastructure development and sustainment. The objective is to minimize the effects of corrosion on life-cycle costs, readiness, reliability, supportability, safety, and structural integrity. Following the guidance in this document in conjunction with applicable program and technical documentation will result in the best possible balance between acquisition and life-cycle costs for DoD systems.

Figure 1-1 outlines the structure of Volume I of this guidebook. The remainder of this chapter further explores the acquisition-related corrosion requirements as they relate to program management. It also identifies general program manager requirements. Chapter 2 outlines specific corrosion-related planning requirements. Chapter 3 focuses on technical and design considerations that may impede or eliminate corrosion.

Figure 1-1. Volume I Organization



[1] *AMMTIAC Quarterly*, Volume 7, Number 4, Winter 2003, p. 9.

1.1.1 Intended Use

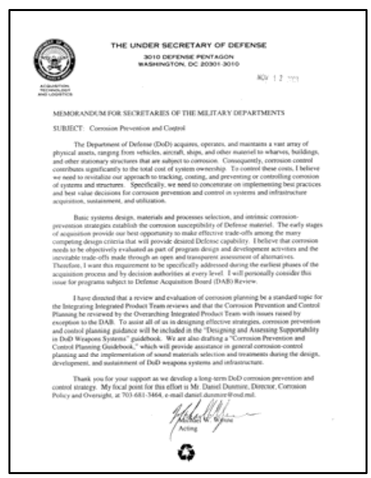
The content of this document is based on broad, in-depth military and industry experience regarding the protection of weapon systems from corrosion and its effects. This volume

- provides tools and techniques for implementing sound material/process selection practices and finish treatments during all phases of DoD weapon system development;
- provides guidance on program management that can be implemented in organizations to address corrosion issues and develop corrosion control plans; and
- describes requirements and methods for
  - establishing and managing a corrosion prevention action team (CPAT) that is appropriately integrated into all design integrated product teams (IPTs) (where applicable), and
  - developing and implementing a corrosion prevention and control plan (CPCP) as described in this document.

1.1.2 Applicability

This guidebook is applicable to all DoD procuring activities (and their respective contractors) involved in the planning, design, and procurement of new DoD systems and the sustainment and upgrade of existing ones. The detailed CPCP and the process/finish specifications apply to all elements of DoD systems, including spare parts.

1.1.3 Policy/Guidance



THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION TECHNOLOGY AND LOGISTICS

NOV 12 2003

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS

SUBJECT: Corrosion Prevention and Control

The Department of Defense (DoD) acquires, operates, and maintains a vast array of physical assets, ranging from vehicles, aircraft, ships, and other materiel to wharves, buildings, and other stationary structures that are subject to corrosion. Consequently, corrosion control contributes significantly to the total cost of system ownership. To control these costs, I believe we need to revitalize our approach to tracking, costing, and preventing or controlling corrosion of systems and structures. Specifically, we need to concentrate on implementing best practices and best value decisions for corrosion prevention and control in systems and infrastructure acquisition, sustainment, and utilization.

Basic systems design, materials and processes selection, and intrinsic corrosion-prevention strategies establish the corrosion susceptibility of Defense materiel. The early stages of acquisition provide our best opportunity to make effective trade-offs among the many competing design criteria that will provide desired Defense capability. I believe that corrosion needs to be objectively evaluated as part of program design and development activities and the inevitable trade-offs made through an open and transparent assessment of alternatives. Therefore, I want this requirement to be specifically addressed during the earliest phases of the acquisition process and by decision authorities at every level. I will personally consider this issue for programs subject to Defense Acquisition Board (DAB) Review.

I have directed that a review and evaluation of corrosion planning be a standard topic for the Integrating Integrated Product Team reviews and that the Corrosion Prevention and Control Planning be reviewed by the Overarching Integrated Product Team with issues raised by exception to the DAB. To assist all of us in designing effective strategies, corrosion prevention and control planning guidance will be included in the "Designing and Assessing Supportability in DoD Weapons Systems" guidebook. We are also drafting a "Corrosion Prevention and Control Planning Guidebook," which will provide assistance in general corrosion-control planning and the implementation of sound materials selection and treatments during the design, development, and sustainment of DoD weapons systems and infrastructure.

Thank you for your support as we develop a long-term DoD corrosion prevention and control strategy. My focal point for this effort is Mr. Daniel Dunmire, Director, Corrosion Policy and Oversight, at 703-681-3464, e-mail daniel.dunmire@osd.mil.

Michael W. Wynne
Acting

Among recent policy accomplishments, the most important may have been the publication of DoD corrosion prevention and control policy guidance.[2] The policy recognizes that "the early stages of acquisition provide our best opportunity to make effective trade-offs among the many competing design criteria that will provide desired Defense capability." Program and project management requirements include the following:

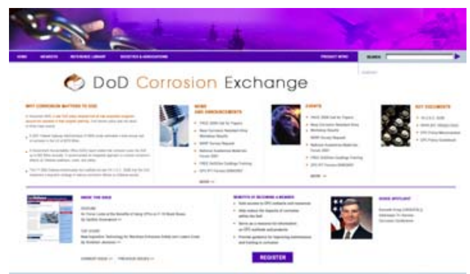
- Make corrosion prevention and control planning an explicit part of performance-based acquisition as well as performance-based logistics, as defined in DoD Directive 5000.1, *The Defense Acquisition Program*.
- Assess and evaluate corrosion planning during the program IPT and the overarching IPT review processes, with issues raised by exception to the Defense Acquisition Board (DAB) (for programs that are subject to DAB review).

[2] USD(AT&L) memorandum, *Corrosion Prevention and Control*, 12 November 2003. See Attachment 1 for a copy of this memorandum.

- Adhere to the corrosion prevention and control guidance in the *Designing and Assessing Supportability in DoD Weapons Systems Guidebook.*[3]
- Implement best business practices and best-value decisions for corrosion prevention and control in system and infrastructure acquisition, sustainment, and utilization.
- Formulate and implement a support strategy that ensures system support and life-cycle affordability considerations are addressed and documented as an integral part of the program's overall acquisition strategy. Specific support strategy requirements are contained in the *Interim Defense Acquisition Guidebook*.[4]

1.1.4 Applicable Documents

Corrosion-related documents from government, industry, academia, and standards organizations are available on the DoD Corrosion website (www.corrdefense.org). The following are examples of applicable documentation:



- DoD's corrosion reports to Congress[5]
- DoD's corrosion points of contact (POCs) (included as Attachment 4)
- The military services' corrosion policies
- Links to corrosion-related laws and regulations
- Links to corrosion-related criteria, specifications, and standards
- Copies of minutes from pertinent conferences and symposia
- Advanced Materials, Manufacturing and Testing Information Analysis Center (AMMTIAC) publications.

1.1.5 Definitions

The term "corrosion" means the deterioration of a material or its properties due to a reaction of that material with its chemical environment.[6] Other key definitions are as follows:[7]

- Corrosion prevention and control is the rigorous application of engineering design and analysis, quality assurance (QA), nondestructive inspection (NDI), manufacturing, operations, and support technologies to prevent the start of corrosion, avoid functional impairment due to corrosion, and define processes for the tracking and repair of corrosion problems.

[3] USD(AT&L), *Designing and Assessing Supportability in DoD Weapons Systems Guidebook: A Guide to Increased Reliability and Reduced Logistics Footprint*, 24 October 2003.

[4] *Interim Defense Acquisition Guidebook*, 30 October 2002, formerly DoD 5000.2-R (dated 5 April 2002).

[5] DoD Report, *Efforts to Reduce Corrosion on the Military Equipment and Infrastructure of the Department of Defense*, June 2007.

[6] Section 1067 of the Bob Stump National Defense Authorization Act for Fiscal Year 2003, Public Law 107-314, enacted 10 U.S.C. 2228.

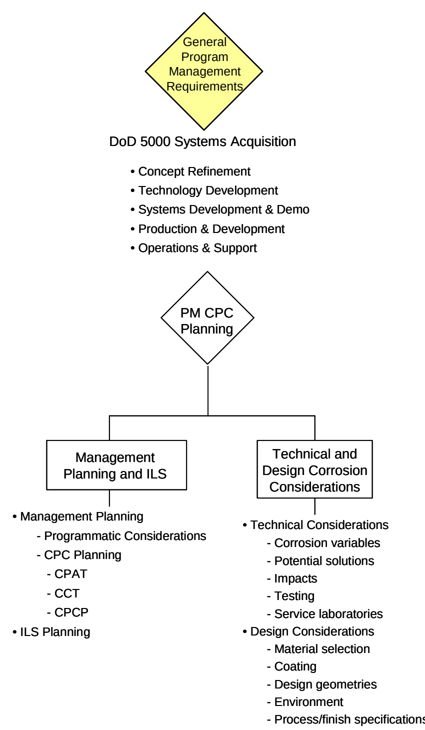
[7] Acronyms are defined in Attachment 2. A complete list of defense acquisition acronyms and terms can be found at http://www.dau.mil/pubs/glossary/preface.asp.

- Integrated product teams are an integral part of the defense acquisition oversight and review process. An IPT is a multifunctional team assembled around a product or service, and responsible for advising the project leader, program manger, or the Milestone Decision Authority (MDA) on cost, schedule, and performance of that product. There are three types of IPTs: program IPTs, working-level IPTs, and overarching IPTs.
- The Defense Acquisition Board advises the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]) on critical acquisition decisions. DAB reviews focus on key principles, such as interoperability, time-phased requirements related to an evolutionary approach, and demonstrated technical maturity.

1.2 General Program Management Requirements

DoD policy requires program managers to accomplish corrosion-related planning during acquisition proceedings. Management for equipment corrosion prevention and control planning specifically applies to systems covered by the DoD 5000-series publications. The need for viable CPC planning is critical to program success.

Effective and viable CPC planning should be smoothly and seamlessly integrated with overall acquisition planning. The initial phases of the acquisition cycle should consider the effects of corrosion on the system and should be reflected in the appropriate documentation. A corrosion prevention and control plan describes how a particular program will implement CPC planning.



1.2.1 Systems Acquisition Community

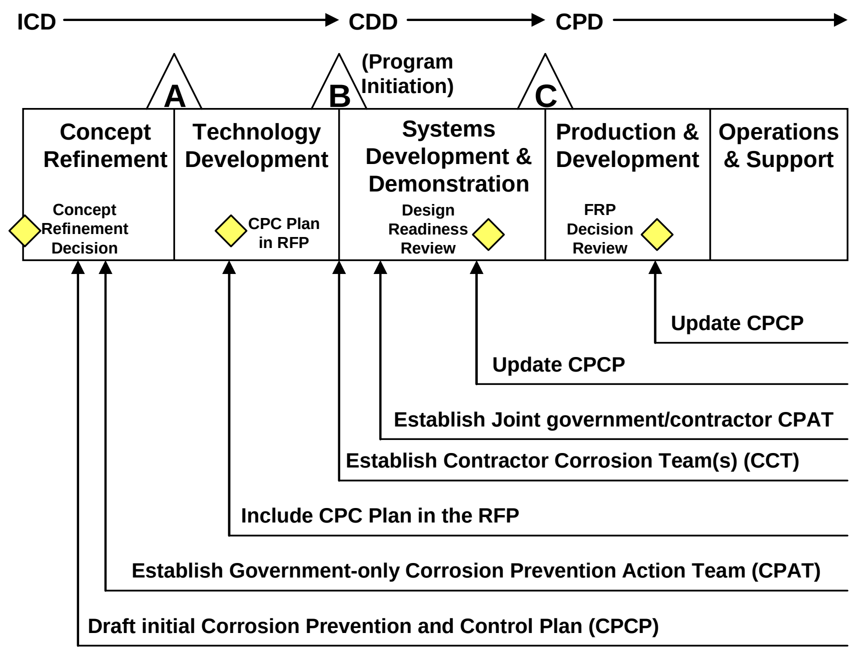
As stated in DoDD 5000.1, *The Defense Acquisition System*, the primary objective of defense acquisition is to acquire quality products that satisfy user needs in a timely manner, at a fair and reasonable price, and with measurable improvements to mission capability and operational support.[8]

Figure 1-2 depicts the acquisition process with the corrosion-related requirements added.[9]

[8] DoD Directive 5000.1, *The Defense Acquisition System*, 12 May 2003, p. 2.

[9] User requirements, including corrosion-related requirements, need to be reflected in the initial capabilities document (ICD), capability development document (CDD), and capability production document (CPD). These documents are explained in detail in Appendix A.

Figure 1-2. Defense Acquisition Process



In general, the program manager and the prime contractor should translate the corrosion prevention requirements into a request for proposal (RFP), performance specifications, and all CPC planning. When developing a system, the CPCP should address the

- establishment of the Corrosion Prevention Action Team;[10]
- development of a process or finish specification;
- environmental testing and verification plans;
- procedure to ensure corrosion prevention and control at the component, assembly, and system levels; and
- guidance for development of corrosion-related technical manuals and maintenance concepts.

Appendix A presents a more complete discussion of the capability documents (initial capabilities document [ICD], capability development document [CDD] and capability production document [CPD]) that are used to implement corrosion control during the DoD acquisition process.

Lesson Learned: Determine corrosion requirements from these documents. If not documented, ask the user about the expected equipment's operational environment as it pertains to corrosiveness.

[10] GAO-07-618, *High-Level Leadership Commitment and Actions are Needed to Address Corrosion Issues*, recommended the Secretary of Defense and the Under Secretary of Defense for Acquisition, Technology, and Logistics provide the necessary leadership and commitment to, "Require major defense acquisition programs to prepare a corrosion prevention advisory team as early as possible in the acquisition process." April 2007, pp. 16 and 17.

1.2.2 System Verification Plan in Acquisition

The system verification plan should include and define the types and levels of corrosion testing that should be incorporated in the environmental test and verification plan. Operational environmental testing should be done at the component, subsystem, and system levels, as appropriate. It should provide the rationale for verification of the corrosion design. This plan should reflect the environmental spectrum expected over the life of the weapon system and the method for monitoring and tracking exposure such that environmental effects can be evaluated. Standard government or industry test methods should be used when possible. The component or subsystem testing should reflect both the severity and duration of exposure.

Success criteria should include both retention of functionality and freedom from required corrosion repair per specified performance requirements. Qualification should be based upon environmental exposure testing to the system requirements. Qualification by analysis or similarity should be on an exception basis only, with the concurrence of the CPAT. Corrosion criteria should be included in full-scale testing, including reliability and environmental testing.

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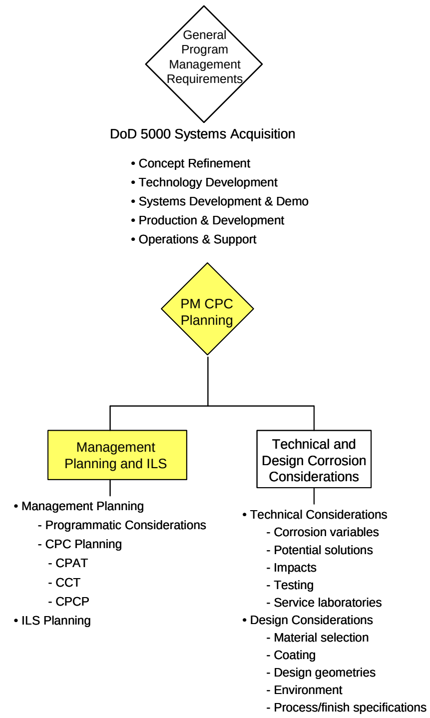
The next chapter covers program management corrosion prevention and control planning.

2. Program Management Corrosion Prevention and Control Planning



Program managers and procuring agencies should consider corrosion prevention and control a key issue in designing, procuring, and maintaining a DoD system and associated facilities. There are two primary aspects to CPC planning:

- Management of the planning
- Technical and design considerations (e.g., requirements and tradeoffs) that lead to viable CPC planning.

While implementation methods and procedures will vary by system and responsible service or agency, it is critical to maintain the intent of these two requirements. Any viable DoD CPC planning should contain these two basic elements.

The remainder of this chapter covers management planning, while Chapter 3 details technical and design corrosion considerations.

2.1 DoD Corrosion Performance Specification Issues

DoD acquisition reform over the last decade has resulted in a shift from traditional military specifications and standards to more commercial and performance-based specifications. This shift challenges the program, project, or engineering manager or designer to develop a meaningful performance specification for corrosion. Several programmatic and technical points must be considered for effective implementation of corrosion performance specifications in DoD acquisition programs. These are detailed in the Management Planning and Integrated Logistics Support (ILS) sections (this chapter) and the Technical and Design sections (Chapter 3).

> Lesson Learned: Corrosion requirements should be specific and not derived from other performance parameters.

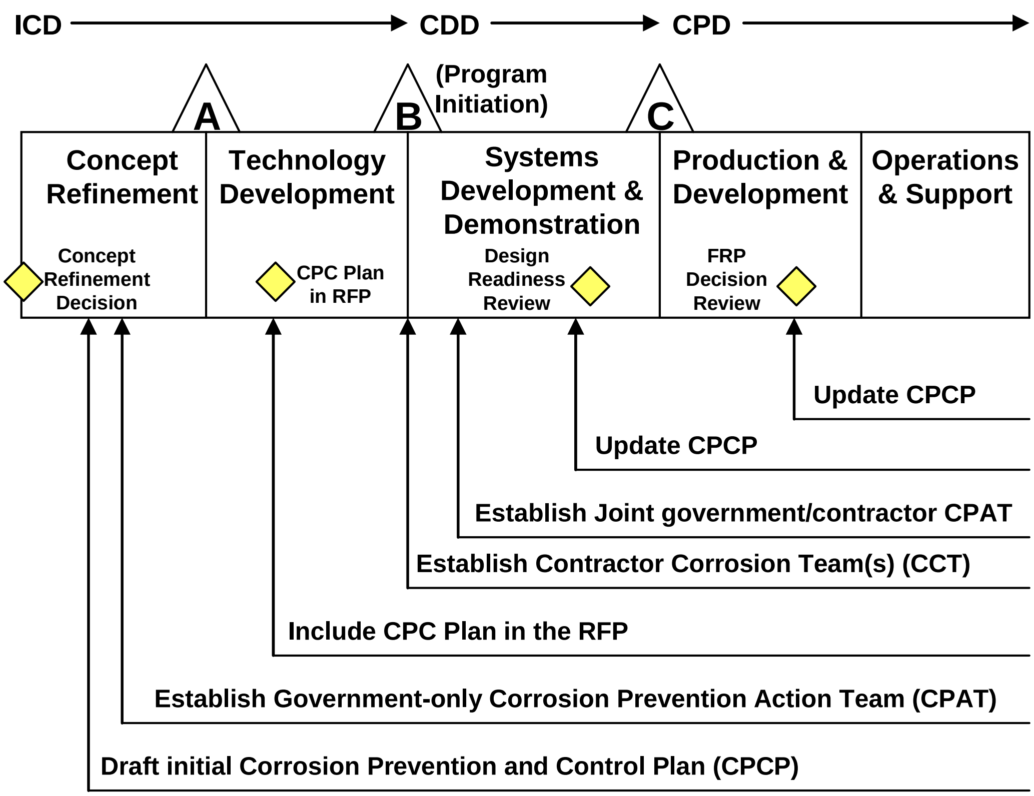
2.2 Management Planning

2.2.1 CPC Planning

To achieve viable CPC planning, program managers should complete the following:

- Prepare a corrosion prevention and control plan as early in a program or project as possible. In the case of weapon systems, the program manager should generate the document no later than Milestone B, Program Initiation.
- Implement the CPCP with an accompanying process/finish specification and organize the Corrosion Prevention Action Team.

Figure 2-1. Defense Acquisition Process



The corrosion prevention and control plan should

- define CPC requirements;
- list applicable specifications and standards;
- address facility or system definition, design, engineering development, production or construction, and sustainment phases, ensuring they are consistent with the design life and affordability of the system;
- establish the management structure to be used for the peculiar system/facility being designed, procured, and maintained, including a CPAT;

- prescribe the membership and organization of the CPAT, describe basic duties of team members, define operating procedures, and prescribe appropriate specifications and standards used in the systems/facilities;
- include the process/finish specification (materials and processes for corrosion prevention and control)[1] that specify the detailed finish and coating systems to be used on the procured weapon system; and
- address sustainability and logistics considerations.

> Lesson Learned: Boilerplate CPC plans are ineffective. CPC plans should be tailored to address specific program requirements.

2.2.2 Programmatic Considerations

Programmatic considerations are part and parcel of the DoD acquisition process. These include acquisition cost, warranties, and the priority of corrosion control in acquisition or construction.

2.2.2.1 Acquisition Cost

Implementing effective corrosion control that reduces life-cycle cost may increase the new unit procurement cost.

The program manager should balance the cost of improved design for corrosion against the life-cycle costs for the system. This may be difficult unless objective measures for corrosion control effectiveness are established.

2.2.2.2 Warranties

With a warranty, the seller essentially assures the buyer that the product will perform as represented over a period of time. If the product fails to perform as represented, the seller may be required to provide a new product or satisfactorily repair the existing product. With respect to corrosion in DoD procurements, such agreements are typically hard to enforce.

- A warranty has little value in a critical situation. Replacement or repair of a corroded part is meaningless to personnel under fire or when the failure has resulted in property damage, personnel injury, or mission capability degradation.
- The terms of warranties are often complex. This may result in burdensome record keeping and may constrain DoD’s flexibility with respect to maintenance procedures.
- The terms can also be somewhat subjective, such as when corrosion affects appearance and objective measures of performance are not available. Previously, many corrosion maintenance actions were considered discretionary until system functionality was affected. Today, however, maintenance concepts and reliability considerations do not allow for deterioration to the point of functional failure.

[1] The specification will be in accordance with CPCP approved process/finish specifications and standards.

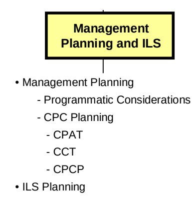
2.2.2.3 Priority of Corrosion Control in Acquisition/Construction

While logistics support has long been recognized as a critical aspect of any procurement, the life-cycle costs incurred as a result of corrosion have only recently received substantial attention. Strong CPC planning often takes a back seat to tactical or strategic capability during budget considerations and definition of constraints.

> Lesson Learned (Other Funding Sources): CPAT may advocate for separate funding to address the issues of concern when there is not program money for studies or R&D to validate the need for such changes. Programs should also make use of alternative sources of funding for R&D needs, such as the sponsoring of topics for the Small Business Innovative Research (SBIR) program, various environmental programs, such as Environmental Security Technology Certification Program (ESTCP), Strategic Environmental Research and Development Program (SERDP), Commercial Technologies for Maintenance Activities program (CTMA), and Value Engineering.

2.2.3 Corrosion Prevention and Control Planning

While corrosion prevention and control planning actually begins before an RFP or specification is developed, the majority of the activity associated with CPC planning occurs after contract award. The initial CPCP requirements should be developed before the RFP to guide the insertion of the program's or project's corrosion planning into the RFP. The initial CPCP also guides the initial performance specification development. CPC planning consists of the following:



- Establishment of the CPAT, which, along with the CCT, guides the direction of CPC planning
- Documentation that implements and reflects the CPC planning
- Actual design, manufacture or construction, testing, and support of the system.

> Lesson Learned: Make CPC part of the source selection criteria and the CPC plan a deliverable documentation requirement.

> Lesson Learned: For commercial derivatives or commercial off-the-shelf systems, insight into the corrosion resistance can be obtained by requesting a list of the top replacement items for corrosion and their replacement frequency.

2.2.3.1 Corrosion Prevention Action Team

2.2.3.1.1 Establishment and Scope

The roles of the CPAT and requirements of when to establish a CPAT—required for all ACAT I programs—vary depending on the type of program. For an acquisition program, form the initial CPAT as early as possible, but certainly as soon as a program manager is assigned (shortly after Milestone B, Program Initiation). An example of a CPAT charter is provided as Appendix B.

The CPAT is actively involved in the review of all design considerations, material selections, costs, and documentation that may affect corrosion prevention and control throughout the life of the system or facility. The CPAT advises the program manager on corrosion-related issues, confirms the adequacy of the corrosion maintenance documentation and guidance as they are developed, and elevate unresolved issues to the Office of the Secretary of Defense Overarching IPT (OIPT). Attachment 4 contains corrosion points of contact for DoD, the Coast Guard, NASA, and selected private sector organizations.

2.2.3.1.2 Membership

A representative of the procuring activity should chair the team, which should include representatives from the contractor's organization and from DoD.

- *Prime contractor members* (once the contract is awarded). The contractor's team members should be authoritative representatives of the contractor's organizations. They ensure proper materials, processes, and treatments are selected and properly applied and maintained from the initial design stage to the final hardware delivery or final construction.
- *DoD members*. The DoD team is designated by the program or project manager and includes all involved military services. Membership from the services should include, but not be limited to,
  - program engineering and support;
  - individual service corrosion program office, technical authority, or the equivalent; and
  - subject matter experts, which may include
    - individual service laboratory material engineers,
    - corrosion personnel from the user command,
    - information analysis center personnel (such as AMMTIAC), and
    - operational test personnel.

Lessons Learned (Personnel Resources and Expertise):

- Address Manpower Need: Early on, program managers should devote adequate manpower to address corrosion issues. While individual programs are charged with this responsibility, increased external emphasis is also needed to assure proper focus. This challenge is being addressed via the DoDI for corrosion, service corrosion executives accountable for this emphasis, etc.
- CPC Training Classes: All CPAT members should be encouraged or required to take the Corrosion Prevention and Control Overview course (Continuous Learning Module [CLM] 038) and subsequent corrosion education courses available on the Defense Acquisition University (DAU) website (https://learn.dau.mil/html/clc/Clc.jsp).
- CPAT Workshop: All CPAT chairpersons and contractor corrosion control team leaders should be encouraged or required to participate in at least one CPAT workshop annually. CPAT workshop announcements will be made available at www.corrdefense.org.
- CPAT Policies, Requirements, Instructions, and Guidance: CPAT leadership should be knowledgeable of corrosion policies, requirements, instructions, and guidance. See Attachment 5.
- User Participation: User involvement and feedback is extremely important, and user involvement in the CPAT should be solicited from the team's inception.

2.2.3.1.3 CPAT Duties

DoD team members have several responsibilities:

- Interface with the contractor corrosion team to ensure the goals outlined in this guidebook are attained.
- Monitor all activity during design, engineering, testing, and production.
- Advise the program or project manager on corrosion-related issues and identify risks as well as corrosion prevention opportunities.
- Attend appropriate CCT meetings.
- Advise the program on technical issues to be resolved.
- Review and resolve discrepancies submitted by the program or project manager.
- Schedule reviews as frequently as deemed necessary by the chairperson.

Lesson Learned (Independent Review): Contractors often have subtle, and sometimes overt, control of changes for improved corrosion performance. It is the role of the CPAT to independently review, analyze, and recommend actions to the program manager in such cases. Where appropriate action does not result, CPAT members may individually elevate their concerns via their separate organizations.

To evaluate the adequacy of the contractor's efforts in corrosion prevention and control, the program or project manager retains authority to conduct scheduled periodic reviews of the contractor's design and the contractor's and subcontractor's facilities where critical parts and assemblies are being fabricated, processed, assembled, and readied for shipment.

2.2.3.1.4 Corrosion Technical Manual Guidance and Corrosion Maintenance Concept Definition and Specifics

The CPAT should provide its recommendations to the program or project manager as to the adequacy of the corrosion maintenance documentation and provide guidance as they are developed. Reliability-centered maintenance (RCM) may be used to assess the adequacy of maintenance documentation and guidance.

2.2.3.2 Contractor Corrosion Team

2.2.3.2.1 Membership

The membership of the contractor corrosion team should include representatives from the project design IPTs, material and process engineering, operations and manufacturing, quality control, material (or subcontractor) procurement, and contracts. This representation is intended to be flexible, and the recommended membership may be altered.

A CCT chairman will be selected and serve as the manager of the CCT and the contractor focal point for the program.

2.2.3.2.2 CCT Duties

The primary function of the CCT is to ensure adequate corrosion prevention and control requirements are planned and implemented for systems during all phases of the system life cycle, and for facilities during all phases of the design and construction process. CCT duties should be outlined in the CPCP, which should be part of the initial contract. Specific CCT responsibilities include the following:

- Ensure the appropriate documents outlined under section 2.2.4 are prepared and submitted in accordance with the required schedule.
- Obtain the necessary design reviews, clarification’s, resolutions of any differences in technical position, and final approval of the documentation on a timely basis.

The chairperson or designee should

- establish periodic meetings as required to resolve problems as they occur;
- convene other meetings if a critical or major problem arises and requires action by the team;
- notify all DoD and contractor members of each meeting date, the topics to be discussed, and any decisions resulting from the previous meeting;
- sign off on all production drawings after review of material selection, treatments, and finishes;
- maintain a continuous record of all action items and their resolutions; and
- establish the principal tasks to be accomplished to implement corrosion prevention and control procedures in all phases of construction, or in the system contractor and subcontractor manufacturing facilities.

2.2.4 Corrosion Prevention and Control Plan

The purpose of a CPC plan is to

- set up the CPC program/project management approach,
- document corrosion-related design needs, and
- identify materials and corrosion control methods for use in the manufacture or construction of the system or facility.

The initial draft of the CPCP should be completed before a program's Milestone B or as early as possible in the program. The plan should describe the specific anticipated CPC measures to be implemented. An example of a CPCP for systems and equipment is provided at Appendix C.

After contract award, the CPCP should be

- maintained by the contractor (or contractor team) and approved by the CPAT and program or project manager; and
- revised as required to properly record changes to materials and processes being used for corrosion prevention and control. Through design studies, analysis of failure reports, and weapons systems inspections, data should be collected for analyses of required revisions to this document.

Copies of the major revisions to the document should be formally submitted to the Defense Technical Information Center (DTIC) so the CPAT's accomplishments are preserved and future programs can benefit from legacy knowledge as they prepare their respective CPCPs.

At a minimum, the CPCP should provide the following information:

- The organization, procedures, and responsibilities for a CCT
- Roles and responsibilities of quality assurance, process control, production operations, manufacturing planning, environmental compliance, personnel safety, and other contractor organizations for the CPC effort
- A discussion of corrosion prevention techniques employed in design and how the design will meet the projected environmental spectrum
- Specifications (process/finish specifications in systems) that outline the application of coatings and other corrosion prevention compounds (if any) and that address personnel training and qualification, material inspection, surface preparation, and coating or compound application procedures
- Any test data developed, or to be developed, for coatings or other corrosion-related materials and processes
- Identification of coating-substrate combinations for which no testing is to be performed, with an assessment of risk levels in the absence of testing
- Recommended specific corrosion control maintenance.

2.3 Integrated Logistics Support as It Applies to the CPC Program

2.3.1 ILS Policy

It is Department of Defense policy to include adequate and timely logistics support planning (including corrosion prevention and control planning) in all phases of the acquisition of defense systems and equipment. Specific performance-based logistics (PBL) guidance states

> PMs shall develop and implement performance-based logistics strategies that optimize total system availability while minimizing cost and logistics footprint. Trade-off decisions involving cost, useful service, and effectiveness shall consider corrosion prevention and mitigation. Sustainment strategies shall include the best use of public and private sector capabilities through government/industry partnering initiatives, in accordance with statutory requirements.[2]

Integrated logistics support is realized through the proper integration of logistics support elements (part of the system engineering process) and the application of logistics considerations as they apply to corrosion prevention and control decisions made during the equipment design phase. The optimum balance of an item of equipment is somewhere between its capability and availability to perform a specified military requirement. This goal can only be achieved by including logistics support considerations in all stages of the CPCP, from formulation and validation of the concept, through engineering design and development, to test and evaluation, production, deployment, and operation. In applying the concept of ILS to system or equipment acquisition, it is important to maintain a proper perspective and remember that logistics support is not an end in itself. ILS exists only to support the operation of the system or equipment to which it is related; therefore, it must be considered as the CPCP evolves.

2.3.2 ILS Elements

In addition to integrating support planning into the entire CPCP design and development process, the elements of logistics support (which are listed below and expanded upon in Attachment 3) should be integrated with each other and into the CPCP:

- Maintenance plan
- Support and test equipment
- Supply support
- Transportation and handling
- Technical data
- Facilities
- Personnel and training.
- Logistics support resource funds
- Logistics support management resources

[2] DoDD 5000.1, *The Defense Acquisition System*, Enclosure 1, paragraph E1.17, 12 May 2003.

When the baseline of any one logistics element is changed—or proposed to be changed—because of a corrosion process application, the effect on all other logistics elements and on the total system/equipment must be considered formally, with the necessary adjustments made.

The key to effective application of the ILS process to the CPCP is a systematic and orderly management process through which the Corrosion Prevention Action Team can identify logistics actions and requisite decisions quickly and can present them to the program manager.

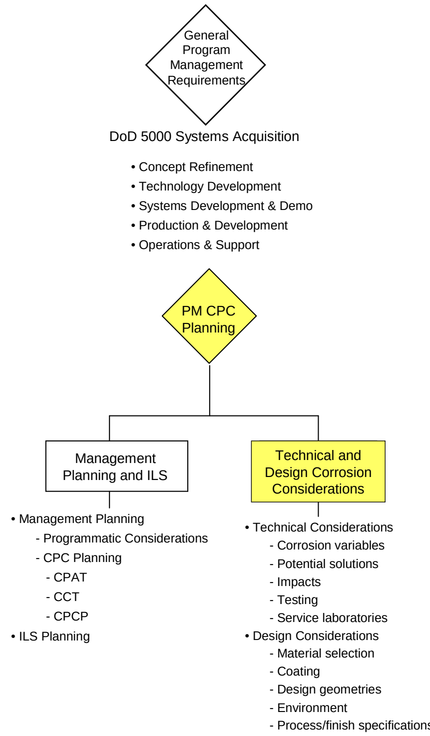
3. Technical and Design Considerations

The design of DoD weapon systems requires the proper blend of safety, affordability, and environmental needs with mission and operational requirements. DoD systems or facilities should

- perform reliably,
- require minimal maintenance over a specified lifetime, and
- deteriorate at a rate that permits maximum service life.

Materials, manufacturing methods, and protective treatments that reduce deterioration failures should be considered during the selection of suitable materials and appropriate manufacturing methods that will satisfy system requirements. The following are among the deterioration modes that contribute to failures:

- General corrosion
- Galvanic corrosion
- Pitting corrosion
- Concentration cell corrosion
- Dealloying
- Intergranular corrosion
- Stress corrosion cracking
- Hydrogen embrittlement
- Corrosion fatigue
- Flow-assisted (erosion) corrosion
- Fretting corrosion
- Stray current corrosion
- Fungus growth



The CPCP and program specifications should detail specific requirements. To assist program managers and others participating in the acquisition of aerospace-related systems, a set of aerospace system guidelines has been developed and included at Appendix D. Likewise, a set of naval ship guidelines has been developed and included at Appendix E.

Fundamentally, the design and design disciplines should allow for the evaluation of the following general approaches:

- Selecting the right materials and manufacturing processes
- Applying protective coatings as necessary

- Using proper corrosion prevention and control designs
- Modifying the environment.

The design should also attempt to eliminate corrosive contaminants. If materials are to be exposed to contaminants, precautionary measures should be taken throughout the design phase to minimize deterioration of individual parts and assemblies (as well as the entire system). Precautionary measures are included in the technical and design considerations discussed below.

3.1 Technical Considerations

Corrosion performance is both an attribute of an entire system and the sum of the performance of components or individual items. Technical considerations in the implementation of effective corrosion performance specifications include the following.

3.1.1 Variables Influencing Corrosion

The following variables influence corrosion:

- The interrelationship between materials and their specific environments
- The effects of design (including configuration and coatings), manufacture or construction, operation, and maintenance
- Corrosion performance specifications for complex systems. (These should be addressed first at the component or item level.)

3.1.2 Potential Solutions to Corrosion Problems

The large number of variables influencing corrosion performance lead to an equally large number of potential solutions, some of which might not be compatible.

A thorough review of relevant technical literature is essential for making informed decisions for corrosion performance requirements. Written corrosion specifications should be sufficiently flexible to allow the designer and manufacturer to consider the entire range of potential solutions.

3.1.3 Assessments of Corrosion Impacts in Acquisition

Because corrosion affects both function and appearance, an accurate assessment of its effects on acquisition systems is difficult:

- The potential loss of function due to corrosion can often be quantified through physical measurements. These may include plating thickness loss, pit depth measurements, torque measurements, and conductivity measurements. Quantitative assessments are costly and, as a result, are typically applied to critical items only.
- Hidden corrosion is difficult to detect and is a major problem.

- Degradation in appearance is typically evaluated in very subjective terms through comparison with visual standards, such as those specified in technical manuals and technical society standards.
- Methods and equipment for corrosion monitoring and inspection should be considered in the development of design and maintenance concepts.

3.1.4 Accelerated Corrosion Tests in Acquisition

Corrosion is a time-based phenomenon. As such, accelerated corrosion tests cannot always determine correlations between corrosion and service performance. Some tests can be predictive (for example, exposure of *x* hours in test simulates *y* years of service life), but most tests cannot make exact correlations. Accelerated tests

- are most useful for ranking the relative performance of materials, coatings, etc. in a specific environment and application in comparison to a known system; and
- often do not adequately reflect the effects of design changes, substantial material changes, and maintenance cycles.

> Lesson Learned (Life Requirements by Qualification Testing): Where corrosion requirements are not specific, strong corrosion requirements from life requirements via qualification testing are necessary to verify life expectancy.

The design of environmental tests and verification planning should duplicate both the levels and types of damage expected from the environmental spectrum defined for the system. This may be achieved by a combination of environmental tests that capture the critical aspects of the exposure, such as wet-dry cycles, specific corrodents, and geometric configurations.

- Accelerated corrosion testing, in conjunction with mechanical testing, should provide insight into the capabilities of the protective systems and allow projections of damage growth in order to facilitate corrosion management.
- The inspection and testing of facility components should be designed to consider both the levels and types of damage expected from the known environmental spectrum for the facility systems. The following variables need to be considered when developing a plan for inspection and testing:
  - Temperature
  - Exposure
  - Pressure
  - Wet-dry cycling.

Lessons Learned (Technical):

- Test and Acceptance Criteria: Defaulting solely to MIL STD 810 test requirements for corrosion will often lead to inadequate materials, processes, and corrosion designs, as specified in MIL STD 810(D) itself. Program managers should consult with corrosion subject matter experts to develop test and acceptance criteria for corrosion.
- Outdoor Exposure: OE testing of the complete configuration to augment accelerated laboratory corrosion testing greatly reduces the risk of unexpected corrosion resulting from factors or changes not considered in the original design.
- Induced Damage Simulation: Prior to corrosion testing, artificially induced damage that simulates what occurs in service increases confidence in the robustness of the corrosion design.

3.1.5 Service Laboratories

The service laboratories may be able to provide added technical guidance. Similarly, AMMTIAC may be able to assist in the preparation of CPCPs and provide direct support through the CPAT.

Lesson Learned (Analysis of Trade Studies): Corrosion often competes with other performance parameters, such as environmental stewardship and low observability. A CPAT review and analysis of trade studies with strong documentation and recommendations to program managers can be effective in preserving corrosion requirements.

3.2 Design Considerations

There are specifications and material selection criteria that should be considered as early in the planning process as possible (and included in the CPCP).

3.2.1 Material Selection

If possible, materials that are unsuitable to the operational environment should be avoided. Consider compatibility when using multiple materials. If dissimilar materials cannot be avoided, isolate those materials from each other. Information sources include the following:

- The *Cambridge Material Selector* (accessible from Granta Design Limited, Material Information Solutions, (http://www.grantadesign.com)
- DoD Corrosion website (http://www.corrdefense.org)
- MIL-STD-889, *Dissimilar Metals*.

3.2.2 Protective Coatings

The CPAT should consider protective coatings to isolate vulnerable materials from the environment.

3.2.3 Design Geometries

Avoid crevices when possible. Avoid design features that make it difficult for protective coatings to function (sharp corners, for instance), and avoid geometries that unnecessarily trap moisture.

3.2.4 Environmental Modifications

When it is necessary for a portion of the system to be exposed to the environment, consider a design that allows for the modification of the environment. Dehumidification and sheltering can be effective means for modifying the environment.

3.2.5 Process/Finish Specification or Equivalent Document in Acquisition

The prime contractor should prepare a process/finish specification or an equivalent document as soon after Milestone B as possible, but prior to Milestone C. This specification document should identify the specific organic and inorganic surface pretreatments and coatings and other corrosion prevention and control materials and processes intended for use. After it has been approved by the responsible DoD procuring activity, all requirements from the specification document should be included in all applicable production drawings and maintenance documents.

Appendix A
DoD Acquisition Process

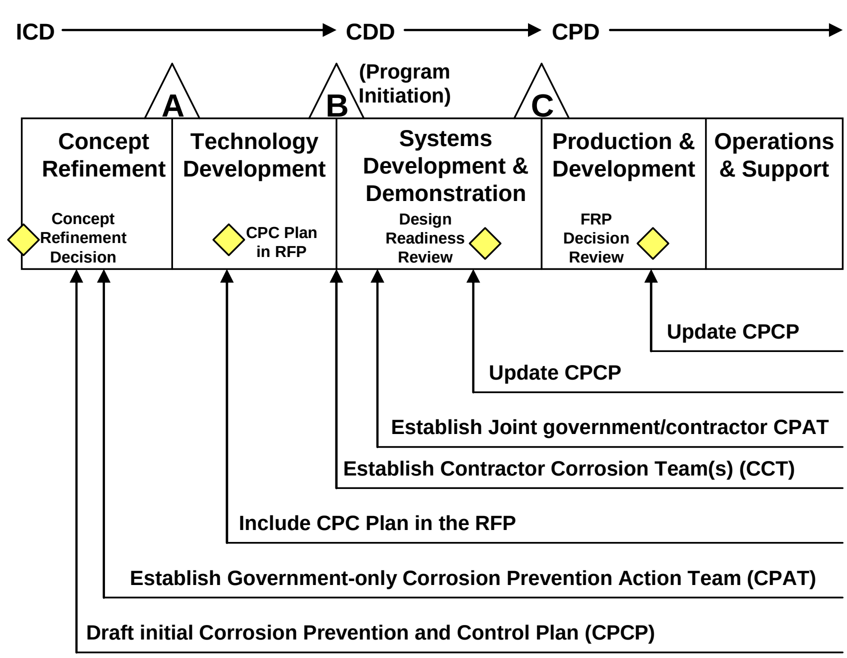
This appendix provides additional background information on DoD's acquisition process that is too detailed to include in Chapters 1, 2, or 3. Readers who require specific acquisition information for decision-making are encouraged to consult the department's acquisition website for current and detailed information (http://akss.dau.mil/jsp/default.jsp).

The capabilities documents that may be used to implement corrosion control during the DoD procurement process are discussed below, and are addressed in CJCSI 3170.O1C. All major defense acquisition programs (MDAPs) are required to have

- an initial capabilities document (ICD),
- a capability development document (CDD) that is validated and approved prior to a Milestone B decision, and
- a capability production document (CPD) that is validated and approved prior to a Milestone C decision.

Mission need statements (MNSs) and operational requirements documents (ORDs) are being phased out and should only be modified if allowed by the Milestone Decision Authority or by directive. Typically, procurements also involve the development of a specification and a request for proposal (RFP) at some point during the procurement process.

Figure A-1. The Acquisition Process and CPC Planning



Initial Capabilities Document

The ICD

- establishes the need for a materiel approach to resolve a specific capability gap;
- defines
  - the capability gap in terms of the functional areas,
  - the relevant range of military operations, time, obstacles to overcome, and
  - key attributes with appropriate measures of effectiveness (e.g., distance effect, including scale); and
- proposes the recommended materiel approach based on analysis of the relative cost, efficacy, sustainability, environmental quality impacts, and risk posed by the materiel approach under consideration.

Normally, an ICD is not updated once it has been approved. The CDD and CPD, however, continue to refine the material approach to address the capability gap.

The ICD, CDD, and CPD describe top-level capability gaps and identify top-level alternatives; corrosion-related wording should be at a similar level. Most importantly, the expected operational environment as it pertains to corrosiveness should be clearly identified. The ICD should discuss whether corrosion (either through cost or impact on readiness) played a role in creating a deficiency. The following statements are examples of corrosion-related wording that should be considered for inclusion in the ICD:

- "Existing systems have been unable to meet required maintenance periodicity as a result of corrosion."
- "Corrosion occurring on existing systems places a large cost and labor-hour burden on the maintenance infrastructure."
- "Excessive corrosion on existing systems has resulted in reduced readiness."
- "The system is expected to operate under severe operational and environmental conditions. The system maintenance should be performed in compliance with Environmental Protection Agency guidelines in effect at the time of the procurement and with minimal use and generation of hazardous materials or ozone-depleting chemicals."
- "The system should meet operational, support, and readiness requirements in all climates and types of terrain where the system may be based or deployed."
- "The system will be supportable within the current accepted maintenance concept."

Capability Development Document and Capability Production Document

The CDD

- takes its guidance from the ICD, the analysis of alternatives, and technology development activities;
- captures information necessary to develop the proposed programs;
- outlines an affordable increment of a capability;[1] and
- provides the operational performance attributes, including supportability, necessary for the acquisition community to design the proposed system. (Corrosion-related wording should address how corrosion would impact system performance.)

The CPD

- addresses the production attributes and quantities specific to a single increment of an acquisition program;
- is finalized after the critical design review when projected capabilities of the increment in development have been specified with more accuracy; and
- supersedes the performance values used in the CDD.

The following statements are suggested wording for use in the CDD and the CPD. A finer level of fidelity can be inserted as the program progresses through Milestones B and C:

- "The system is expected to meet the operational, support, and readiness requirements in all types of climate and terrain where the system may be based or deployed."
- "The system is expected to operate under severe operational and environmental conditions. Common tools; standard maintenance practices; and standard, common, or general purpose support and test equipment will be used to the maximum extent possible. Maintenance of the system will be performed in compliance with the National Environmental Policy Act (NEPA) and other pertinent environmental and safety guidelines in effect at the time of the procurement."
- "Existing systems have been unable to meet required maintenance periodicity as a result of corrosion."
- "Corrosion occurring on existing systems places a large cost and labor-hour burden on the maintenance infrastructure."
- "Excessive corrosion on existing systems has resulted in reduced readiness."
- "The system should meet readiness and logistics requirements in anticipated corrosive environments: (provide specifics on the environment)."

[1] An increment is a militarily useful and supportable operational capability that can be effectively developed, produced or acquired, deployed and sustained. Each increment will have its own set of attributes and associated performance values.

- “The system operational availability should be reduced by no more than 1 percent (zero is the objective) from corrosion due to exposure to environmental conditions.”
- “The system should have a mean time between failures (MTBF) for corrosion-caused failures of greater than or equal to *xx* hours.”
- “The system should have a mean time to repair (MTTR) for corrosion-related damage of less than or equal to 1 hour throughout its lifetime (half-hour objective).”
- “The system will be supportable within the current accepted maintenance concept.”
- “The system should be designed for corrosion-related preventative maintenance (PM) to be accomplished at the organizational level.”
- “The system should not require the use of special tools, maintenance practices, nor test equipment for corrosion-related maintenance.”
- “The system should provide training for operators and trainers to perform their duties for corrosion prevention and repair.”
- “The system should provide technical and repair manuals that describe the corrosion prevention measures used on the system and provide guidance for restoration, repair, and replacement.”

Request for Proposal and Specifications

Requests for proposal and specifications define, in detail, the desired performance of the system being procured. RFPs are the precursor to the final system specification. Recurring procurements can then be made to the final system specification.

Request for Proposal

When beginning the contracting process for a new system or system modification, it is critical that program managers complete the following:

- Define what will be expected from the bidders in the development, implementation and management of CPC planning.
- Describe the managerial and technical aspects of CPC planning to ensure the contractors fully realize the type of robust CPC planning they are expected to develop and implement.
- Explain the CPC planning organization, including
    - how the government is expected to participate in the planning,
    - the contractor’s responsibilities, and
    - the deliverable documents.

Specifications

Two types of specifications will be developed as part of CPC planning:

- Performance specifications, which are used with the RFP to award the initial contract and to procure follow-on items
- Process/finish specifications, which are developed as the CPC planning is developed and implemented.

Performance Specification

Performance specifications are outlined in MIL-STD-961, which

- provides a checklist of items to address in performance specifications, and
- suggests breaking the specification into six sections.

The following text provides guidelines and recommended input for Sections 2, 3, 4, and 6 of the performance specification.

Section 2: Applicable Documents

- Place references to government corrosion-related performance specifications (MIL-PRF), DoD-adopted industry standards, and non-governmental standards used in Sections 3 and 4. Reference to these types of documents is made in Section 2 of the performance specification.
- No document should be listed in Section 2 of a specification unless it is called out in Section 3 or 4 of that document.

Section 3: Requirements

- Requirement specifications should contain detailed requirements for materials, design, service environment, maintainability, and environmental compliance.
- Requirement specifications should state these requirements in terms of quantifiable performance.

Section 4: Verification

- Verification specifies which tests should be conducted to verify conformance to requirements established in Section 3.
- Verification also establishes first-article inspection, qualification inspection, sampling procedures, and inspection conditions.

Section 6: Notes

- Notes establish data item description (DID) and technical manual requirements. The documentation prescribed in this section can be used to require the contractor to provide information regarding how corrosion control for the system will be achieved and to provide quality assurance data.

- Notes also establish three key elements of the requirements and verification procedures when conducting CPC planning for a system:
  - Corrosion tests are required for the basic constituents of the system.
  - Corrosion tests are required for the full-scale system to evaluate the impact of design and fabrication practices on corrosion resistance.
  - The manufacturer must provide a process and supporting documentation in the form of a corrosion prevention and control plan (CPCP) and corrosion prevention quality assurance program.

Process/Finish Specification

The prime contractor should prepare a process/finish specification in accordance with the CPC plan that is developed collaboratively between the government and the contractor. The content of the process/finish specification will be addressed in Appendix C.

Appendix B
Example of Charter for Corrosion Prevention Action Team

This appendix provides an example of a corrosion prevention action team (CPAT) charter; it is intended to be representative only. The contents of this appendix are not direction. The contents of a program's actual CPAT charter will vary and should reflect the needs of the particular program or project.

1.0 Introduction

Past experience has shown that corrosion in systems can impede operational readiness, impact life-cycle cost, and jeopardize system effectiveness. Corrosion, which is defined as the environmental deterioration of any material, metallic or nonmetallic, includes the operating environment's degradation of all materials. DoD *Corrosion Prevention and Control Guidelines* define the objectives and responsibilities aimed at minimizing these threats throughout all phases of a weapon system's life cycle. The guidance recommends a CPAT be established for each system. The intention is to bring the designer, maintainer, and the user together so they may contribute their unique experience to problem definition, formulate recommendations for solution, and track final resolution. This charter defines the purpose, membership, responsibilities, and procedures of the weapon system.

2.0 Purpose

The CPAT provides assistance and advice to the program manager on the most current methods of providing and maintaining effective corrosion prevention and material compatibility planning for the weapon system.

3.0 Membership

The following organizations constitute the CPAT membership. Each organization identifies, in writing, any changes to their primary and alternate representatives to the CPAT. This charter is reviewed annually by the CPAT to update content and membership, as required.

- Program engineering (chairperson)
- Other concerned program elements
- Prime contractor (co-chairperson)
- Other major contractor participants
- User representatives
- Test and evaluation representatives
- Service program office representatives
- Service R&D laboratory representatives
- Defense contract management representatives.

4.0 Responsibilities

The specific responsibilities of CPAT members are summarized below. These responsibilities are derived from the DoD guidance in addition to contractor support requirements.

4.1 The PM chairperson, as the program manager's representative, the contractor team co-chairperson, as the prime contractor, and the Service Corrosion Prevention and Control Office, as corrosion prevention and control program managers, will organize the CPAT effort and accomplish the following tasks:

- Establish and chair a CPAT to evaluate the adequacy of corrosion prevention and material compatibility measures included in the design, to review the program's approach to corrosion prevention, and to advise on corrosion prevention and control for inclusion in specifications and technical data.
  - Make sure the engineering effort conducted by the integrated product teams (IPTs) during design and fabrication focuses on the prevention and control of corrosion and the compatibility of composites/materials with the system operating environment. This will be done during the Technology Development, Systems Development and Demonstration (SDD), and Production and Deployment phases.
  - Evaluate compliance with applicable standards, specifications, design handbooks, and related technical documentation
    - Direct Contractor Corrosion Team (CCT) Quality Assurance members to conduct spot inspections during manufacturing to ensure manufacturing and fabrication processes do not include practices that would eventually cause corrosion and material degradation problems, and to ensure approved techniques adopted by the air vehicle IPTs early in SDD are being followed.
    - Direct CCT Quality Assurance members to inspect preservation and packaging procedures at the contractor facilities of all materials being delivered to activities to ensure practices adopted by the IPTs are being followed.
  - To the extent they support structural requirements, use standard materials for weapon system sustainment for corrosion prevention.
  - Make sure each proposed redesign or modification is evaluated for potential corrosion, material, and environmental compatibility effects and requirements for the prevention and control of corrosion and material are addressed.
  - Interface with the chairperson of the major subsystem CPATs to ensure data exchange and resolution of mutual concerns.
  - Interface with all team members to ensure data exchange and incorporation of technical advancements into the system.
- Make sure the results of testing to environments outlined in by verification requirement and contract are reviewed by the CPAT to identify future potential corrosion and material compatibility issues.

4.2 The following are tasks for the Service program office members:

- Co-chair the CPAT and assist the PM and user in tracking/resolving action items.
- Ensure the proper requirements for corrosion prevention and control are included in specifications, tailored standards, and procedures; cite newly approved materials in updating specification revisions, design handbooks, and technical data.
- Evaluate the CPCP to confirm it covers the proper steps for preventing corrosion and ensuring material compatibility.
- Identify and help solve corrosion and material compatibility problems in the design, maintenance, and use of the system.
- Periodically review and update technical data; send pertinent information to appropriate training organizations for use in training courses.
- Review modification proposals to ensure proper requirements for corrosion prevention and control are included.
- Review and validate Corrosion maintenance facility requirements documents.

4.3 User members will

- serve on the CPAT;
- take part in contractor reviews and other actions to identify potential corrosion and material compatibility problems;
- assist in the review of the contractor’s effectiveness in preventing corrosion through the design, production, and sustainment phases of acquisition;
- ensure recommendations for corrective actions or CPAT action items are submitted as early as possible and followed up; and
- ensure field-level support capabilities for corrosion prevention are evaluated by the CPAT.

4.4 Test and Evaluation Organization members will have the same responsibilities for corrosion prevention and control as the user during testing and evaluation.

5.0 Procedure

The following are the procedural responsibilities of the CPAT:

- Convene at least annually or as often as required throughout the life cycle of this system at the times and places arranged by the chairperson. The interval will normally be semiannually during the SDD phase, unless the chairperson determines that more or less frequent sessions are necessary.
- Review corrosion prevention/material compatibility contract requirements and prepare the appropriate design guidance tailored to the unique aspects of this program.
- Advise the CCT to conduct plant site inspections, as appropriate, at contractor and subcontractor facilities to evaluate the adequacy of the design as it relates to corrosion prevention, and to assess the manufacturing, fabrication, engineering liaison, and quality control procedures for corrosion prevention and material compatibility.
- Advise the CCT to conduct field site inspections at flight test/ground test, demonstration facilities, and operational facilities to evaluate the effectiveness of the corrosion prevention/material compatibility considerations/designs. Define discrepancies and propose possible solutions.
- The lead contractor will prepare and distribute minutes (no more than 60 days after the date of the CPAT meeting) that assign action items to the responsible agencies for resolution. The lead contractor will maintain a continuing agenda or log of specific efforts, problems, action items, discrepancies, etc., with the following for each item:
    - Definition or description
    - Alternatives
    - Team recommendation
    - Responsible action individual or agency
    - Final disposition.
- Make recommendations to the program manager for all changes, corrections, or improvements that require action by a government agency or a contractor.

Note: The CPAT has no authority to direct any government agency or contractor to take any action as a result of its finding. The chairperson will make clear the nonbinding advisory nature of the opinions, findings, suggestions, and recommendation of the team to all parties at all team meetings and activities.

Appendix C
Example of Corrosion Prevention and Control Plan for Systems and Equipment

This appendix provides an example of a corrosion prevention and control plan (CPCP); it is intended to be representative only. The contents of the appendix are not direction. The contents of a program's actual CPCP will vary and should reflect the needs of that program.

Section 1.0 Introduction

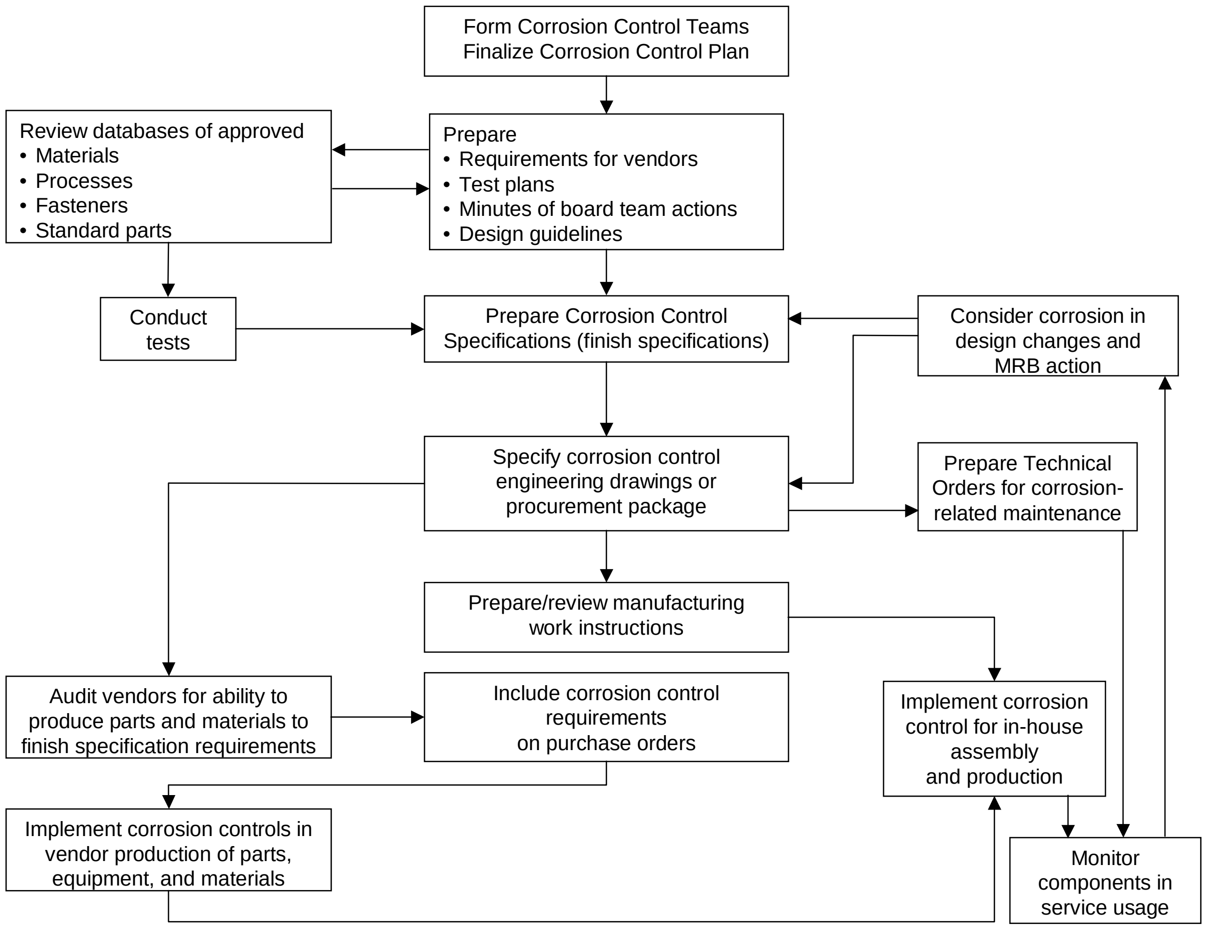
The purpose of the corrosion prevention and control plan (CPCP) is to describe the corrosion control tasks and responsibilities for the system and support equipment. Corrosion prevention and control (CPC) is defined as the rigorous application of engineering design and analysis, quality assurance (QA), nondestructive inspection (NDI), manufacturing, operations and support technologies to prevent the initiation of corrosion, avoid functional impairment due to corrosion, and define processes for the tracking and repair of corrosion problems.

Corrosion prevention and control requires the coordinated efforts of numerous disciplines and organizations across the contractor teams and the government program office. A contractor corrosion team (CCT) will be established at each company to oversee the corrosion control system and to provide a forum for the coordination of the CPC tasks assigned to each organization.

Suppliers or vendors who have been granted design authority will actively participate in the CPC process by formulating their own CPC plans that meet the intent of this document and participating in CCT meetings on an as-required basis. A corrosion control group, which includes the chair of each CCT, will ensure team uniformity and coordination of CPC. The CCT will follow the integrated product team (IPT) philosophy by ensuring all decisions are properly coordinated and implemented with the full knowledge of the appropriate design IPT. Section 2 of this corrosion prevention and control plan defines the CCT, and assigns each corrosion control task to the responsible organization or discipline.

The flow of these tasks is illustrated in Figure 1. Section 3 details specific CPC practices to be implemented through the Process/Finish Specification or Engineering Dataset. Section 4 provides background information and general design information for the interrelation of corrosion with the operating environments.

Figure 1. Flow of Corrosion Prevention and Control Tasks



Section 2.0 Organization and Responsibilities

This section defines the team organization to establish and implement the corrosion prevention and control system. This section also assigns task responsibilities.

2.1 Team Coordination of Corrosion Control

A contractor corrosion team will be formed. It will consist of at least one program representative from each of the team companies, and be chaired by the company IPT corrosion control specialist. This team will provide and coordinate a consistent corrosion prevention and control policy. The following are among the responsibilities of this team:

- Develop, document, and maintain the Corrosion Prevention and Control Plan.
- Establish regular meetings and call special meetings if required.
- Coordinate and document material selection guidelines for corrosion protection/avoidance.
- Coordinate the documentation of corrosion design guidelines.
- Coordinate corrosion prevention policies and procedures with other team policies and practices.
- Review corrosion test results for process/finish material qualifications.
- Establish corrosion test requirements for procured items in conjunction with the cognizant IPTs.
- Establish and maintain team-common process/finish requirements.
- Establish criteria for identification of corrosion specialists within IPTs.
- Resolve any impasse in determining the preferred process or treatment method for corrosion control at any team site.
- Maintain a log of problems, action items, corrective actions, and status of each for all sites.
- Coordinate and interface with government program office on the above.

The CCT will meet as needed to resolve corrosion control issues and to ensure coordination of the CCT and their activities. Meetings, whether formal, informal, electronic, or in person, will be documented by minutes distributed to all CCT members. The lead company CCT chairman will be the primary liaison with government personnel on matters relating to corrosion control. All CCT members will participate in Corrosion Prevention Action Team (CPAT) meetings. CCT members will support CPAT and CCT meetings on an as-required basis.

2.2 Contractor Corrosion Teams

A CCT will be established at each of the team companies that have design responsibilities to provide coordination among the organizations and technical disciplines responsible for or involved in corrosion control tasks. Each company will have a team chairman to manage the respective corrosion control team and to represent the company on the CCT. The CCT chairman will be a member of the applicable IPTs and an expert in the area of corrosion. Each CCT will provide a forum, through the representatives of the affected disciplines and consistent with CCT direction, to establish engineering, manufacturing, and quality requirements that will be implemented by the responsible organizations at that company. The teams support the writing of the Corrosion Prevention and Control Plan and establish requirements for the generation of design guidelines, material specifications, process specifications, and quality control guidelines. Each CCT will consist of knowledgeable personnel who represent, at a minimum, the following disciplines, which are necessary to implement this corrosion prevention and control plan:

- Materials and processes
- Design
- Reliability, maintainability, and supportability
- Production operations
- Quality assurance
- Manufacturing
- Hazardous materials
- Affected IPTs.

2.2.1 Contractor Corrosion Team Responsibilities

The CCT will guide, direct, and instruct the contractors on corrosion prevention and control measures and verify all measures implemented on the program are necessary, adequate, timely, and cost effective. The CCT principal responsibilities are as follows:

1. Review internal controls to ensure corrosion prevention and control techniques are established, implemented, and maintained.

2. Review procedures for interim protection during all phases of manufacture and during preparation for storage/packaging for shipment.

3. Review training programs to ensure the required corrosion prevention and control techniques (e.g., finishing, sealing, and drainage systems) are properly addressed.

4. Provide technical input to corrosion control and other related technical publications and review/approve the documents.

5. Review and recommend approval of cleaning materials, solutions, and chemicals not covered by approved specifications for use on the system, parts, and components.

6. Conduct failure analyses and provide corrective action for corrosion problems. These analyses will be conducted and documented by the appropriate Failure Analysis Group, reported to the Material Review Board, and recorded in the corresponding corrosion control engineer's log. A summary of this log from each team leader will be given to the CCT chairperson.

7. Conduct quarterly CCT meetings to ensure implementation of this plan and to coordinate solutions for problems that arise during the development, design, and manufacturing phases. Additional CCT meetings will be conducted as required. Close communication of the CCT chairperson, company team leaders, and CPAT chairperson is to be maintained.

8. Maintain a log of problems and solutions/actions covered.

9. Ensure periodic reviews are made of all facilities to evaluate the adequacy of corrosion prevention and control measures.

10. Make field site inspections of systems when requested by the CPAT or on a schedule as established by the CPAT.

11. Incorporate environmental resistance requirements and verification methods into the testing and selection of materials. Environment is defined as natural and man-made or operational environments. Materials include metallic and non-metallic materials.

12. Incorporate corrosion prevention and control measures into avionics, electro-magnetic environmental effects, low observable technology, biological/chemical vulnerability and other related technologies.

13. Monitor and investigate industrial developments for processing and/or process/finish improvements related to corrosion prevention and for cost effectiveness or compliance with environmental regulations.

14. Notify the CCT chairperson of each CCT meeting date, meeting topics, and any decisions resulting from the previous CCT meeting.

15. Ensure a balance is maintained between electrical bonding/grounding needs and corrosion control approaches.

2.2.2 Corrosion Control Team Functional Tasks

The CCT is responsible for ensuring the following functional tasks are accomplished in accordance with this plan.

2.2.2.1 Materials and Processes

1. Write and maintain a process/finish specification for the engineering and manufacturing development and production models in accordance with MIL-STD-7179.

2. Serve as design consultants for the selection of materials, processes, and finishes.

3. Review and approve engineering drawings, system and component specifications, and technical order manuals related to corrosion prevention and control.

4. Assist in the disposition of parts with a damaged or defective surface finish.

5. Initiate changes to material and process specifications and design as required.

6. Assist Procurement in the evaluation of subcontractor capabilities.

7. Assist Procurement in the review of subcontractor specifications, which may be used in lieu of those previously approved for the system and be subject to final approval by the procuring activity.

8. Submit logs of corrosion problems and solutions/actions to the CCT chairperson.

9. Maintain records of all inputs from the CCT.

10. Resolve disagreements (if any) during the SDD and production phases.

11. Monitor developments in processing or finish requirements relative to corrosion prevention for design incorporation.

12. Provide shop/manufacturing surveillance and support to assure compliance with specification requirements.

13. Participate in or assist with, as applicable, the Engineering Material Review Board for materials and processes technical disciplines.

2.2.2.2 Design

1. Incorporate CCT decisions into product designs

2. Coordinate the resolution of corrosion-related design problems.

2.2.2.3 Reliability, Maintainability, and Supportability

1. Review drawings for conformance to standard corrosion prevention design practices.

2. Ensure the incorporation of reliability, maintainability, and supportability (RM&S) considerations for material and finish selection and development.

3. Ensure corrosion-related supportability design-to-requirements is current and available to the designers. This includes design reviews that ensure hidden or inaccessible areas on the airplane are minimized.

4. Participate in design trade studies during all phases of design development. Provide guidance on corrosion prevention based on experience gleaned from other aircraft programs.

5. Develop and recommend corrective and preventive procedures based on reliability and maintainability analyses of field data on similar in-service equipment.

6. Document maintenance procedures and applicable logistics resources.

2.2.2.4 Production Operations

1. Review and analyze corrosion-related problems in all departments. Consultations with materials and process (M&P) corrosion engineers should be conducted when they are required during this process.

2. Request changes to engineering documentation to correct finishing procedures or to implement new procedures.

2.2.2.5 Quality Assurance

The CCT quality assurance authority consists of process control and quality control items as described below.

2.2.2.5.1 Process Control

1. Audit the incorporation of engineering specification or design changes.

2. Perform tests on processing solutions and chemicals to monitor compliance of process parameters with applicable engineering or government specifications.

3. Maintain records of scheduled processing solution tests and prepare test reports on specification compliance.

4. Initiate corrective action for nonconforming processes.

5. Help procurement office evaluate processing capabilities of subcontractors when such assistance is requested.

6. Perform initial and subsequent subcontractor audits, as required, to verify capability in applying the finish systems specified.

2.2.2.5.2 Quality Control

1. Verify parts and assemblies are properly protected from corrosion during manufacture, while in stock, and when packaged for shipment.

2. Verify parts are processed in accordance with the applicable specifications/standards.

3. Verify applied finishes conform to design and specification/standard requirements.

4. Reject any material or part that has been damaged or has not been finished in accordance with applicable specification or standards.

2.2.2.6 Manufacturing (Planning)

1. Translate processing and finishing requirements of engineering data to planning documentation.

2. Provide planning requirements to ensure in-process corrosion protection of the material or parts during manufacture.

3. Revise planning documentation when engineering design or specification requirements are changed.

2.2.2.7 Hazardous Materials

1. Ensure materials and processes comply with all federal and state regulations.

2. Serve as focal point for coordination and distribution of new regulations with the CCT, including new regulations regarding materials and processes.

Section 3.0 Corrosion Prevention and Control Processes

3.1 General Requirements

3.1.1 Process/Finish Specification

The primary engineering document used to implement the CPCP is the process/finish specification, which should be incorporated into the released engineering dataset. The specification contains detailed finish instructions and guidelines, which are incorporated by the design activity into engineering datasets and drawings. The materials and processes activity will verify that these instructions and guidelines have been included in the datasets via the approval and sign off processes. The finish codes specify the material and process specifications, which are used by Procurement to order material and by the manufacturing (planning) activity to incorporate into the manufacturing operation sheets. For vendor-designed parts and equipment, the vendor may elect to finish per the process/finish specification, or they may provide, through the CCT, alternate finish materials for approval by the CCT, procuring activity, and the relevant IPT. All finishing materials should be used in conformance with federal and state regulations.

3.1.2 Material Limitations

Mill product forms of aluminum alloys 2020, 7079, and 7178 should not be used for structural applications. The use of 7XXX-T6 aluminum alloys should be limited to thicknesses not to exceed 0.080 inches.

3.1.2.1 Precipitation Hardening Steels

Precipitation hardening steels should be aged at temperatures not less than 1000°F. Exception is made for castings that may be aged at 935°F ± 15°F, fasteners that may be used in the 950 condition, and springs, which have optimum properties in the CH 900 condition. Corrosion-resistant maraging steels should not be used in sustained load applications. Corrosion resistant 19-9DL and 431 steels should not be used for any applications. Series 400 martensitic grade corrosion resistant steels should not be used in the 700°F to 1100°F tempered condition. Unstabilized austenitic steels may be used up to 700°F. Only stabilized austenitic steels (321 and 347) should be used above 698°F. All welded or brazed austenitic steel should be solution heat-treated after welding; however, welded 321 and 347, and 304L and 316L may be used without heat treatment.

3.1.2.2 Magnesium Alloys

Magnesium alloys will not be used for structural applications. All proposed nonstructural applications for components or subsystems should be submitted to the procurement activity for approval prior to incorporation into the design.

3.2 Material Surface Treatments

3.2.1 Aluminum Alloys

Surface treatments for aluminum alloys.

1. Bare 2000 series and 7000 series. Chromic acid anodize per MIL-A-8625 Type 1B or boric sulfuric acid anodize per MIL-A-8625, Type I C, or thin-film sulfuric acid anodize per MIL-A-8625, Type IIB.

   Note: Sulfuric acid anodize per MIL-A-8625, Type II, Class 1 or 2 may be used as an alternate to chromic acid anodize except on fracture or maintenance critical parts or those parts sized by fatigue requirements. Use of any other anodize treatments requires approval.

2. Inherently corrosion resistant alloys of the 1000, 3000, 5000, and 6000 series and aluminum casting alloys. Chemical conversion coat per MIL-DTL-5541 Type 1 Class 1A using materials conforming to MIL-DTL-81706. Where a low resistivity contact is necessary for electrical bonding purposes, MIL-DTL-5541 Class 3 may be used.

3. Exterior surfaces of adhesive bonded assemblies and spot-welded or lap-welded assemblies should be chemical conversion coated per MIL-C-5541 Type 1 Class 1A using materials conforming to MIL-DTL-81706. The exterior surfaces of adhesive bonded assemblies may be coated with an approved corrosion-inhibiting adhesive primer in lieu of the MIL-C-5541 chemical conversion coating.

3.2.2 Titanium Alloys

Titanium alloys do not require finishes for the purpose of corrosion protection. However surfaces contacting titanium should be protected from galling and dissimilar metal corrosion. Contact surfaces constituting dissimilar metal joints should have both surfaces coated with two coats of primer. As an alternative, both surfaces may have one coat of applied primer and then be assemble wet with that primer. Similar metal contact points with titanium should have one coat of primer applied to each surface in the joint to protect against galling. Prior to application of primer, the titanium surface should be conversion coated in accordance with AMS 2486. Application of primer should begin within 16 hours after the application of conversion coating.

Titanium alloys should not be cadmium- or silver-plated. Cadmium-plated tools, clamps, fixtures and jigs should not be used for fabrication or assembly of titanium components.

3.2.3 Non-Corrosion-Resistant Steel Alloys

Non-corrosion resistant steel alloys should be protected from corrosion as follows:

- Non-corrosion resistant steel alloys with a maximum ultimate tensile strength of 180,000 psi or less should be IVD aluminum coated in accordance with MIL-DTL-83488, Class 3, Type II, followed by glass bead peening or cadmium plating in accordance with AMS QQ-P-416, Class 2, Type II. Cadmium plate is allowable *if and only if* no suitable alternate is acceptable and each use of cadmium plating will require the approval of the materials and processes activity.

- Non-corrosion-resistant steel alloys with ultimate tensile strength ranging from 180,000 to 220,000 psi should be IVD aluminum coated in accordance with MIL-DTL-83488, Class 3, Type II, Aluminum Ion Vapor Deposition, followed by glass bead peening.
- Non-corrosion resistant steel alloys with an ultimate tensile strength range of 220,000 psi or greater should be cleaned and cadmium plated per AMS-C-8837, Type II, Class 2, Vacuum Cadmium Plating; or coated per MIL-DTL-83488, Class 3, Type II, Aluminum Ion Vapor Deposition, followed by Glass Bead Peening. Cadmium plate is allowable *if and only if* no suitable alternate is acceptable and each use of cadmium plating will require the approval of the materials and processes activity.
- When a wear-resistant coating is required on non-corrosion resistant steel alloys the surface should be nickel plated in accordance with AMS 2423QQ-N-290, Class 2, minimum thickness 0.002 inches or electrolysis nickel plated in accordance with MIL-C-26074 Class 1 or 2, Grade C, minimum thickness 0.0015 inch—which has been superseded by AMS C 26074, which is non-current and is not a direct replacement (i.e., Class 2). This treatment is limited to steel alloy that is heat treated to 240,000 psi maximum.

Exceptions to the above requirements will be made for individual parts based on function and location as necessary.

3.2.4 Corrosion-Resistant Steel Alloys

Corrosion resistant steels should be passivated in accordance with AMS 2700 (or by methods approved by materials and processes engineering) except as noted in the following.[1]

- Carburized or nitrided surfaces or surfaces to be carburized or nitrided should not be passivated.
- Corrosion resistant steel castings should not be passivated, but should be cleaned in accordance with MIL-S-5002.
- Silver soldered joints and spot welded assemblies should not be passivated.
- Assemblies containing crevices, slip joints and bellows that might trap cleaning or passivation solution should not be passivated without specific written approval from Materials and Processes Engineering
- Rough forgings, forged bar, and rolled plate should be descaled or machined on all surfaces prior to passivation. Descaling should be in accordance with AMS 2700 or methods approved by Materials and Processes Engineering. If acid etching is used to descale, the part should be baked for 4 hours at 350°F, within 8 hours following the cleaning.

3.2.5 Graphite-Reinforced Composites

Surfaces of graphite composites in contact with aluminum or other dissimilar materials should incorporate a glass ply in the contact area. For epoxy-based laminates, the glass barrier ply

[1] Note: AMS 2700 permits the use of citric acid for passivation. This process is not approved for NAVAIR.

should extend a minimum of 1 inch beyond the contact region. For condensation polyimide–based laminates (e.g., bismaleimide, cyanate ester), the glass barrier ply should fully cover the laminate surfaces in contact. In addition, a minimum of one coat of primer, or fuel tank coating should be used in the contact area. On assembly, the joint between the composite surface and this dissimilar metal should be fay and fillet sealed with sealant and fasteners wet installed using MIL-S-81733 or AMS 3276. Fasteners should be overcoated to the maximum extent practical using primer, fuel tank coating, or sealant.

3.2.6 Other Coatings

All structural materials exposed to fuel in fuel tanks will receive one coat of SAE-AMS-C-27725 (that replaced MIL-C-25525).

Soft surface coatings such as nickel-cadmium, and aluminum should not be used for sliding or wear applications. Silver plated surfaces should not be used in applications where surface temperature exceeds 232°C (450°F). Cadmium should not be used without approval of the Hazardous Materials Team and review by the CCT. Cadmium plated fasteners should not be used.

Protective systems to be used, specialty coatings for fuel tank interiors, rain erosion, crew compartment, anti-glare, etc., are defined in the engineering dataset and included in the process/finish specification. Refer to Table 1 (when completed) and Table 2 for guidance on these coatings. Dissimilar metals as defined in Table 2 are protected from galvanic corrosion in accordance with the requirements of the process/finish specification**.**

Table 1. Coating Thickness (in millimeters)

Spec#	Description	1-coat	2-coats

3.3 Sealing

Faying surfaces composed of dissimilar metals as defined in Table 2, in addition to receiving one coat of primer (0.0006 inch–0.0009 inch) should be sealed with MIL-S-8802, MIL-S-81733, or AMS 3276 sealant. The joint should be subsequently fillet sealed using the same sealant as was used for the fay surface. Joints that require separation as a part of normal maintenance may have a form-in-place seal substituted for a fay seal.

Joints common to exterior locations should be fay surface, fillet, seam, and edge sealed with MIL-S-8802, MIL-S-81733 or AMS 3276 sealant. Joints on the exterior should be sealed to prevent moisture intrusion from external sources.

Attaching parts and fasteners such as screws, bolts, nuts, bushings, spacers, washers, rivets, and clamps, or the surfaces to which they attach should be wet installed with MIL-PRF-23377 primer or MIL-S-81733 or MIL-S-29574 sealant. Neither primer nor sealant should be applied to the threaded portion of fasteners for which torque requirements are established without the coating. All non-aluminum fasteners installed in aluminum structure should be overcoated with a minimum thickness of 0.006 inch of MIL-S-81733, MIL-S-29574, MiIL-S-8802, or AMS 3276 sealant. After installation, all attaching parts should be overcoated with primer or primer and topcoat corresponding to the finish requirements of the surrounding area. Topcoat should match the color of the adjacent topcoat. Nuts and heads of bolts that are subsequently lubricated need not receive final finishing.

The exterior of electrical bond connections should be touched up to restore the finish in the surrounding area and subsequently sealed over with MIL-S-81733, MIL-S-8802, MIL-S-29574, or AMS 3276 sealant.

Table 2. Grouping of Metals and Alloys

Group I	Magnesium and its alloys (use requires approval)
Group II	Cadmium, zinc (use requires approval) Aluminum alloy 5052, 5056, A356 (and other casting alloys), 6061, 6013, 6063 (and other 6000 series alloys) and 7000 aluminum alloys
Group III	2000 Series aluminum alloys
Group IV	Iron, lead, and tin and their alloys (except corrosion-resistant steel)
Group V	Copper, chromium, nickel, cobalt, and rhodium and their alloys; brass and corrosion-resistant steel
Group VI	Silver, gold, platinum, titanium and graphite

Notes: Metals classified in the same groups are considered as similar metals. Materials classified in different groups are considered as dissimilar metals.

Section 4.0 Operational Environment

4.1 General

This section is presented as background information only. The operational environment is defined in the Environmental Criteria Document.

Corrosion is defined as the environmental deterioration of any material, metallic or non-metallic, and includes the environmental degradation of all materials. Ordinarily, corrosion is associated with metallic materials that are in the process of reverting to their natural states (oxides, carbonate, etc.). Some metals and metalloids (graphite, for example) are not corrosion prone, but they will cause and accelerate corrosion on less noble metals in contact with them. For this reason, all vulnerable and metallic materials used on the system should be protected from the environment by the selection and use of the proper metallic materials; application of finish systems; faying surface sealing and wet installation of fasteners; and elimination of moisture traps or provision of adequate ventilation. Designers should not depend upon interior equipment and interior surfaces to be adequately protected by sealing systems alone since it has frequently been shown that the sealant is also removed during paint stripping. More detailed information concerning solar radiation, humidity/rainfall, and icing temperatures may be found in the team Environmental Criteria Document.

4.2 Breathing and Condensation

Breathing will occur in enclosures when a cyclic flow of air will go in and out of the enclosure primarily due to pressure changes during altitude variations or temperature fluctuations. In temperate and tropical zones, breathing will occur during daily temperature changes in the morning and evening hours, when the outside air heats or cools, or when an airplane descends to warmer lower altitudes. For example, generally, the temperature will drop 3.5°F (1.95°C) per 1,000 feet of ascent; therefore, at 85°F (29.4°C) at seal level, the temperature will be −20°F (−28.9°C) at 30,000 feet. The critical amount of moisture for corrosion initiation is 0.01 grams per square meter on unprotected metallic surfaces. By comparison, the amount of moisture on a metal surface in an outdoor atmosphere is 1.0 g/m^2 when wet with rain. Depending upon design area, breathing will vary; however, breathing most likely will occur in enclosed areas open to the outside through unsealed joints in unpressurized areas and in instruments and electronic equipment boxes.

4.3 Atmosphere Salt

Normal sea breezes can carry from 10 to 100 pounds of salt per cubic mile of air. Although the salt-laden air may travel inland on sea breezes for a distance of up to 12 miles, the major amount of salt fallout occurs within the first half mile of the beach. Beyond about 10 miles inland, the fallout is insignificant. In the northern, cooler latitudes, the salt content of air is much less of a problem than in temperate and equatorial regions. Salt is also much more concentrated in air at lower altitudes than at higher altitudes. The heaviest concentrations are below 3,000 feet over the water in areas of trade winds. Also, systems at bases on the seacoast in temperate areas are sometimes subject to fallout of corrosive iodine produced by masses of kelp floating along the coastline.

4.4 Sulfur Oxides

Sulfur oxides are normally associated with industrial and large urban areas. In the past, sulfur-containing fuels, such as coal, produced enormous quantities of byproducts. Automobiles and volcanoes also emitted some of these same contaminants. Within the last 10 or so years, there has been considerable reduction in emission output due to federal and state laws which require smoke stack scrubbers, catalytic converts, etc. Even though there have been reductions in sulfur oxides, the levels are still high enough that, when mixed with moisture, a strong sulfurous acid, principally sulfuric acid, is formed (acid rain), which can cause corrosion and also attack other materials, particularly rubber products, which are the most vulnerable.

4.5 Firefighting Agents

Some fire fighting agents used to extinguish fires pose no risk at all to metallic structure; however, many fire-extinguishing agents are corrosive and can very quickly produce severe corrosion. Foam and bromochloromethane and, to a slightly less degree, dibromochloromethane agents are the most notable offenders in this regard. Some of the more commonly used dry powder agents, such as potassium bicarbonate (PKP) are in themselves only mildly corrosive, but after exposure to heat, the residue may convert to potassium hydroxide, a product that is very corrosive to aluminum. Both of these potassium salts are hygroscopic and will absorb moisture, creating a corrosive deposit on airplane surfaces.

4.6 Soot

Soot, generated by a fire or from normal engine operation, is carbon, including a variety of combustion byproducts and sulfur oxides, depending on what has been burned. Soot is both corrosive and hygroscopic. It imbeds itself into painted surfaces and is very difficult to clean off. Severe corrosion will result wherever paint has been chipped on aluminum structure because of the small anode (aluminum) and very large cathode (soot) being in contact with each other in the presence of moisture.

4.7 Sand and Dust

Blowing sand and dust can cause erosion of leading edges and settle into all accessible areas of the airplane, impeding the function of oil and air filters and contaminating electrical and avionic equipment. When damp, a poultice is formed against the structure, resulting in corrosion. Furthermore, even though the climate may otherwise be acceptable in some desert regions, many deserts are the sites of ancient sea beds and the sand often contains a significant amount of salt.

4.8 Rainfall

Rainfall provides some benefit in corrosion prevention by washing away some contaminants. During periods of high acid rain activity, the beneficial effect of rain will be somewhat diminished. In either case, improperly sealed joints, open cavities, and trap areas will allow corrosion initiation within these areas.

4.9 Volcanic Ash

Volcanic ash contains corrosive substances such as sulfur compounds, fluoride and chloride salts, and strong inorganic acids. These chemical are often carried on the surface of ash particles, which are highly abrasive bits of pulverized rock and can erode leading edges and internal engine parts.

Particle sizes usually range from .05 microns to 100 microns, and, since most airplane filters will remove material down to 15 microns, smaller material could impede air and fluid filters. The ash will most likely be encountered as a fine powder, similar to talcum powder and will be light gray in color. In the presence of moisture, the ash becomes a corrosive paste that tends to set up somewhat like concrete. Airplanes that may have accumulated this material during flight, or on the ground, may need special cleaning, both inside and out. Even when ash is not visible, airplanes that operate within the vicinity of volcanic activity can be contaminated with corrosive acids. Exposure to the acids can be checked with nitrizine paper. A pH of 4 or below is an indication that cleaning is required.

4.10 Solar Radiation

Solar radiation (sunlight) causes chalking of paint; hydrolysis of chlorinated organics; and degrades exposed plastics and elastomers. Degradation of these materials allows an electrolyte, usually in the form of moisture and its corrosive constituents, free access to the underlying metallic surfaces.

4.11 Runway Deicing Materials

There are several types of runway deicers. The glycol-based material is not considered to be a corrosion problem. Urea type deicers are the most commonly used. Calcium magnesium acetate can, when ingested into the engine or APU in conjunction with sea salt, initiate corrosion on turbine parts. Potassium acetate and sodium formate by their chemical nature have the potential, if ingested by the engine core, to cause hot corrosion on turbine parts. The level of hot corrosion, however, would probably be no worse than hot corrosion caused by airborne salt. Runway deicing salts can also cause chemical attack, especially in low areas. There materials should not be allowed to puddle, and joints and crevices should be sealed to prevent entry.

4.12 Chemicals

Maintenance chemicals, such as cleaners, acids, paint strippers, solvents, etc., can present as many different problems as there are chemicals being used. Paint strippers, solvents, and some cleaning agents can, when improperly used, deteriorate paint, plastics and elastomers. Some paint strippers, some cleaners, and most acids are very corrosive to airplane structure. Designers should select materials or impose preventive measures to prevent or lessen damage from chemical attack. Additionally, maintenance personnel should be thoroughly familiar with the chemicals they use while performing maintenance on the airplane.

4.13 Damage by Personnel

Maintenance personnel can greatly contribute to corrosion on the system. Walking on surfaces and dropped tools and equipment will sufficiently damage the paint to allow corrosion initiation in addition to possible structural damage. Removal of cast in place and mechanical seals and sealant, without proper reinstallation, will allow moisture to enter internal areas of the system.

4.14 Chemical Warfare Agents

During periods of war, the system may be required to operate and be maintained in an environment of chemical agents. All removable equipment, unsealed compartments, etc. are susceptible to contamination. The system should be able to survive in the chemical threat environment and be capable of decontamination after exposure. Contaminants and the decontamination process should not cause corrosion of the exposed structure and equipment.

4.15 Shipboard Environment

Normal shipboard conditions are highly corrosive. Gases containing sulfur and nitrogen oxide from ship stacks and aircraft exhaust combine with 3.5 percent sodium chloride sea spray to form highly acidic moisture film of pH 2.4-4.0. Relative humidity of 70 percent to 100 percent conditions exist simultaneously with sand and dust particle concentrations ranging from $1.32 \times 10 - 4$ to $4.0 \times 10 - 6$ lbs/ft^3. In addition, maintenance is much more difficult aboard ship, often leading to less than optimum repairs to protective coatings.

Section 5.0 References

[1] *Joint Services Specification Guide*.

[2] *System Environmental Criteria Document*

[3] *Process/Finish Specification*

[4] MIL-A-8625, *Anodic Coatings for Aluminum and Aluminum Alloys*

[5] MIL-C-5541, *Chemical Conversion Coatings on Aluminum and Aluminum Alloys*

[6] AMS 2486, *Conversion Coatings of Titanium Alloys*

Appendix D
Aerospace Systems Guidelines

1.0 Scope

1.1 Scope

This appendix establishes the guidelines for aerospace systems in determining materials, processes, techniques, finishes, coatings, and sealants that lead to an effective corrosion prevention and control program during the conceptual, validation, development, production, and support phases of DoD aerospace systems. The intent is to minimize the effects of corrosion on life-cycle cost, readiness, reliability, supportability, safety, and structural integrity of aerospace systems.

1.2 Intended Use

This appendix emphasizes the implementation of sound materials and practices during the design, development, production, and operational cycles of aerospace systems. This appendix, when supported by the program management guidelines contained in this guidebook, ensures that, when the corrosion prevention action team (CPAT) is established, strong technical guidance is available to ensure delivery of a robust and effective corrosion prevention and control plan (CPCP) and process/finish specification. The process/finish specification (materials and processes for corrosion prevention and control) is needed to specify the detailed materials, processes, finish, and coating systems to be used on aerospace systems, in accordance with the process/finish specifications and standards approved in the CPCP. This guidance represents fundamental technical guidance for incorporation in the CPCP and process/finish specification, and can be augmented or tailored as deemed appropriate by the procuring activity.

1.3 Applicability

As an appendix to the *Corrosion Prevention and Control Planning Guidebook,* this guidance is applicable to all DoD procuring activities and their respective contractors involved in the design, procurement, and upgrade of DoD aerospace systems. The detailed CPCP and the process/finish specification should apply to all elements of DoD aerospace systems, including spare parts. This guidance, when used in conjunction with supportability, reliability, maintainability, structural integrity programs and applicable specific technical guidance will result in reliable DoD aerospace systems having a good balance between acquisition costs and life-cycle cost.

1.4 Acronyms

AFMC	Air Force Materiel Command
AMT	accelerated mission test
ARL	Army Research Laboratory
ASC	Aeronautical Systems Center
ASIP	Aircraft Structural Integrity Program
ASTM	American Society for Testing and Materials
CARC	Chemical Agent Resistant Coating
CPAT	Corrosion Prevention Advisory Team
CPCP	Corrosion Prevention and Control Plan
DID	data item description
DSC	Defense Supply Center
EMI	electromagnetic interference
IAW	in accordance with
IVD	ion vapor deposited
KSI	kilo pounds per square inch
LOGSA	Logistics Support Activity (US Army)
MPa	MegaPascaals
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
PSI	pounds per square inch
PWB	printed wiring board
RTV	room temperature vulcanizing
SAE	Society of Automotive Engineers
SCC	stress corrosion cracking
UAV	unmanned aerial vehicle
USAF	United States Air Force
UTS	ultimate tensile strength
VOC	volatile organic compounds

2.0 Applicable Documents

Listed below are a number of aerospace documents, including their status and date. Some of the documents have been cancelled or inactivated and are listed for information only. Questions pertaining to the accuracy of the information contained in canceled or inactivated documents should be made to the proponent, which can be identified using the ASSIST database.

The following are useful websites:

- http://assist.daps.dla.mil/quicksearch/
- http://www.ihs.com.

2.1 Government Documents

2.1.1 Specifications and Standards

2.1.1.1 Specifications

The Department of Defense Single Stock Point (DoDSSP) was created to centralize the control, distribution, and access to the extensive collection of military specifications, standards, and related standardization documents either prepared or adopted by the DoD. In October 1990, the Defense Automated Printing Service (DAPS), Philadelphia, assumed the mission and responsibilities of the DoDSSP. The responsibilities of the DoDSSP include electronic document storage, indexing, cataloging, maintenance, publication-on-demand, distribution, and sale of military specifications, standards, and related standardization documents and publications comprising the DoDSSP Collection.

The DoDSSP also maintains the Acquisition Streamlining and Standardization Information System (ASSIST) management and research database (website above), which retains electronic versions of the following federal and military specifications.

2.1.1.1.1 Federal

TT-P-28, *Paint, Aluminum, Heat Resisting* (1200ºF), active, 28 June 2007

QQ-C-390, *Copper Alloy Castings* (including cast bar) has been cancelled. Refer to SAE AMS 4842E, SAE AMS 4845G, SAE AMS 4855F, SAE AMS 4860E, SAE AMS 4862F, SAE AMS 4890C, ASTM B 148, ASTM B 176, ASTM B 22, ASTM B 271, ASTM B 30 REV A, ASTM B 369, ASTM B 427, ASTM B 505/B 505M, ASTM B 584 REV A, ASTM B 61, ASTM B 62, ASTM B 66/B 66M, ASTM B 67, ASTM B 763, ASTM B 770, ASTM B 806][FLIS].

TT-P-1757, *Primer Coating, Alkyd, One Compound*, active, 15 March 1997

TT-P-2756, *Polyurethane Coating: Self-priming Topcoat, Low Volatile Organic Compounds* (VOC) *Content*, active, 29 February 1996

TT-P-2760, *Primer Coating: Polyurethane, Elastomeric, High Solids*, active, 30 December 1994

2.1.1.1.2 Military

MIL-PRF-3043, *Resin-Coating, Permanent, For Engine Components and Metal Parts*, active, 13 February 1998

MIL-C-5056, *Coating, Permanent Resin, Process for Application of Aircraft Parts*, inactive, 28 August 1996

MIL-DTL-5541, *Chemical Conversion Coatings on Aluminum and Aluminum Alloys*, active, 11 July 2006

MIL-C-8514, *Coating Compound, Metal Pretreatment, Resin-Acid*, active, 20 October 1999

MIL-C-8779, *Colors, Interior, Aircraft Requirements for;* active, 15 March 1989

MIL-S-8784, *Sealing Compound, Low Adhesion for Removable Panels and Fuel Tank Inspection Plates,* inactive, 24 March 1997

MIL-C-11796, *Corrosion Prevention Compound, Petrolatum, Hot Application*, active, 4 November 1986

MIL-PRF-16173, *Corrosion Preventive Compound, Solvent Cutback, Cold-Application*, active, 6 January 1993

MIL-F-18264, *Finishes: Organic, Weapon System: Application and Control of,* inactive, 30 September 1999

MIL-O-19838, *Oil Systems, Aircraft, Installation and test of*, inactive, 7 August 1996

MIL-PRF-22750, *Coating, Epoxy, High Solids*, active, 31 May 1994

MIL-PRF-23377, *Primer Coatings: Epoxy, High Solids*, active, 10 April 2007

MIL-L-23398, *Lubricant, Solid Film, Air-Cured, Corrosion Inhibiting,* NATO Code Number S-749, active, 18 January 1994

MIL-M-24041, *Molding and Potting Compound, Chemically Cured, Polyurethane*, active 19 October 2005

MIL-PRF-32033, *Lubricating Oil, General Purpose, Preservative* (Water-Displacing, Low Temperature), active, 11 July 2006

MIL-M-38510, *General Specification Microcircuit for;* inactive, 15 March 2001

MIL-DTL-38999, *Connector, Electrical, Circular, Miniature, High Density Quick Disconnect, Environment Resistant, Removable Crimp and Hermetic Solder Contacts, General Specification*, active 22 August 2003

MIL-PRF-46010, *Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting*, active, 10 August 2000

MIL-I-46058, *Insulating Compound, Electrical* (for coating printed circuit assemblies), inactive, 30 November 1998

MIL-A-46146, A*dhesive-Sealants, Silicone, RTV, Non-Corrosive* (for use with sensitive metals and equipment), active, 28 October 1992

MIL-C-46168, *Coating, Aliphatic Polyurethane, Chemical Agent Resistant*, canceled, 15 August 1985

MIL-P-53022, *Primer, Epoxy Coating, Corrosion Inhibiting, Lead and Chromate Free*, active, 1 June 1988

MIL-P-53030, *Primer Coating, Epoxy, Water Reducible, Lead and Chromate Free*, active, 20 August 1992

MIL-C-53039, *Coating, Aliphatic Polyurethane, Single Component, Chemical Agent Resistant*, active, 8 June 2005

MIL-DTL-53072, *Chemical Agent Resistant Coating (CARC) System Application, Procedures and Quality Control Inspection*, active, 6 June 2003

MIL-P-53084, *Primer, Cathodic Electrodeposition, Chemical Agent Resistant*, active, 24 June 1994

MIL-PRF-63460, *Lubricant, Cleaner and Preservative for Weapons and Weapon Systems* (Metric), active, 15 March 2006

MIL-DTL-64159, *Coating, Water Dispersible Aliphatic Polyurethane, Chemical Agent Resistant*, active, 30 June 2002

MIL-PRF-81309, *Corrosion Preventive Compounds, Water Displacing, Ultra-Thin Film*, active, 16 May 2005

MIL-I-81550, *Insulating Compound, Electrical, Embedding, Reversion Resistant Silicone*, active, 31 July 2002

MIL-PRF-81322, *Grease, Aircraft, General Purpose, Wide Temperature Range*, active, 24 January 2005

MIL-DTL-81706, *Chemical Conversion Materials for Coating Aluminum and Aluminum Alloys*, active, 2 May 2006

MIL-PRF-81733, *Sealing and Coating Compound, Corrosion Inhibitive*, active, 15 May 1998

MIL-PRF-83282, *Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Metric,* NATO Code Number H-537, active, 10 December 1997

MIL-PRF-83483, *Thread Compound, Antiseize, Molybdenum Disulfide-Petrolatum*, active, 20 February 1998

MIL-DTL-83488, *Coating, Aluminum, High Purity,* active, 1 April 1999

MIL-P-83953A, *Pencil, Aircraft Marking,* canceled without replacement, 24 October 1995

MIL-DTL-85054, *Corrosion Preventive Compound, Water Displacing, Clear* (Amlguard), active, 22 February 2007

MIL-PRF-85285, *Coating: Polyurethane, Aircraft and Support Equipment*, active, 22 September 2006

MIL-C-85322, *Coating, Elastomeric, Polyurethane, Rain-Erosion*, active, 30 September 1999

MIL-PRF-85582, *Primer Coatings: Epoxy, Waterborne,* active, 9 June 2006

MIL-HDBK-729 *Corrosion and Corrosion Prevention, Metals*, active, 26 July 1989

2.1.1.2 Standards

The DoDSSP's ASSIST management and research database also retains electronic versions of the following federal and military standards.

2.1.1.2.1 Federal

FED-STD-595, *Colors Used in Government Procurement*, active, 11 January 1994

2.1.1.2.2 Military

MIL-STD-171, *Finishing of Metal and Wood Surfaces*, active, 18 July 2006

MIL-STD-464, *Electromagnetic Environmental Effects, Requirements for Systems*, active, 19 December 2002

MIL-STD-883, *Test Methods and Procedures for Microelectronics*, active, 28 February 2006

MIL-STD-889, *Dissimilar Metals*, active, 19 October 2006

MIL-STD-1250, *Handbook for Corrosion Prevention and Deterioration Control in Electronic Components and Assemblies*, canceled, 18 August 1995

MIL-STD-1500, *Cadmium-Titanium Plating, Low Embrittlement, Electrodeposition*, inactive, 1 March 2007

MIL-STD-1530, *Aircraft Structural Integrity Program, Airplane Requirement*, active, 1 November 2005

MIL-STD-2073, *DoD Material Procedures for the Development and Application of Packaging Requirements*, canceled, 14 June 2006

MIL-STD-2161, *Paint Schemes and Exterior Markings for U.S. Navy and Marine Corps Aircraft*, active, 1 May 1993

MIL-STD-7179, *Finishes, Coatings and Sealants for the Protection of Aerospace Weapons Systems*, active, 30 September 1997

2.1.2 Handbooks

MIL-HDBK-275, *Guide for Selection of Lubricants, Fluids, and Compounds for Use in Flight Vehicles and Components*, active, 29 June 1976

MIL-HDBK-808, *Finishes, Materials and Processes for Corrosion Prevention Control in Support Equipment*, active, 18 July 1998

MIL-HDBK-838, *Lubrication of Military Equipment*, active, 3 December 1997

MIL-HBK-1250, *Handbook for Corrosion Prevention and Deterioration Control in Electronic Components and Assemblies*, inactive, 30 November 2006

MIL-HDBK-83377, *Requirements* for *Adhesive Bonding (Structural) For Aerospace and Other Systems, Requirements for*, active, 31 December 1997

NAVMATP-4855-2, *Design Guidelines for Prevention and Control of Avionic Corrosion*, active, June 1983, accessible at http://www.bmpcoe.org/library/books/navmat%20p-4855-2/index.html

2.1.3 Other Government Documents, Drawings, and Publications

MMPDS, *Metallic Materials Properties Development and Standardization* (Formerly MIL-HDBK-5), active, 18 January 2007

2.2 Non-Government Publications

Non-government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or through informational services.

2.2.1 American Society for Testing and Materials

For the following publications, refer to http://www.astm.org or contact ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, Phone (610)832-9585, Fax (610)832-9555.

ASTM A380, *Stainless Steel Parts, Equipment and Systems, Cleaning, Descaling, and Passivation of,* active, 25 March 1988

ASTM B117, *Salt Spray (Fog) Apparatus, Operating,* active, 25 March 1988

ASTM B194, *Standard Specification for Copper-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar*, active, 15 November 1992

ASTM B196/196M, *Standard Specification for Copper-Beryllium Alloy Rod and Bar*, 29 June 1990

ASTM B197, *Wire, Alloy, Copper-Beryllium,* active, 3 October 1994

ASTM D1732, *Painting for Magnesium Alloy Surfaces, Preparation of,* active, 8 September 1967

ASTM D2247, *Water Resistance Testing of Coatings in 100 Percent Relative Humidity*, active, 3 October 1994

ASTM D2803, *Metal Organic Coatings on Filiform Corrosion, Resistance of,* active, 3 October 1994

ASTM G47, *Aluminum Alloy Products, Determining Susceptibility to Stress-Corrosion Cracking of 2XXX and 7XXX*, active, 30 October 1994

ASTM G64, *Standard Classification of Resistance to Stress-Corrosion Cracking of Heat-Treatable Aluminum Alloys*

ASTM G85, *Standard Practice for Modified Salt Spray* (Fog), active, 3 October 1994

2.2.2 Society of Automotive Engineers Publications

For the following publications, refer to http://www.sae.org/servlets/index, or contact SAE World Headquarters, 400 Commonwealth Drive, Warrendale, PA 15096-0001, (877)606-7323 (U.S. and Canada only) or (724)776-4970.

SAE-AMS2700 (supersedes SAE-AMS-QQ-P-35), *Steels, Passivation, Corrosion-Resistant* , active, 23 March 2004

SAE-AMS2403, *Nickel Plating* (Electrodeposited), October 2004 (may supersede or be superseded by SAE-AMS-QQ-N-290 Class1, active, 3 May 2001)

SAE-AMS2423, *Nickel Plating* (Electrodeposited), May 2004 (may supersede or be superseded by SAE-AMS-QQ-N-290 Class2, active, 3 May 2001)

SAE-AMS2460, Chromium Plating (Electrodeposited), July 2007 (may supersede or be superseded by SAE-AMS-QQ-C-320, active, 3 May 2001)

SAE-AMS-QQ-P-416, *Plating, Cadmium* (Electrodeposited) (supersedes SAE-AMS-QQ-N-290 Class1); active, 28 March 2002

SAE-AMS-STD-2175, *Classification and Inspection Castings of*; withdrawn, 15 November 2004

SAE-AMS2424, *Plating, Nickel,, Low Stressed Deposit*; active, 29 April 1991

SAE-AMS-M-3171, *Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion on*; active, 7 May 1998

AMS-3265, *Sealing Compound, Polysulfide (T) Rubber, Fuel Resistant, Nonchromated Corrosion Inhibiting for Intermittent Use to 360Mdf* (182Mdc), work-in-process, revision C, June 2007

SAE-AMS3276, *Sealing Compound, Integral Fuel Tanks and General Purpose, Intermittent Use to 360Mdf* (182Mdc); active, 10 January 1994

SAE-AMS3277, *Sealing Compound, Polythioether Rubber, Fast Curing for Integral Fuel Tanks and General Purpose, Intermittent Use to 400°F* (204°C); active, 17 April 1995

SAE-AMS3281, *Sealing Compound, Polysulfide (T) Synthetic Rubber for Integral Fuel Tank and Fuel Cell Cavities Low Density* (1.20 to 1.35 Sp Gr), *for Intermittent Use to 360Mdf* (182Mdc); active, 28 March 2006

SAE-AMS3374, *Sealing Compound Aircraft Firewall*; active, 29 November 1985

SAE-AMS4890, *Copper-Beryllium Alloy Castings 97Cu-2.1Be-0.52Co-0.28Si Solution Heat Treated* (TB00) (UNS C82500); active, 9 September 1993

SAE-AMS-S-8802, *Sealing Compound, Temperature Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High Adhesion*; active, 28 September 1999

SAE-AMS-C-8837, *Coating, Cadmium* (Vacuum Deposited); active, 10 September 1999

SAE-AMS-C-27725, *Coating, Corrosion Preventive, Polyurethane for Aircraft Integral Fuel Tanks for Use to 250 Mdf* (121 Mdc); active, 25 October 1999

SAE-AMS-C-83231, *Coatings, Polyurethane Rain Erosion Resistant for Exterior Aircraft and Missile Plastic Parts*; active, 24 September 1999

2.2.3 American Welding Society

For the following publication, refer to http://www.aws.org, or contact AWS, 550 N.W. LeJeune Road, Miami, Florida 33126, Phone (800)443-9353 or (305)443-9353.

AWS D17.1, *Specification for Fusion Welding for Aerospace Applications*

2.3 Order of Precedence

In the event of conflict between the text of this document and the cited references, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3.0 Definitions

3.1 Aerospace System

All types of aircraft (including unmanned aerial vehicles, or UAVs), rotorcraft, missile systems, and unique weapon system ground equipment are considered aerospace systems.

3.1.1 Coatings and Platings

3.1.1.1 Coatings

A coating is a material applied onto or impregnated into a substrate for protective, decorative, or functional purposes. Such materials include paints, varnishes, sealers, metals, ceramics, phosphates, oxides, films, appliqués, adhesives, and inks.

3.1.1.2 Platings

Plating is a layer (or layers) of metal deposited on or applied to a surface from a solution by chemical or electrochemical action. Such metals include, but are not limited to, aluminum, copper, chromium, nickel, cadmium, zinc, tin, lead, silver, gold, and metal alloys, such as zinc-nickel and tin-lead.

Plating is a coating, but a coating is not necessarily a plating.

3.2 Exterior Surfaces

All surfaces of an aerospace system normally exposed to an external environment during flight or on the ground are considered exterior surfaces. All interior surfaces that may become regularly wetted with water or corrosive fluid are considered exterior surfaces. These surfaces include, but are not limited to wheels and landing gear, wheel wells, and their fairings, control surfaces, wing-fold areas, battery compartments, and bilge area on aircraft with latrines.

3.3 Extreme Conditions

Extreme conditions include, but are not limited to exhaust trails, gun-blast surfaces, rocket-blast areas, hull bottoms, leading edges, areas that may trap or be exposed to fumes from exhaust, guns or rockets, or surfaces subjected to temperatures above 250ºF (121ºC) as the result of thermal radiation, aerodynamic heating, or other sources of heat.

3.4 Fayed Surface

A fayed surface comprises two or more surfaces joined with overlap of adjacent surface or fitted closely or tightly together.

3.5 Hull Bottom

The hull bottom is defined as the surface area of a seaplane fuselage that is below the line that is 12 inches (0.31 meters) above the full-load water line.

3.6 Seaplanes

All aircraft operating wholly, or in part, from water, such as flying boats, airplanes with float-type alighting gear, aircraft with hydro-skis, amphibians, or convertibles are considered "seaplanes."

4.0 General Requirements

4.1 General Requirements

For ACAT I programs, the program manager shall prepare a corrosion prevention and control plan. This CPC Planning Guidebook assists the PM in meeting that requirement. The program plan should define corrosion prevention and control requirements and considerations for system definition, design, engineering development, production, and sustainment phases, consistent with the design life of the system. CPC requirements for the aerospace system should include the materials, processes, finishes, coatings, and sealants to be used, and those being approved by the CPAT and contained in the CPCP and process/finish specification.

4.2 Managing Corrosion Prevention and Control Program

The prime contractor should prepare a process/finish specification in accordance with this *CPC Planning Guidebook* and good engineering practices. The process/finish specification should identify the specific organic and inorganic surface pretreatments, coatings, and other corrosion prevention and control materials and processes intended to be used for protection against corrosion of the materials selected for the DoD aerospace system as previously identified in the CPCP.

4.3 Data Requirements

DI-MFFP-81402, *Finish Specification Report*

DI-MFFP-81403, *Corrosion Prevention and Control Plan*

The above DID was current as of the date of this standard. The ASSIST database at http://assist.daps.dla.mil must be researched to ensure only current and approved DIDs are cited on the DD Form 1423.

5.0 Detail Requirements

5.1 Materials and Process Considerations in Design

Corrosion design should be in accordance with design concepts defined in MIL-STD-1530. Because corrosion may be both a safety and structural integrity issue, it is to be managed as such during the design and sustainment phases of the weapon system life according to the requirements of MIL-STD-1530. MIL-STD-1530 provides guidance for programmatic tasks for the conceptual definition, development, acquisition, maintenance, and modification of the primary and secondary structures of crewed and unmanned flight vehicles and external stores to ensure their structural integrity while maintaining the affordability of these systems throughout their period of use. Structural deficiencies must be identified and corrected as early as possible to minimize repairs, modifications, and life-cycle costs while cost and schedule risks are managed. The Aircraft Structural Integrity Program (ASIP) consists of a series of disciplined, time-phased actions, procedures, analyses, tests, etc. When developed and applied in accordance with the information in this guidebook, the ASIP will ensure reliable, affordable, and supportable primary and secondary flight vehicle structures, thus contributing to the enhancement of total systems mission effectiveness and operational suitability while minimizing cost and schedule risks.

5.1.1 Selection Considerations

The primary consideration in the design and construction of DoD aerospace systems is the ability of the design to comply with structural and operational requirements. In addition, the DoD aerospace systems are expected to perform reliably and require minimum maintenance over a specified lifetime, which includes minimizing the rate of deterioration. Therefore, in the selection of suitable materials and appropriate processing methods to satisfy system requirements, consideration must also be given to materials, processing methods and protective treatments that reduce failures due to deterioration. Deterioration modes that contribute to failures include pitting corrosion, galvanic corrosion, exfoliation corrosion, stress corrosion, crevice corrosion, filiform corrosion, corrosion fatigue, thermal embrittlement, fretting fatigue, oxidation, hydrolytic instability, hydrogen embrittlement, weathering, and fungus growth. In the entire design phase, attention should be given to precautionary measures to minimize deterioration of individual parts and assemblies as well as the entire system. Required precautionary measures are included in the following paragraphs.

5.1.2 General Design Guidelines for Corrosion Prevention

5.1.2.1 Exclusion of Rain, Airborne Spray and Moisture Accumulation

The design of the system should prevent water leaking, or being driven, into any part of the system interior in the operational or storage environments. All windows, doors, panels, canopies, etc. should be provided with sealing configurations such that the entry of water is eliminated when these items are correctly closed. Particular care should be taken to prevent wetting of equipment, thermal insulation, and sound proofing materials. Recesses should be avoided so that moisture and solid matter cannot accumulate to initiate localized attack. Sealed floors should be provided for galleys, toilets, and cockpits. Provision should be made to protect weather seals and pressurization system seals from damage as a result of normal maintenance activities and from normal entrance and egress by crew. The cockpit and air intake rain watertightness should satisfy the requirements of MIL-W-6729.

5.1.2.2 Ventilation

Ventilation should be sufficient to prevent moisture retention and buildup.

5.1.2.3 Drainage

Drain holes should be provided to prevent collection or entrapment of water or other unwanted fluid in areas they can enter by various methods. A "dams and drains" drawing/plan should be developed to ensure adequate drainage is provided. This is critical because separate groups or contractors are often responsible for the design of modules or structure, and they may not be able to eliminate fluids except via adjacent modules or structure. Minimum diameter for all drains should be 9.525 mm (0.375 inches) unless otherwise approved by the procuring activity. All designs should include considerations for the prevention of water or fluid entrapment and insure that drain holes are located to permit maximum drainage of accumulated fluids. All draining should be through meniscus-free drain holes. Closed sections, where used, should have provision for drainage of condensation or other fluids. Special effort should be made to ensure free draining of rain, seawater, or other fluids. End fittings used with open tube should not form pockets, which may collect moisture. Cork seals, dams, and metal end plugs machined to fit should not be used. A single valve installation to the side of aft cockpit should be provided for drainage. Low points should not be required in the aft cockpit floor, provided alternate drainage provisions are satisfactory for the intended purpose. Drainage provision should be provided as required by the engine model specification and should be in accordance with MIL-O-19838. The drain valves should be readily accessible for drainage and oil should drain clear of the aircraft. Airframe supplied drain valves should contain a locking feature.

5.1.2.4 Dissimilar Metals

Use of dissimilar metals, as defined by Table 1 in direct contact should be limited to applications where similar metals cannot be used due to design requirements, and should be approved by the procuring activity.

Table 1. Grouping of Metals and Alloys

Group I	Magnesium and its alloys (use requires approval)
Group II	Cadmium, zinc (use requires approval) Aluminum alloy 5052, 5056, A356 (and other casting alloys), 6061, 6013, 6063 (and other 6000 series alloys), and 7000 aluminum alloys
Group III	2000-series aluminum alloys
Group IV	Iron, lead, and tin and their alloys (except corrosion-resistant steel)
Group V	Copper, chromium, nickel, cobalt and rhodium and their alloys; brass and corrosion-resistant steel
Group VI	Silver, gold, platinum, titanium and graphite

Notes: Metals classified in the same groups are considered as similar metals. Materials classified in different groups are considered as dissimilar metals.

When it is necessary to use dissimilar metals in direct contact, the metals should be adequately protected against galvanic corrosion. Galvanic corrosion can be minimized by interposition of a material, which will reduce the overall electrochemical potential of the joint or by interposition of an insulating or corrosion inhibiting material. Composite materials containing graphite fibers should be treated as graphite in Table 1. Items electrically bonded or used for EMI hardening should be sealed to prevent moisture intrusion. Frequently removed items or items that it is not practical to seal should be of similar materials. Emphasis should be place on using fasteners versus bare metal-to-metal contact to achieve bonding. During the structural design and material/process selection, consideration should be given to various design alternatives, which preclude the traditional galvanic corrosion problems created by dissimilar metal bushings (e.g. beryllium copper, aluminum bronze) installed in aluminum structure. Consideration should be given to the avoidance of using removable graphite/bismaleimide (BMI) composite doors/panels fastened to aluminum alloy substructure, particularly on upper surfaces where moisture/salt spray can potentially migrate through the fastener holes and cause corrosion of the aluminum substructure. Unless suitably protected against electrolytic corrosion, dissimilar metals should not used in direct contact.

5.1.3 Metallic Materials

Aerospace materials selection and materials substitution information critical to improved corrosion design can be obtained from http://www.grantadesign.com.

5.1.3.1 Aluminum

5.1.3.1.1 Alloy Selection

The selection of aluminum alloys for structural application requires consideration of their resistance to pitting, exfoliation and stress-corrosion cracking (SCC). Maximum use should be made of alloys and heat treatments that minimize susceptibility to pitting, exfoliation and SCC. Relative SCC ratings for high strength aluminum alloy products based on ASTM G64 and service experience are given in Table 2. Although the ratings are based primarily on the results of standard corrosion tests, an experience factor can be substituted for those materials that have established service records. The ratings are given for the short transverse grain direction, as this is the most critical SCC condition in structural applications. In addition, recommended alloys and tempers for exfoliation and stress corrosion resistance are listed in Table 3.

Table 2. Rating for Resistance to SCC Aluminum Alloys in the Short Transverse Grain Direction

Alloy and Temper	Rolled plate	Rod and bar	Extruded shapes	Forgings
2014-T-6	Low	Low	Low	Low
2024-T3, T4	Low	Low	Low	Low
2024-T6		High		Low
2024-T8	High	Very High	High	Intermediate
2124-T851	High			
2219-T351X, T37	Very High		Very High	Very High
2119-T6	Very High	Very High	Very High	Very High
6061-T6	Very High	Very High	Very High	Very High
7005-T53, T63			Low	Low
7039-T64	Low		Low	
7049-T74	Very High		High	High
7049-T76			Intermediate	

Table 2. Rating for Resistance to SCC Aluminum Alloys in the Short Transverse Grain Direction

Alloy and Temper	Rolled plate	Rod and bar	Extruded shapes	Forgings
7149-T74			High	High
7050-T74	High		High	High
7050-T76	Intermediate	High	Intermediate	
7075-T-6	Low	Low	Low	Low
7075-T736				High
7075-T74	Very High	Very High	Very High	Very High
7075-T76	Intermediate		Intermediate	
7175-T736			High	
7475-T6	Low			
7475-T73	Very High			
7475-T76	Intermediate			

All aluminum sheets used in external environments and interior corrosive environments should be clad on both sides except where the design requires surface metal removal by machining, chemical milling, adhesive bonding or where alloys of the 1000, 3000, 5000, or 6000-series type are used.

Table 3. Recommended Alloys and Tempers for Exfoliation and Stress Corrosion Resistance

Exfoliation resistance alloy	Temper
2124-	Artificially aged
2219-	Artificially aged
2014-	Artificially aged
2024-	Artificially aged
7075-	T76XX, T74XX
7175-	T76XX, T74XX
7049-	T76XX, T74XX
7050-	T76XX, T74XX
7150-	T77XX

If these alloys and tempers, or other approved alloys, are not used, the susceptibility to stress corrosion cracking of the selected alloy should be established for each application in accordance with the American Society for Testing and Materials, test methods G44 and G47.

5.1.3.1.2 Limitation on Use of Aluminum Alloys

Mill product forms of aluminum alloys 2020, 7079, and 7178 in all temper conditions should not be used for structural applications. Use of 2000-series aluminum alloys in the -T3 and -T4 tempers and 7000-series aluminum in the -T6 tempers in thicknesses greater than 2.032 mm (0.080 inch) should not be used.

Suitably clad aluminum alloys or inherently corrosion-resistant alloys should be used in exterior skin that is 0.125 inch or less in thickness; forms a leading-edge, exhaust trail area of any source or wheel well area; is spot- or seam-welded; or is the face sheet in bonded sandwich construction. Non-clad materials may be used for the aileron skins, the flap shroud skins and the flap shroud closure pocket. To preclude partial aging in heat treatable alloys, the bonded sheet should be in the artificially aged condition prior to bonding. The references above to exterior surfaces and skin mean the external surface only and do not preclude use of material clad only on one side or the removal of cladding from internal surfaces. Clad high strength aluminum alloys should not be fusion welded.

5.1.3.1.3 Maximum Metal Removal

Maximum metal removal from surfaces of non-stress relieved structural parts after final heat treatment should not exceed 3.81 mm (0.150 inch) per side unless the final temper of condition has been demonstrated to have a stress-corrosion resistance of 173 MPa (25 ksi) or higher in the short transverse grain direction as determined by a 20-day alternate immersion test given in ASTM G47. This is applicable to 2000 and 7000-series alloys, but 30 days should be used on 2000-series alloys. Stretch stress-relieved or compression stress-relieved aluminum products should be used wherever possible. Maximum metal removal requirements are not intended to apply to mechanically stress-relieved products because of the low level of internal stresses resulting from mechanical stress relief. This guidance may be tailored as appropriate with approval by the procuring activity.

5.1.3.1.4 Shot Peening for Stress Corrosion Resistance

All critical surfaces of all structural forgings, machined plate and extrusions, where accessible after final machining and heat treatment, must be completely shot peened in accordance with AMS-S-13165, ensuring 100 percent coverage as a minimum or placed in compression by other suitable means, except for alloys having a demonstrated stress corrosion resistance of 173 MPa (25 ksi) or higher in the short transverse direction and web areas under 2.032 mm (0.080 inch) thick where no short-transverse grain is exposed by machining. Those areas of forgings requiring lapped, honed, or polished surface finishes for functional engineering requirements should be shot peened prior to such subsequent surface finish operations. All aluminum products with an ASTM G47 stress corrosion threshold less than 173 MPa (25 ksi) should, after shot peening, have essentially no residual surface tensile stresses in the final heat-treated and machined condition. Finish cleanup of shot peened surfaces as required for fit up will not exceed 0.076 mm (0.003 inch) of surface removal for aluminum alloys. This guidance may be tailored as appropriate with approval by the procuring activity.

5.1.3.1.5 Stress Corrosion

High strength aluminum alloy parts should be designed, manufactured, assembled, and installed so that sustained residual tensile stresses are sufficiently low to prevent premature failures due to stress corrosion cracking. Various methods (e.g. mechanical, thermal) of optimizing the residual stress state of surface and subsurface material should be considered. The residual stress state of subsurface material should be considered when determining the extent of metal removal required during machining. Practices, such as the use of press or shrink fits, taper pins, clevis joints in which tightening of the bolt imposes a bending load on the female lugs, and straightening or assembly operations, which result in sustained or residual surface tensile stresses should be avoid. In case where such practices cannot be avoided, corrective practices such as stress relief heat treatment and optimum grain flow orientation should be used to minimize the hazard of stress corrosion cracking. These corrective practices should be done on both test and production parts. For aluminum alloy, the stress corrosion guidelines for aluminum alloys detailed in MMPDS (formerly MIL-HDBK 5) should be followed.

5.1.3.2 Low Alloy, High Strength Steels

All low alloy, high strength steel parts, 1241 MPa (180 Ksi) ultimate tensile strength (UTS) and above, including fasteners, require corrosion preventative metallic coatings by a process proven to be nonembrittling to the alloy/heat treatment combination. Applicable metallic coatings and finishes are described in subsequent sections of this document.

Selection of steels should be as follows:

a. Aircraft-quality, vacuum-melted steel should be used for parts which are heat treated to an ultimate tensile strength of 220,000 psi and above.

b. The maximum ultimate tensile strength in production parts should not be greater than 20,000 psi above the established allowable minimum requirement.

c. Preference should be given, in selection of carbon and low alloy steels, to compositions having the least hardenability, which will provide thorough hardening of the part concerned.

d. Compositions should be selected such that heat treatment to the required strength and service temperatures should preclude temper embrittlement, blue brittleness, or brittle temper.

e. Steels should be selected having ductile-brittle fracture transition temperatures as determined by impact test below the minimum operating temperature.

f. Steels whose mechanical properties are developed by cold deformation should have the recovery temperature of at least 50ºF above the expected operating temperature range.

g. Critical parts should be designed and processed so as to result in no decarburization in excess of 0.003 inch of highly stressed areas. Elsewhere, decarburzation should be avoided and where unavoidable should be compensated by appropriate reduction in design fatigue strength. Unless otherwise specified, designs should preclude use of as-forged surfaces. Carburization and partial decarburization of fully hardened steel parts should be restricted such that the difference in hardness from the surface to the nominal subsurface hardness should not exceed two points Rockwell C (HRC).

h. The mechanical drilling of holes in martensitic steels after hardening to strength levels of 180,000 psi and above should be avoided. When such drilling is unavoidable, detailed information concerning the processes to be used should be in accordance with the procuring activity approved contractor material and process specifications.

i. Grinding of martensitic steels and chromium plated martensitic steels hardened to 200,000 psi and above should be in accordance with MIL-STD-866.

j. Use of high fracture toughness materials is required in major landing gear components and critical fittings. Materials should be procured in accordance with contractor or industry specifications appropriate for the application. Aeromet 100 should be procured in accordance with AMS-6532. Standard pins, fasteners, springs and other standard parts are excluded from this requirement.

k. H-11, D6-AC, 4340M and 300M steels should not be used without specific approval of the procuring activity.

5.1.3.2.1 Limitation on Use of Protective Metallic Coatings

Soft surface coatings such as cadmium, nickel-cadmium, and aluminum should not be used for sliding or wear applications. Cadmium plated surfaces should not be used in applications where surface temperature exceeds 232ºC (450ºF). Cadmium should not be used on parts that may be in contact with hydraulic fluids, fuels, lubricating oil, and other petroleum based fluids. Cadmium should not be used on parts that will be subsequently soldered. Cadmium should not be used on components that will come into contact with titanium and graphite composites. Cadmium should not be used in confined spaces, in the presence of organic materials that give off corrosive or damaging vapors. Cadmium plated fasteners, used in areas where contact with fuel can occur, should be overcoated with an approved fuel tank coating (such as AMS-C-27725) and subsequently coated with fuel tank sealant. Chromium plating should be considered an acceptable corrosion preventative for alloy steel wear surfaces only when the chrome plating is periodically lubricated (fluid or grease types only) or a 0.038 mm (0.0015 inch) minimum layer of nickel plating is applied under the chromium. All chromium plated steel parts used in fatigue applications should be shot peened prior to electroless nickel (EN) plating. Chromium plated surfaces should not be used in applications where service temperatures exceed 371ºC (700ºF).

5.1.3.2.2 Stress Corrosion Factors

Titanium and alloy steel parts heat treated to 1241 MPa (180 Ksi) UTS and above should be designed, manufactured, assembled, and installed such that sustained residual surface tensile stresses should be minimized to prevent premature failures due to stress corrosion cracking or hydrogen embrittlement. The residual stress state of subsurface material should be considered when determining the extent of metal removal required during machining. Whenever practicable, the use of press or shrink fits, taper pins, clevis joints in which tightening of the bolt imposes a bending load on the female lugs, and straightening or assembly operations that result in sustained residual surface tensile stresses in these materials should be avoided. In cases where such practices cannot be avoided, apply protective treatment such as stress relief heat treatments, optimum grain-flow orientation, wet installed (with a protective material) inserts and pins, and shot peening or similar surface working to minimize the hazard of stress-corrosion cracking or hydrogen embrittlement damage. These corrective practices should be done on both test and production parts. Various methods (e.g., mechanical, thermal) of optimizing the residual stress state of surface and subsurface material should be considered. Only the following corrosion resistant and high strength steels should be used for critical parts: HP-9-4-30, 13-8, AF-1410, Modified AF-1410, and AERMET 100. Use of any other high strength steel for critical parts should only be used upon engineering approval of the procuring activity.

5.1.3.3 Corrosion Resistant Steels

All corrosion resistant steels should be passivated in accordance with AMS-QQ-P-35 or ASTM A380. It should be noted that AMS-QQ-P-35 has been superseded by AMS 2700. Both AMS 2700 and ASTM A380 permit the use of citric acid for passivation however this process is not approved by NAVAIR. In addition, 400 series martensitic steel require coatings for protection against corrosion. Table 4 should be used as a guide in the selection of corrosion resistant steels for structural applications.

5.1.3.3.1 Limitation on Use of Corrosion Resistant Steels

Precipitation hardening steels should be aged at temperatures not less than 538ºC (1000ºF). Exception is made for castings that may be aged at 501.5 +9.4ºC (935ºF +15ºF), for fasteners that may be used in the 950 condition, and for springs that have optimum properties at the CH 900 condition. Corrosion resistant maraging steels should not be used in sustained load applications and if use (ALMAR 362, CUSTOM 455, CUSTOM 450) should be aged at temperature not less than 1000ºF. Corrosion resistant 19-9DL and 431 steels should not be used for any applications. Series 400 martensitic grade corrosion resistant steels should not be used in the 700ºF to 1100ºF tempered condition (150 to 180 ksi strength ranges). Unstabilized austenitic steels may be used up to 370ºC (700ºF). Unstabilized austenitic steels should not be fusion welded. Precipitation hardening semi-austenitic grades should not be used in applications that require extended exposure to temperatures in the 750 through 900ºF range. Only stabilized austenitic steels (321 and 347) should be used above 370ºC (698ºF). Free machining stainless steels should be avoided for all applications. All welded or brazed austenitic steel should be solution heat treated after welding; however, welded 321 and 347, 304L, and 316L may be used without heat treatment.

Table 4. Corrosion Characteristics of Corrosion Resistant Steels

Class	Alloy	General Corrosion Resistance	Stress Corrosion Resistance
Austenitic	301	High	Very High
	302	High	Very High
	304	High	Very High
	310	High	Very High
	321	High	Very High
	347	High	Very High
Martensitic	440C 420 410 416	Low to Moderate–Will develop superficial rust film with atmospheric exposure	Susceptibility varies significantly with composition, heat treatment, and product form

Table 4. Corrosion Characteristics of Corrosion Resistant Steels

Class	Alloy	General Corrosion Resistance	Stress Corrosion Resistance
Precipitation Hardening	21-6-9	Moderate	Susceptibility varies significantly with composition, heat treatment, and product form
	13-8Mo	Moderate	
	15-7Mo	Moderate	
	14-8Mo	Moderate	
	17-4PH	Moderate	
	15-5PH	Moderate	Very High
	AM355	Moderate	Very High
	AM350	Moderate	Low
	9Ni 4Co-0.20C	Moderate	
	9Ni 4Co-0.30C	Moderate	
	9Ni 4Co-0.45C	Moderate	
Other	A286	High	Very High

5.1.3.4 Titanium

Titanium alloys other than recrystallized annealed 6Al-4V should not be used for fatigue crack propagation critical applications or fracture toughness critical applications. The use of titanium alloy 8Al-1Mo-1V in other than the beta heat-treated condition should not be used.

5.1.3.4.1 Surface Considerations

The surfaces of titanium mill products (sheet, plate, bar, forging, casting and extrusion) should be 100 percent machined, chemically milled, or pickled to remove all contaminated zones and layers formed while the material was at elevated temperature. This includes contamination as a result of mill processing, heat-treating, and elevated temperature forming operations.

5.1.3.4.2 Fretting

Titanium alloys are highly susceptible to the reduction of fatigue life by fretting at interfaces between titanium alloys or titanium and other metals. In any design where fretting is suspected, tests should be made to determine whether such a condition will exist and insure that fatigue life requirements are met. Design considerations should be applied to minimize fretting in structural applications including provision made for anti-fretting coatings or inserts.

5.1.3.4.3 Special Precautions

Titanium parts or fasteners should not be cadmium or silver-plated. Cadmium-plated hardware, clamps, tools, fixtures, and jigs should not be used for fabrication or assembly of titanium components or structures. Cadmium-plated parts should not be used in intimate contact with titanium. Silver parts and fasteners should not be in contact with titanium components at temperatures in excess at 355ºF, respectively. Application requiring cadmium-plated or silver-plated parts in contact with titanium should be approved by the procuring activity.

5.1.3.5 Magnesium

Magnesium alloys are highly corrosion prone and should be avoided. Magnesium alloys should be used only with specific engineering approval from the procuring activity.

5.1.3.6 Beryllium

In applications where beryllium is an approved material, consideration should be given to suitable protective coatings to protect parts against corrosion. All beryllium should be used in a passivated condition by a process approved by the procuring activity. High content Beryllium alloys (>3 percent Be) should not be used without specific approval of the procuring activity. The use of beryllium and beryllium-based alloys for structural parts is discouraged, except for beryllium copper alloys containing less than 2 percent beryllium by weight. Beryllium copper alloy should be considered for use in high bearing load applications, critical wear applications, and wear applications where good structural load capability is required. Alloy UNS C17200 or UNC 17300 or equivalent is required. Wrought beryllium copper should be acquired to ASTM B196, ASTM B197, or ASTM B194. Beryllium copper castings should be acquired to AMS-4890 and classified (class and grade) per AMS-2175.

5.1.3.7 Mercury

Mercury and many compounds containing mercury can cause accelerated stress cracking of brass, aluminum and titanium alloys. Mercury should not be used where spillage can contact these materials.

5.1.3.8 Depleted Uranium

The general finish for depleted uranium should be nickel plate to the requirements of AMS 2403 (that superseded AMS-QQ-N-290) or aluminum coated to the requirements of MIL-DTL-83488, plus one coat of MIL-PRF-23377 Type I primer, thickness 0.015 to 0.023 mm (0.0006 to 0.0009 inch). Depleted uranium must not be used without the specific approval of the procuring activity.

5.1.3.9 Bronze Bearing Alloys

For moderate and light duty bearing loads wrought UNS C63000 aluminum-nickel bronze per ASTM B150 and B 169 is the preferred alloy. Aluminum bronze (alloys UNS C95200-C95800) casting is acceptable and, where used should be classified (class and grade) per AMS-STD-2175, and acquired per QQ-C-390. The use of bronze alloys other than those discussed above is discouraged.

5.1.3.10 Composites

Composites are defined as materials that consist of reinforcing fibers made of graphite, fiberglass, aromatic polyamide, boron, or other materials in a matrix consisting of organic resin or metal.

Imide-based or graphite composites should not be in contact with or adjacent to parts/materials that are susceptible to corrosion (aluminum, steel, tin) including, brackets, clips, gang channels, tubing, fasteners, etc. without the specific approval of the procuring activity.

Imide-based or graphite composites should not be used in structures not accessible for nondestructive inspection, non-inspectable structure, or non-removable by organizational level maintenance, without the specific approval of the procuring activity.

The use of metal or ceramic matrix composites and ceramics is prohibited, except for rudder and aileron servocylinder end glands. These materials should only be used upon engineering approval by the procuring activity.

5.1.3.11 Organic Materials

The following restrictions should apply to the selection of elastomers, plastics, and other organic materials used in the fabrication of aircraft structures and components:

All organic materials should have resistance to degradation and aging (including resistance to hydrolysis, ozonolysis and other chemical processes attendant upon atmospheric exposure), and minimum flammability consistent with performance requirements for the intended use.

Decomposition and other products, including volatile and leachable constituents, released by organic materials under normal operating conditions should not be injurious or otherwise objectionable with respect to materials or components or to personnel with which they may be reasonably expected to come in contact.

Cellular plastics, foams and wood should not be used for skin stabilization in structural components, other than in all-plastic sandwich components. Use of foam as sandwich core materials should not be used without the specific approval of the procuring activity.

Natural leather degrades quickly and should not be used.

Elastomeric encapsulating compounds used should conform to MIL-PRF-8516, MIL-S-23586, MIL-M-24041, MIL-A-46146, or MIL-I-81550. Use of hydrolytically unstable encapsulation materials is prohibited. These materials should only be used with engineering approval by the procuring agency. Use of polyester polyurethanes requires substantiation of hydrolytic stability.

The use of adhesives in the fabrication of the aircraft structure, including metal faced and metal core sandwich, without the specific approval of the procuring activity is prohibited.

Integral fuel tank sealing compounds should conform to AMS-S-8802, AMS-S3276, or AMS-S-3281.

Materials that are in direct contact with fuels should be resistant to fuel-related deterioration and capable of preventing leakage of the fuel, if required.

All elastomeric components should possess adequate resistance to aging, operational environmental conditions and fluid exposure for the intended system use. Asbestos and asbestos containing material shall not be used.

5.1.4 Non-Metallic Materials—Insulation Blankets

Where thermal/acoustical insulating blankets are required, they should be either procured with a permanent baked on water repellent binder system or suitably protected with sealant to prevent any moisture absorbed by the blanket from contacting the metal structure. Consideration must be given to ease of removal of the blankets to facilitate maintenance and inspection. If these design or installation requirements are not applicable to blankets considered for use, justification for alternative installation methods must be provided to the procuring activity.

5.2 Materials and Process Considerations in Manufacturing Operations

Adequate precautions should be taken during manufacturing operations to maintain the integrity of corrosion prevention requirements and to prevent the introduction of corrosion or corrosive elements.

5.2.1 Cleaning

Cleaning of the various types of metallic surfaces, prior to application of the surface treatments and coatings, should be as specified in MIL-S-5002, using materials and processes which have no damaging effect on the metal, including freedom from pits, intergranular attack, and significant etching. After cleaning, all parts should be completely free of corrosion products, scale, paint, grease, oil, flux, and other foreign materials including other metals, and should be given the specific treatment as soon as practical after cleaning. Particular care should be exercised in the handling of parts to assure that foreign metals are not inadvertently transferred, as may occur when steel is allowed to come into contact with zinc surfaces.

5.2.1.1 Titanium Contamination

Care should be taken to ensure cleaning fluids and other chemicals are not used on titanium assemblies where entrapment can occur. The following substances are known to be contaminants and can produce stress corrosion cracking:

a. Hydrochloric acid
b. Trichloroethylene/Trichloroethane
c. Carbon tetrachloride
d. All chlorides
e. Chlorinated cutting oil
f. Halogenated hydrocarbons
g. Methyl alcohol.

5.2.2 Surface Damage

Damage to any previously applied surface treatment or protective finish should be repaired. Damage to surfaces that will become inaccessible because of mating with other parts should be touched up prior to mating. Organic coatings used for repair should be the same as those on the undamaged areas.

5.2.3 Marking Pencils

Ordinary lead pencils containing graphite should not be used to mark metal parts. Nongraphitic marking pencils conforming to MIL-P-83953 (cancelled without replacement) should be used.

5.2.4 Cleaning After Assembly

All closed compartments should be cleaned after assembly to remove debris such as metal chips, broken fasteners, and dust. Insure that drain holes are not blocked.

5.2.5 Protection of Parts During Storage and Shipment

All parts and assemblies should be given adequate protection to prevent corrosion and physical damage during temporary or long-term storage and shipment. Packaging practices should conform to MIL-STD-2073.

5.3 Protective Finish Systems

5.3.1 Surface Treatment

All metal surfaces, regardless of whether they are to be painted or are specifically excluded from painting, should be surface treated in accordance with MIL-S-5002, except as modified by 5.5.1.1.c.

5.3.2 Inorganic Finishes

Alternative inorganic finishes can be inserted over the entire life of the system when feasible. This document suggests some alternatives as possible substitutes for selected finishing systems. The same engineering considerations used for the initial material selection must be considered every time an alternative finish is considered for substitution into a system after fielding. All inorganic finishing alternative selections must be made with the understanding of their impact on the entire system and with the specific approval of the procuring activity.

5.3.2.1 Detail Requirements

Cleaning, surface treatments, and inorganic finishes for metallic surfaces of DoD aerospace systems parts should be in accordance with MIL-S-5002. Those parts or surfaces of parts, located in corrosion susceptible areas or which form exterior surfaces of the system, should require chemical finishing providing maximum corrosion resistance.

5.3.2.1.1 Aluminum

All nonclad parts made from 7000 series aluminum alloys should be sulfuric acid anodized in accordance with MlL-A-8625, Type II or chromic acid anodized, MIL-A-8625, Type IB. All nonclad parts made from 2000 series aluminum alloys should be anodized in accordance with MIL-A-8625, Type I or II. Clad 2000 and 7000 series aluminum alloys may be anodized in accordance with MIL-A-8625, Type I or II, or should have a chemical film in accordance with Type 1, Class 1A MIL-DTL-5541 using materials qualified to MIL-DTL-81706 as a minimum corrosion preventative coating. All 5000 and 6000 series aluminum alloys should have a chemical filming in accordance with MIL-DTL-5541 using materials qualified to MIL-DTL-81706 as a minimum corrosion preventative coating.

5.3.2.1.2 Cadmium Coatings

Cadmium coatings for all steel parts with threads including fasteners should have a minimum thickness of 0.008 mm (0.0003 inch) and should be subsequently treated with a chromate conversion coating. Cadmium coatings for all other (non-threaded) applications should be Class 1 thickness (0.0005 inch), Type II (supplemental chromate treatment).

5.3.2.1.3 Aluminum Coatings

Aluminum coating per MIL-DTL-83488 or equivalent may be considered an acceptable alternative coating to cadmium with the approval of the procuring activity. Ion Vapor Deposited (IVD) aluminum coatings shall be peened to eliminate porosity where galvanic dissimilarities are adverse to the material being coated. IVD aluminum coatings should not be used where dissimilarity with the base material will result in corrosion pitting if there is damage or porosity.

5.3.2.1.4 Nickel Plating

Except when used as an undercoating, nickel plating should be in accordance with SAE AMS 2423, Class 2 (engineering) with a minimum thickness of 0.002 inch, unless otherwise specified. Nickel plating shall be used for the following applications only with specific approval of the procuring activity:

- Where temperatures do not exceed 1000^{o}F (538^{o}C) and other coatings would not be suitable.
- To minimize the effects of crevice corrosion with unplated corrosion-resisting steel or stainless steel in contact with other stainless steel.
- As an undercoat for other functional coatings.
- To restore dimensions by rebuilding worn surfaces.
- For resistance to sand erosion.

5.3.2.1.4.1 Low Residual Stress

Where applications require low residual stress in the plated nickel, plating shall be in accordance with AMS-2424.

5.3.2.1.4.2 Undercoating

Where the selected coating does not provide corrosion protection for the base metal and the coated surface or portion thereof is exposed to corrosive environment, an undercoat of 0.0010 to 0.0016 inch of nickel on steel or zinc parts or an undercoat of 0.0008 to 0.0010 inch of nickel on copper alloy parts in accordance with AMS-2423 or AMS-2424 shall be used. Coatings proposed for applications where temperatures exceed 1,000^{o}F (538^{o}C) in service shall be subject to engineering approval by the procuring activity.

5.3.2.1.5. Chromium Plating

Chromium Plating shall be used for all surfaces subject to wear or abrasion, except where other surface hardening processes, such as nitriding or carburizing, are used, or where other wear and abrasion resistant coatings are specified. Chromium plating shall be in accordance with

AMS-2460, with a minimum thickness of 0.002 inch, unless otherwise specified. If a Class 1 (corrosion) coating is specified, and the part will not be subjected to lubricants during use, a nickel undercoat shall be applied in accordance with AMS-2403 having a minimum thickness of 0.0015 inch. When chromium plating is specified, it shall be used on only one of two contacting surfaces.

5.3.2.1.6 Magnesium

When using magnesium alloys, refer to section 5.1.3.5. Magnesium alloys should be treated in accordance with ASTM D1732 prior to painting. Hole(s) drilled after finishes have been applied, should be treated in accordance with AMS-M-3171 Type VI. Parts, subsequent to anodizing, may be given a surface sealing treatment per AMS-M-3171, Type VII.

5.3.3 Organic Finishes

Alternative organic finishes can be inserted over the entire life of the system when feasible. This document suggests some alternatives as possible substitutes for selected finishing systems. The same engineering considerations used for the initial material selection must be considered every time an alternative finish is considered for substitution into a system after fielding. All organic finishing alternative selections must be made with the understanding of their impact on the entire system and with the specific approval of the procuring activity. The application of organic coatings and finish systems prescribed herein should be in accordance with MIL-F-18264 or MIL-DTL-53072, as applicable.

In addition, with respect to detail requirements, all finishes and coatings should comply with the requirements of MIL-STD-7179.

5.3.3.1 Finishes

The organic finishes or finish systems used should provide the necessary protection against corrosion for all materials used in areas subjected to corrosive environments. All exterior paints and colors should be consistent with thermal design requirements. The appropriate exterior finish systems should be selected based upon the base material in accordance with MIL-STD-7179, MIL-DTL-53072, or other appropriate specification. All interior surfaces exposed to an exterior environment should be considered as exterior surfaces and should be primed and painted. Interior primer should conform to MIL-PRF-23377, Type I, Class 1 or 2, or MIL-P-85582, Type I, Class 2, except in high temperature areas, the selected material should be approved by the procuring activity. Integral fuel tank coatings should meet the requirements of AMS-C-27725. All exterior plastic parts that are subject to rain or solid particle erosion should be protected by coatings that conform to specifications AMS-C-83231 or AMS-C-83445. Justification data, including both laboratory and service experience, should be submitted for approval by the procuring activity whenever materials other than those given above are proposed.

5.3.3.2 Applications

The MIL-PRF-85285 aliphatic polyurethane coating should be applied in two coats to a thickness of 0.045 to 0.058 mm (0.0017 to 0.0023 inch), for an overall average total topcoat thickness of 0.51 mm (0.0020 inch). The MIL-PRF-23377, Type I, Classes 1 or 2, of MIL-P-85582, Type I, Class 2 primer should be applied to a thickness of 0.015 to 0.023 mm (0.0006 to 0.0009 inch), for an overall average primer thickness of 0.020 mm (0.0008 inch). Organic finishes should be applied in accordance with MIL-F-18264.

5.3.3.3 Magnesium Surfaces

Magnesium surfaces should preferably be protected, as allowed by design, first with an electrolytic coating per AMS-M-3171, or similar or conversion coating meeting the same specification. A resin coating should be applied, followed by two coats of primer and two coats of topcoat prior to assembly. This coating scheme does not completely mitigate the highly corrosion prone nature of magnesium alloys, but offers the best protection available. During manufacture, breaches to this protection scheme should be repaired using AMS-M-3171, Type VI, conversion coating, followed by resin, if possible, and then two coats each of primer and topcoat. All faying surfaces should be sealed and all the edges should be fillet seal with a corrosion inhibiting sealant conforming to MIL PRF 81733 or AMS-3265. All fasteners should be wet installed and overcoated with sealant conforming to MIL PRF 81733 or AMS-3265.

5.3.4 Protective Finish System Requirements—Interior Surfaces

Primer coating and topcoat, where applicable, as specified in Tables 3 and 4, should be applied to the interior surfaces of items in accordance with MIL-F-18264 or MIL-DTL-53072, as applicable. The primer coating should be applied such that the dry-film thickness is in accordance with coating thicknesses specified in Tables 3 and 4, with the exception that the topcoat may be applied after final assembly, subject to the requirements of 5.5.1. When a topcoat is required for interior surfaces, such as to prevent fluid intrusion or to enhance visibility, and those surfaces are primed and top coated prior to assembly, a finish coat should be applied after final assembly. The interior color of the aerospace system should be in accordance with MIL-C-8779.

5.3.5 Protective Finish System Requirements—Exterior Surfaces

Primer coatings and topcoats should be applied to the exterior surfaces of items as specified in coating thicknesses specified in Tables 3 and 4, and in accordance with MIL-F-18264 or MIL-DTL-53072, as applicable. The exterior color of the aerospace system should be as specified by the procuring agency. The exterior of Department of the Navy aircraft should be in accordance with MIL-STD-2161.

5.3.6 Protective Finish System Requirements—Coating Thickness

The maximum applied dry-film thickness of the coatings in Table 5 should be as specified in Table 7. The minimum applied dry-film thickness of the coatings in Table 5 should be as specified in Table 6. On interior surfaces of all materials and on the exterior surfaces of magnesium, the applied dry-film thickness of the coatings should be not greater than 150 percent of that specified in Table 6.

5.4 Environmental Sealing—Detail Requirements

All joints and seams located in exterior or internal corrosive environments, including those in landing gear wells, control surface veils, attachment wells and structure under fairings should be faying surface sealed with sealant containing a corrosion inhibiting package and conforms to MIL-PRF-81733 or AMS-3265 except when operational temperatures exceed 107ºC (225ºF). Those areas that operate at temperatures from 107ºC (225ºF) to 135ºC (275ºF), should use sealant conforming to AMS-3276 or AMS-3277. For areas that operate at 135 to 260ºC (275 to 500ºF) sealant conforming to MIL-A-46146 or MIL-A-46106 should be used. (Note: MIL-A-46106 releases acetic acid during cure and is corrosive to metallic components. Its use is prohibited except in specific applications on composites and where etching may be required. Specific approval by Materials and Processes Engineering is required for use.) AMS-3277 may be used in areas where the operational temperature is a maximum of 149ºC (300ºF). Sealants used in integral fuel tanks should conform to AMS-S-8802 or AMS-3281, or approved alternative specification. Removable panels and access doors should be sealed, either by mechanical seals or separable faying surface sealants conforming to MIL-S-8784 or AMS 3267, except in Navy aircraft. High adhesion sealants such as AMS-S-8802, AMS-3276, AMS-3281, AMS-3277, or approved alternative, may also be used for access door sealing providing a suitable parting agent is used on one surface. Justification data, including laboratory and service experience, should be submitted for approval by the procuring activity whenever materials other than those given above are proposed.

5.5 Specific Parts Requirements

In applying the requirements of this section, the groupings of the more commonly used aircraft metals should be selected in accordance with MIL-STD-889, with the exception that the protection requirements specified for attaching parts and fasteners (see 5.5.11) will take precedence, where applicable.

Table 5. Primer Topcoat System Compatibility

Specification	MIL-PRF-22750 6/9/	MIL-C-46168 2/7/	MIL-C-53039 2/7/	MIL-PRF-85285 6/7/	TT-P-2756 4/7/	MIL-DTL-64159 2/
MIL-PRF-23377 4/6/	x	x	x	x	1/	x
MIL-P-53022 2/5/7/	x	x	x	x	1/	x
MIL-P-53030 2/5/6/8/	x	x	x	x	1/	x
MIL-PRF-85582 4/6/8/	x	x	x	x	1/	x
TT-P-2760 3/4/6/	–	–	–	–	1/	
MIL-P-53084 2/	x	x	x			x

[1/]TT-P-2756 is a self-priming topcoat. Application of an appropriate primer coating is required for all AF systems. Application of a primer coating is not required, with the exception of FED-STD-595, color number 36495, for all other services. For infrared reflectance protection, TT-P-2756 requires the use of a primer coating conforming to TT-P-2760, Type II; MIL-PRF-23377, Type II; or MIL-PRF-85582, Type II. TT-P-2756 is authorized for use on aluminum, aluminum alloy, and polymer matrix composite structures only. TT-P-2756 is compatible with all of the primer coatings listed above. If the item to be coated with TT-P-2756 has been preprimed, removal of the primer coating prior to application of TT-P-2756 is not necessary. TT-P-2756 is to be applied to a dry film thickness of 2.0 to 2.6 mils (51 to 66 µm).

[2/]For CARC finish systems refer to MIL DTL-53072.

[3/]TT-P-2760 is primarily intended for use on aircraft in areas where there is a high degree of structural flexing. TT-P-2760 is to be applied to a dry film thickness of 1.5 to 2.0 mils (38 to 51 µm).

[4/]These coatings are best suited for aluminum and polymer matrix composite substrates.

[5/]These coatings are best suited for ferrous and magnesium substrates.

[6/]Contains at least one type or class with a VOC of less than or equal to 340 grams/liter (2.8 pounds/gallon).

[7/]Contains at least one type or class with a VOC of less than or equal to 420 grams/liter (3.5 pounds/gallon).

[8/]This material may cause flash rusting of bare steel. Do not use on bare steel unless proven satisfactory for the intended purpose.

[9/]Approved for interior use only on U.S. Army weapon systems per MIL-DTL-53072

Table 6. Protective Finish System Requirements [5/]

Item	Material	Minimum applied dry film thickness, mil (um)			
		Primer[3/]		Topcoat	
		Exterior	Interior	Exterior	Interior
1	All aluminum alloys (except bottoms and interior trailing edge control surfaces, for which item 7 applies) [1/]	0.6 (15)	1.2 (30)	1.7 (43)	–
2	Sacrificial metal coatings and non-sacrificial coatings applied to non-corrosion-resistant metals	0.6 (15)	1.2 (30)	1.7 (43)	–
3	Titanium alloys [2/]	–	–	–	–
4	Magnesium alloys	1.2 (30)	1.2 (30)	1.7 (43)	1.7 (43)
5	Armor plate-ferrous	0.6 (15)	1.2 (30)	1.7 (43)	–
6	Corrosion resistant alloys	0.6 (15)	0.6 (15)	1.7 (43)	–
7	All metals not covered above	0.9 (23)	1.5 (38)	1.7 (43)	–
8	Polymer matrix composites [1/]	0.6 (15)	1.2 (30)[4/]	1.7 (43)	–

[1/]TT-P-2756 may be used; see Table 5, footnote 1/.

[2/]These metals do not require primer coating or topcoats for corrosion protection except for faying surfaces as noted in 5.5.1. Primer coatings and topcoats may be applied to blend with adjacent areas (use item 2 requirements).

[3/]See Table 5, note 3/.

[4/]Application of primer on interior surfaces is only required at dissimilar metal interfaces (see 5.5.1.c).

[5/]For CARC finish system on U.S. Army weapon systems see MIL-DTL-53072.

Table 7. Maximum Applied Dry Film Thickness

Coating	Maximum Applied Dry Film Thickness mils (um)
MIL-PRF-23377	0.9 (23) [1/]
MIL-P-53022	1.5 (38)
MIL-P-53030	1.5 (38)
MIL-PRF-85582	0.9 (23) [1/]
TT-P-2760	2.0 (51)
MIL-PRF-22750	2.3 (58)
MIL-C-46168	[1/]
MIL-C-53039	[1/]
MIL-PRF-85285	2.3 (58)
TT-P-2756	2.6 (66)
MIL-DTL-64159	[1/]
AMS-C-27725	1.5

[1/]See MIL-DTL-53072.

5.5.1 Fayed Surfaces, Joints and Seams

5.5.1.1 Surfaces of Similar Metals

Seams and joints that possess fayed surfaces of similar metals should be protected, at a minimum, by the application of primer coating to each surface, in accordance with 5.2.1 and Table 5 and Table 6. The dry film thickness of the primer coating should be as prescribed for interior surfaces (see 5.3, and Table 5 and Table 6). Exceptions to the above are as follows:

a. Where 5.3 and Table 5 and Table 6 specify application of a specific thickness of primer coating to fayed surfaces, one-half of the required thickness of primer coating may be applied to each surface being joined.

b. Primer coating should not be applied to resistance-welded fayed surfaces. Only weld-through sealants approved by the procuring activity should be used prior to assembly. Primer coating should be applied to fayed surfaces after spot welding. All exterior edges should be primer coated.

c. Fayed surfaces that are to be adhesively bonded should be cleaned, treated, and processed as specified in the procuring activity approved bonding procedures documents for the assemblies concerned, or in accordance with MIL-HDBK-83377, as applicable (except for Navy assets).

d. Titanium to titanium and corrosion resistant steel to corrosion resistant steel constructions should be protected by application of primer coating (see paragraph 5.3) or sealant, conforming to AMS-S-8802, AMS-3276, AMS-3277, MIL-PRF-81733, AMS-3265, or approved alternative, to the fayed surfaces. Where protection against fretting is required for these constructions, the contractor should propose a method of protection for approval by the procuring activity.

e. In addition to any required primer coating, all exterior fayed surfaces, seams, and edges should be sealed with a sealant conforming to AMS-S-8802, AMS-3276, AMS-3277, MIL-PRF-81733, AMS-3265, or approved alternative. A minimum gap of 0.02 inch (0.5 mm) should exist at exterior surface butt joints to allow for effective sealing.

5.5.1.1.1 Defect Filling

The use of filling material for the purpose of sealing and concealing nicks, dents, gouges, and joints resulting from poor workmanship is prohibited. These materials should be used only upon engineering approval by the procuring agency.

5.5.1.2 Surfaces of Dissimilar Metals

Surfaces of dissimilar metals should each receive a minimum of 0.0006 inch (15 microns) of primer coating except as specified in 5.5.1.1.c. When fayed surfaces are of dissimilar metals, they should be sealed with sealant conforming to AMS-S-8802, AMS 3276, AMS-3277, MIL-PRF-81733, AMS-3265, or approved alternative, and the thickness of the primer coating applied to each surface should be in accordance with 5.3 and Table 5 and Table 6. In addition, the following precautions should be taken:

a. Where magnesium is part of a dissimilar metal fayed surface, sealant conforming to MIL-PRF-81733, AMS-3265, or approved alternative, should be applied between surfaces and squeezed out of all boundaries. The excess should be removed in a manner that will ensure a fillet on all edges. Except for bushing installation, the fillet width should be a minimum of 0.25 inch (6.4 mm). For bushings, the fillet should be the largest practical. Joint areas that may retain water should be filled with sealant compound. Justification data must be provided for approval of any alternative corrosion-inhibiting sealants.

b. Butt joints in exterior locations consisting of dissimilar metals should be protected by grooving the seam to a width of 0.09 inch ± 0.03 inch (2.3 mm ± 0.76 mm) and filling with sealing compound. The depth of the groove should be capable of retaining hardening sealing compound, which should be subsequently applied and smoothed flush with the surfaces of adjacent dissimilar metals.

c. In joints constructed of reinforced composite containing electrically conductive phase and aluminum, or other dissimilar metals, there should be a final glass barrier ply. The final ply should extend a minimum of 1 in. (25.4 mm) beyond the metal member. For condensation polyimide based laminates (e.g., bismaleimide and cyanate ester), the glass barrier ply shall fully cover the laminate surfaces in contact. Primer coating should be applied to a dry-film thickness of 1.2–1.8 mil (30–46 µm) to each of the interior surfaces. The surfaces of joints should be fayed and fillet sealed and the fasteners wet installed with sealant conforming to AMS-S-8802, AMS-3276, AMS-3277, MIL-PRF-81733, AMS-3265, or approved alternative. Fasteners shall be overcoated to the maximum extent practical using primer, fuel tank coating or sealant. Joints that require separation as part of normal maintenance may have formed-in-place sealants applied with a suitable release agent on one surface.

5.5.1.3 Sealing

For exterior locations, openings (with the exception of drain holes at low points) that are not required for aircraft operations should be sealed to prevent fluid intrusion from external sources. Sealing around access plates should be accomplished by the application of sealant to the structure in a manner such that that the access plates can be removed without damaging the formed-in-place sealant or the surrounding metal. The recommended thickness of sealant for formed-in-place seals should be 0.030 inch (0.76 mm).

5.5.2 Slip Fits

The sealing of slip fits should be accomplished with wet primer coating conforming to MIL-PRF-23377, Type I or II, Class C or N (with engineering approval for Class N), TT-P-1757, or wet sealant conforming to MIL-PRF-81733 or AMS-3265. If design requires disassembly, primer coating conforming to MIL-PRF-23377, Type I or II, Class C or N (with engineering approval for Class N), or TT-P-1757 should be applied and permitted to dry thoroughly prior to assembly. In instances where the above materials are incompatible with the function of the part or assembly, corrosion preventative compound conforming to MIL-PRF-16173, grade 3 or 4, should be used. NOTE: TT-P-1757, zinc chromate primer, generally offers less corrosion protection than alternative chromated primers such as MIL-PRF-23377 or MIL-PRF-85582. It is the chromate that causes cancer. While there may be some usage of TT-P-1757 on existing systems, its use should be prohibited for new systems and designs.

5.5.3 Press Fits

The sealing of press fit component assemblies, with the exception of assemblies permanently housed in grease or oil, should be accomplished with either wet primer coating conforming to MIL-PRF-23377, Types I or II, Classes C or N (with engineering approval for Class N), TT-P-1757, or wet sealant conforming to MIL-PRF-81733 or AMS-3265. Exterior edges of the press fit component should be sealed with sealant conforming to AMS-S-8802, AMS-3276, AMS-3277, AMS-3281, MIL-PRF-81733, AMS-3265, or approved alternative, with the exception that sealing with primer coatings (see 5.3 and Table 5) may be used for bushings with walls of 0.094 in. (2.4 µm) or less. The completed assembly should then be finished as specified in 5.3 and Table 6. Parts permanently housed in grease or oil should be assembled with the grease or oil to be used in the housing. (Note: TT-P-1757, zinc chromate primer, generally offers less corrosion protection than alternative chromated primers such as MIL-PRF-23377 or MIL-PRF-85582. It is the chromate that causes cancer. While there may be some usage of TT-P-1757 on existing systems, its use should be prohibited for new systems and designs.)

5.5.4 Cut Edges

The edges of all metals should be rounded to permit adhesion of an adequate thickness of applied paint coatings or sealants. After rounding of the edges and prior to the application of paint or sealant, chemical surface treatments should be applied, if applicable.

5.5.5 Functional Surfaces

Paint-type coatings should not be applied to functional, working, or wearing surfaces; to lubricate surfaces; to adjustable screw threads; to lubrication or drain holes; to bearing or sliding surfaces; to areas where they could be rubbed or scraped onto surfaces that must be clean and bare to function properly; or to any other surface where the application of the coating may cause malfunction of the part or system. The interior walls of drain holes should be coated with paint-type coatings for corrosion protection.

5.5.6 Control Cables and Control Chains

Control cables and control chains should not be painted. However, prior to installation, control cables should be protected with a dip coating of corrosion preventive material conforming to MIL-PRF-16173, grade 4, with the exception of those surfaces requiring lubrication for functional purposes. Those surfaces requiring lubrication should be cleaned and coated with the required lubricant in lieu of corrosion preventive material. After installation, the control cables and control chains should be inspected. If touch-up of the corrosion preventive compound is necessary, touch up should be accomplished with the same material used prior to installation. Nylon jacketed cables do not require treatment, with the exception of exposed end fittings.

5.5.7 Closely Coiled Springs

Springs that are closely coiled, preventing the application of plating to internal surfaces, or springs not plated for other reasons, should receive a minimum of 0.0012 inch (31 µm) of primer coating conforming to MIL-PRF-23377 or MIL-PRF-85582, or should be coated with corrosion preventive compound conforming to MIL-PRF-16173, grade 4, or MIL-C-11796, Class 2.

5.5.8 Parts in Oil or Grease

Parts that are housed in lubricating oil, hydraulic oil, or grease should be finished with a baked resin coating conforming to MIL-PRF-3043, applied in accordance with MIL-C-5056. Parts constructed of corrosion-resistant metals need not be coated, unless they contact dissimilar metals. Functional surfaces, such as bearing surfaces, should not be coated.

5.5.9 Metal Tanks

5.5.9.1 Temporary and Auxiliary Fuel Tanks

The interior surfaces of aluminum alloy tanks should be surface treated in accordance with MIL-C-5541, Class 1A, using materials qualified to MIL-DTL-81706 or with MIL-A-8625, Type II, and 0.0009 to 0.0015 inch (23 to 38 µm) of corrosion preventive fuel tank coating conforming to AMS-C-27725 shall be applied. The interior surface of steel tanks should be finished with baked resin coating conforming to MIL-PRF-3043, applied in accordance with MIL-C-5056. Sealant conforming to AMS-3276 or AMS-3277, may be used in lieu of MIL-PRF-3043 when authorized by the procuring activity.

5.5.9.2 Welded Fuel Tanks (Including External Auxiliary Fuel Tanks)

The interior surfaces of aluminum tanks should be thoroughly cleaned and surface treated in accordance with MIL-C-5541, Class 1A, using materials qualified to MIL-DTL-81706, and interior surfaces that are fayed, whether sealed or not, should be coated with 0.0009 to 0.0015 inch (23 to 38 µm) of corrosion preventive coating conforming to AMS-C-27725. AMS-C-27725 should not be applied to exterior surfaces, but should not be painted. Droppable steel tanks should be finished on the interior with a baked resin finish conforming to MIL-PRF-3043, applied in accordance with MIL-C-5056, or sealant conforming to AMS-3276 or AMS-3277.

5.5.9.3 Integral and Riveted Fuel Tanks

The inside surface of integral or permanently fastened, such as riveted, fuel tanks should be finished and sealed with sealant conforming to AMS-S-8802, AMS-3276, AMS-3277, AMS-3281, or approved alternative, to prevent corrosion and leakage of fuel. Interior fayed surfaces, whether sealed or not, should be coated with 0.0009–0.0015 inch (23–38 µm) corrosion preventive coating conforming to AMS-C-27725. AMS-C-27725 should not be applied to exterior surfaces.

5.5.9.4 Lubricating Oil and Hydraulic Fluid Tanks

The inside surfaces of lubricating oil tanks constructed of corrosion-resistant materials should not be painted. Tanks of other materials should be finished with a baked resin coating conforming to MIL-PRF-3043, applied in accordance with MIL-C-5056.

5.5.9.5 Miscellaneous Aluminum Alloy Tanks

Interior surfaces of miscellaneous aluminum alloy tanks, with the exception of potable water tanks, should be surface treated in accordance with MIL-A-8625, Type II, or MIL-C-5541, Class 1A, using materials qualified to MIL-DTL-81706. The interior surfaces of potable water tanks should not be painted or conversion coated.

5.5.10 Tubing

Refer to Table 8 for coatings to be used on tubing types.

5.5.10.1 Nonstructural Tubing

With the exception of tubing constructed of titanium alloy, corrosion-resistant steel alloy, heat-resistant steel alloy, and as otherwise specified herein, all nonstructural tubing and plumbing lines should receive the complete interior or exterior paint system, as applicable, on the exterior of the lines, and should be protected in accordance with Table 6.

5.5.10.1.1 Oxygen Tubing

Surface finishes (paints, primer coatings, and electrical coatings) and conversion treatments (anodizing or non-electrochemical chromate or phosphate conversion coatings) are not to be applied to the interior of oxygen tubing. Oxygen tubing is to be thoroughly cleaned of all contaminants prior to any mechanical processing, such as double boring, being performed.

5.5.10.1.2 Aluminum Tubing and Plumbing Lines

Interior and exterior surfaces of aluminum-alloy tubing and plumbing lines should be surface-treated in accordance with MIL-C-5541, Class 1A, using materials qualified to MIL-DTL-81706, or MIL-A-8625, Type II. The exterior of aluminum plumbing lines in fuel tanks that are not made from either 5052 or 6061 require the application of a corrosion preventive coating conforming to AMS-C-27725.

Paint coatings should not be applied to the interior surfaces of airspeed indicator tubing or other sensing lines. Aluminum tubing used in fire-extinguishing systems employing halogenated agents should be finished internally and externally with a baked resin coating conforming to MIL-PRF-3043, applied in accordance with MIL-C-5056.

Table 8. Tubing Categories and Required Coatings

Category	Category Description	Primary Coating [1/]	Final Paint System [2/]
I	Single tubes having separate connections at each end.	Applied after all required forming operations have been completed and prior to fabrication of the assembly.	Topcoat applied after fabrication and prior to installation.
II	Assemblies made up of individual tubes permanently joined by non-separable type fittings (brazing, welding, swaging) and having separable type connectors at each end.	Primer coating applied, followed by application of sealant (MIL-S-8802, MIL-S-29574, MIL-S-81733, or AMS-3276 after all required bending and permanent joining has been completed and prior to final fabrication of the assembly.	Same as for category I.
III	Single or multiple tube assemblies that have one or more free ends that must be permanently joined by nonseparable type fittings.	Same as for category II. For tube assemblies employing a permanent joining process not compatible with the primer coating during fabrication, the primer coating may be omitted from the affected free ends at a distance acceptable to the procuring activity.	Same as for category I. For all assemblies having been only partially primed, additional primer coating should be applied as required, followed by the coating of all nonseparable joints with sealant (MIL-S-8802, MIL-S-29574, MIL-S-81733, or AMS-3276), followed by the required exterior paint system.
IV	Other types of tube assemblies not covered in categories I, II, or III. For this category, the contractor should establish a paint protection system acceptable to the procuring activity.	Not Applicable.	Not Applicable.

[1/]Apply primer coatings in accordance with Tables 2 and 3. Assemblies in categories I, II, and III, in which sleeves or ferrules are used in the separate connection, and the sleeves or ferrules are fixed in position by deformation of one or both members into contact, the primer coating need not extend beyond the initial point of intimate contact. For all tubing categories where flare fittings are used, primer coating must be applied to the end of the tube.

[2/]Any damage occurring to the finish system during installation should be touched up using the initial finish system for repair. For aluminum plumbing lines, see 5.10.22.

5.5.10.1.3 Protection of Tubing Joints after Installation

After installation of the tube assemblies, all remaining non-sealed joints that will not be disconnected during normal servicing, should receive a coating of sealant conforming to AMS-S-8802, AMS-3276, AMS-3277, AMS-3281, or approved alternative, followed by the appropriate top coating. All remaining non-sealed joints that must be disconnected during normal servicing operations should be coated with corrosion preventive compound conforming to MIL-PRF-16173, grade 4, or MIL-DTL-85054, which should seal all exposed spaces between the parts. A second coat of the same material should be applied to the same areas after a period of 60 minutes. Contractor-prepared maintenance instructions should require periodic reapplication of this material in-service.

5.5.10.2 Structural Tubing

5.5.10.2.1 Carbon Steel Tubing

All exterior surfaces and all interior surfaces without completely welded or crimped ends of structural carbon steel tubular assemblies should be finished in accordance with 5.3.6, Tables D-6 and D-7, and with the following, where applicable:

a. Assemblies completely closed by welding or to which the application of primer coating is impractical or ineffective, such as crimped-end tubing not closed by welding or tubing heat treated after assembly, should be treated after assembly (and heat treated, if necessary) with hot [160°F (71°C) minimum] linseed oil conforming to A-A-371, or corrosion preventive compound conforming to MIL-C-11796, Classes 1 or 1A, or MIL-PRF-16173, grades 2 or 4. The corrosion preventive compound should be applied under pressure into the hollow member through holes drilled in the tubing, or by immersion of the tubing in a bath of the preservative.

b. For large tubing structures, interconnecting holes may be drilled between members to promote circulation of the corrosion preventive compound, described in 5.2.10.2.1a.

c. Parts subjected to immersion in corrosion preventive oil should be manipulated in such manner to ensure the absence of air pockets and should remain in the bath until all bubbling has ceased. The members should be thoroughly drained after treatment and all access holes drilled in the members should be closed with cadmium plated, self-tapping screws, or blind rivets. The screws or rivets should be wet installed with sealant conforming to MIL-PRF-81733 or AMS-3265, Type II, and overcoated with the same sealant after installation. The exterior surface of the tubing assemblies should be free of oil, grease, and dirt prior to application of the prescribed finish system.

5.5.10.2.2 Aluminum Alloy Tubing

Interior surfaces of structural aluminum alloy tubing should be protected in accordance with 5.5.1 and Tables 3 and 4. The interior surfaces of structural aluminum alloy tubing closed by welding should be coated with primer coating conforming to MIL-PRF-23377, Type I or II, class C or N, or corrosion preventive compound conforming to MIL-PRF-16173, grade 2 or 4, applied through appropriately drilled holes.

5.5.10.2.3 Copper Alloy, Corrosion-Resistant Alloy and Heat-Resistant Alloy Tubing

Interior and exterior surfaces of structural copper alloy, corrosion-resistant alloy, and heat-resistant alloy tubing need not be painted, except as required for dissimilar metal contact.

5.5.10.3 Mechanical Attachment

Tubular parts that have fittings mechanically attached should have all edges of the attachment sealed with a sealant conforming to AMS-S-8802, AMS-3276, AMS-3277, AMS-3281, or approved alternative.

5.5.11 Attaching Parts and Fasteners

Attaching parts and fasteners, such as screws, nuts, bolts, bushings, spacers, washers, rivets, high-shear rivets, self-tapping screws, sleeves for “shake proof” fastener studs, self-locking nuts, “speed nuts”, and clamps, need not be painted in detail, except when dissimilar metals are involved in the materials being joined. All attaching parts, or the surfaces with which they are in contact, should be wet installed with primer coating conforming to MIL-PRF-23377, type I or II, Class C or N (with engineering approval for Class N), TT-P-1757, or sealant conforming to MIL-PRF-81733 or AMS-3265. Primer coating or sealant should not be applied to the threaded portions of fasteners for which torque requirements are established without the coating. When installed in aluminum structures, all steel, cadmium plated, and non-aluminum fasteners should be overcoated with sealant conforming to AMS-S-8802, AMS-3276, AMS-3277 or MIL-PRF-81733. Thickness of sealant should be a minimum of 0.006 inch (152 μm). Note: TT-P-1757, zinc chromate primer, has been identified as a known carcinogen and generally offers less corrosion protection than alternative chromated primers such as MIL-PRF-23377 or MIL-PRF-85585. While there may be some usage of TT-P-1757 on existing systems, its use should be prohibited for new systems and designs.

5.5.11.1 Fastener Installation

Permanently installed fasteners (all fasteners not normally removed for regular access or servicing) used in areas up to 107ºC (225ºF) should be wet installed with either a corrosion inhibiting sealant conforming to MIL-PRF-81733 or an epoxy primer conforming to MIL-PRF-23377, Type I, Class 1 or 2, or a MIL-P-85582, Type I, Class 2, material that does not contain water. In high temperature areas, exceeding 107ºC (225ºF), Type I, Class 1 or 2, epoxy primer, or a sealant that is suitable for the thermal environment should be used. Fasteners in integral fuel tanks should be installed with wet sealant conforming to MlL-S-8802 or AMS-3276. The use of sealant or corrosion inhibiting coatings not addressed by this paragraph should be approved by the procuring activity.

5.5.11.1.1 Removable Fasteners

Quick release fasteners and removable fasteners penetrating exterior surfaces should be designed and installed so as to provide a seal to prevent moisture or fluids from entering. Holes for these fasteners should be primed with MIL-PRF-23377, Type I, Class 1 or 2, or MIL-P-85582, Type I, Class 2, epoxy primer and allowed to completely dry prior to installing the fastener. The fastener should be installed with corrosion preventive compound. Contractor-prepared maintenance instructions should require periodic reapplication of this material in-service.

5.5.11.1.2 Fasteners in Titanium

Bare titanium, Monel, and stainless steel fasteners installed in titanium structures may be installed dry, unless sealing is required for liquid tightness or pressurization.

5.5.11.1.3 Monel and Stainless Steel Fasteners

Monel fasteners or stainless steel fasteners should be coated with cadmium or aluminum when used in contact with aluminum components.

5.5.11.1.4 Fasteners in Graphite Composites

Fastener materials for use in graphite composite structures should be titanium or Monel. Fastener materials for joining graphite composite structure to aluminum structure should be titanium. Cadmium plated steel, stainless steel and aluminum fasteners should not be used. Fasteners should be wet when installed using specified sealants.

5.5.11.1.5 Interference Fit Fasteners

Cadmium plated interference fit fasteners shall not be used in contact with titanium. Applications requiring cadmium-plated parts in contact with titanium should be approved by the procuring activity. Fastener holes for interference fit fasteners should be primed with MIL-PRF-23377, Type I, Class 1 or 2, or MlL-P-85582, Type I, Class 2, and be completely dry prior to assembly.

For AF Systems only: Dry installation (without sealant or primer) of permanent, interference fit fasteners may be allowed in aluminum and titanium structures with approval of the procuring activity. Fastener shall be Titanium pin-type with chromated aluminum-filled, organically bonded coating (Hi-Kote 1).

5.5.11.2 General Finish

Attaching parts and fasteners, such as screws, nuts, bolts, bushings, spacers, washers, rivets, high-shear rivets, self-tapping screws, sleeves for “shakeproof” fastener studs, self-locking nuts, “speed nuts”, and clamps, need not be painted in detail, except when dissimilar metals are involved in the materials being joined. All attaching parts, or the surfaces with which they are in contact, should be wet installed with primer coating conforming to MIL-PRF-23377, Type I or II, Class C or N (with engineering approval for Class N), TT-P-1757 or sealant conforming to MIL-PRF-81733 or AMS-3265. Primer coating or sealant should not be applied to the threaded portions of fasteners for which torque requirements are established without the coating. When installed in aluminum structures, all steel, cadmium plated, and non-aluminum fasteners should be overcoated with sealant conforming to AMS-S-8802, AMS-3276, AMS-3277, AMS-3281, MIL-PRF-81733, AMS-3265, or approved alternative. Thickness of sealant should be a minimum of 0.006 inch (152 μm). For magnesium dissimilar metal combinations, 5.5.1.2 should apply. NOTE: TT-P-1757, zinc chromate primer, generally offers less corrosion protection than alternative chromated primers such as MIL-PRF-23377 or MIL-PRF-85582. It is chromate that causes cancer. While there may be some usage of TT-P-1757 on existing systems, its use should be prohibited for new systems and designs.

5.5.11.3 Close Tolerance Bolts

Prior to installation, close tolerance bolts should receive application of primer coating conforming to MIL-PRF-23377, Type I or II, Class C or N (with engineering approval for Class N), TT-P-1757, or sealant conforming to MIL-PRF-81733, except where frequent removal of the bolts is required. For close tolerance bolts requiring frequent removal, use corrosion preventive compound conforming to MIL-C-11796, Class 3 or MIL-PRF-16173, or corrosion-inhibiting, solid film lubricant conforming to MIL-PRF-46010 or MIL-L-23398. MIL-PRF-46010 requires heat curing and should not be used on aluminum parts. MIL-L-23398 is air curing and may be used on all types of metallic parts. When a solid film lubricant is used, it should be applied and completely cured prior to assembly. The bolt should then be wet installed and fillet sealed (after installation) with sealant conforming to MIL-PRF-81733. NOTE: TT-P-1757, zinc chromate primer, generally offers less corrosion protection than alternative chromated primers such as MIL-PRF-23377 or MIL-PRF-85582. It is the chromate that causes cancer. While there may be some usage of TT-P-1757 on existing systems, its use should be prohibited for new systems and designs.

5.5.11.4 Adjustable Parts

Threads of adjustable parts, such as tie rods and turnbuckles, should be lubricated and protected, both before and after assembly, with anti-seize compound conforming to MIL-PRF-83483, with lubricating oil conforming to MIL-PRF-63460, with corrosion preventive compound conforming to MIL-PRF-16173, grade 3, or with lubricating oil conforming to MIL-PRF-32033, followed by corrosion preventive compound conforming to MIL-PRF-16173, grade 2.

5.5.11.5 Touch-Up

All attaching parts should receive final coating after installation. Topcoats should be applied over the primer coating to match the color of adjacent exterior surfaces, when necessary. Nuts and heads of bolts in joints that are subsequently lubricated need not receive final finishing.

5.5.11.6 Washers

Washers constructed of aluminum alloy 5356 or 5052, or high pressure phenolic laminates should be used under machine screws, countersunk fasteners, bolt heads and nuts that would otherwise contact magnesium and should be wet installed and fillet sealed after installation with sealant conforming to MIL-S-81733.

5.5.12 Areas Subjected to Corrosive Fluids

Battery compartments constructed of leakproof and corrosion-resistant material require no further finishing. All other battery compartments and adjacent areas subject to vapors and spills should be coated with a polyurethane casting resin approved by the procuring activity. All bilge areas, all surfaces within 24.0 in. (610 mm) of urinals, and all areas beneath lavatories and galleys should be finished with a primer coating conforming to TT-P-2760 applied to a dry film thickness greater than or equal to 2 mils (51 μm), or applied to a dry film thickness greater than or equal to 0.0009 inch (23 μm) of MIL-PRF-23377 or MIL-PRF-85582 and topcoated with coating conforming to MIL-PRF-85285, in accordance with section 5.3.6, Tables D-6 and D-7 for exterior surfaces. Justification data, including laboratory and service experience, should be submitted for approval by the procuring activity whenever materials other than those given above are proposed.

5.5.13 Fastenings and Strut Ends on Seaplanes

All fastenings, strut ends, and other similar parts of seaplanes (see 3.6) exposed to the action of sea water or salt spray should receive additional protection in the form of a coat of corrosion preventive compound conforming to MIL-PRF-16173, grade 4. Subsequent to painting, all open-ended struts should be coated by dipping in corrosion preventive compound conforming to MIL-PRF-16173, grade 4, followed by draining and wiping the exterior surfaces prior to installation. If it is not possible to coat parts completely by dipping, application by brush or spray is permissible.

5.5.14 Float Bumpers

The forward face of the float or hull under the bumper pad and all parts of the bumper should receive a coat of corrosion preventive compound conforming to MIL-PRF-16173, grade 4, in addition to the protection required by 5.3.6, Tables D-6 and D-7.

5.5.15 Surfaces and Components Exposed to High Temperatures

Areas and components that are exposed to temperature ranges:

a. 300 to 400°F (149 to 204°C), either on the ground or in flight (other than instantaneous effects), should be finished in accordance with 5.3.6, Tables D-6 and D-7, the appropriate color and gloss. For exposure to operational temperatures of 250 to 350°F (121 to 177°C), sealant conforming to MIL-A-46146, MIL-A-46106 or AMS-3276 should be used. (Note: MIL-A-46106 releases acetic acid during cure and is corrosive to metallic components. Its use is prohibited except in specific applications on composites and where etching may be required. Specific approval by Materials and Processes Engineering is required for use.) AMS-3277 may be used in areas where the operational temperature is a maximum of 300°F (149°C).

b. 400 to 500°F (204 to 260°C), a silicone finishing system should be applied directly to surface treated metal, omitting the wash primer and primer coating. The color should conform to the color scheme for the aerospace system. For exposures up to 450°F (232°C), sealant conforming to MIL-A-46146 or MIL-Q-46106 may be used, when authorized by the procuring activity. (Note: MIL-A-46106 releases acetic acid during cure and is corrosive to metallic components. Its use is prohibited except in specific applications on composites and where etching may be required. Specific approval by Materials and Processes Engineering is required for use.)

c. Above 500°F (260°C), heat-resistant finishes conforming to TT-P-28 may be used; however, each application must be approved by the procuring activity.

5.5.15.1 Fire Insulating Paint for Naval Aircraft

Within power-plant compartments of U.S. Navy aircraft and other compartments normally operating at temperatures below 300°F (149°C), where fires are likely to occur as a result of flammable fluid leakage, and in areas adjacent to bleed air ducts and valves that contain air at temperatures above 300°F (149°C), all fluid containers (air bottles, oxygen containers, hydraulic reservoirs, accumulators, and cylinders) which could escalate the intensity of a fire by explosion due to excessive heat, can be protected by a finish system consisting of a minimum of 0.6 mil (15 μm) of primer coating conforming to MIL-PRF-23377 or MIL-PRF-85582 plus a minimum of 0.020 in. (0.51 mm) dry film thickness of MIL-PRF-46081 thermal insulating paint (normal interior finish requirements apply). Alternative thermally insulating fire barrier materials, such as AMS-3374 qualified sealants, may be used if approved by the acquiring agency.

5.5.15.2 Coatings for Temperature Control

Surfaces subject to heating due to radiation from adjacent hot components or from exposure to a thermal pulse should be finished with low-absorption coatings. The procuring activity must approve coatings for temperature control prior to use. The request for approval should include all necessary technical information concerning the proposed material and application, with data supporting the effectiveness of the coating system.

5.5.16 Hull and Float Bottoms

Flying-boat hull bottoms and float bottoms should be finished with a system in accordance with Tables D-6 and D-7 that provides protection from the erosive effects of high speeds in water in order to be aerodynamically smooth. Use of rubber grommets under the head of rivets, bolts, and screws on the exterior skin is prohibited. Where antifouling paint is prescribed, the procuring activity is the approving authority.

5.5.17 Wood and Phenolic Surfaces

Wood and phenolic surfaces should be finished with a minimum of two coats of varnish or enamel, plus an additional two coats, if in contact with metal surfaces or in exterior locations, in accordance with MIL-STD-171.

5.5.18 Molded Plastic and Ceramics

Transparent plastic parts should not be painted. Other plastic parts (except fiberglass laminates, antenna and magnetic azimuth detector housing and radomes) need not be painted, except for color-matching purposes. Plastic or ceramic insulators (used for radio antennae) should not be painted. Their edges, however, should be sealed with sealant conforming to AMS-S-8802, AMS-3276, AMS-3277, AMS-3281, MIL-PRF-81733, AMS-3265, or approved alternative, after installation in exterior locations.

5.5.19 Finishing of Ducts

The interior surfaces of aluminum alloy heating and cooling ducts need not be painted, provided that those surfaces have been anodized in accordance with MIL-A-8625, Type II, and sealed. Aluminum alloy duct work treated in accordance with MIL-C-5541, Class 1A, using materials qualified to MIL-DTL-81706, should be painted as required for interior surfaces (see Tables D-6 and D-7). Prior to application of insulation material, the exterior surfaces of insulated ductwork, regardless of composition, should be coated with material to withstand the temperatures and environment of the system. Titanium and nickel alloys do not require painting.

5.5.20 Reinforced Plastics

Plastic parts reinforced with fibers should be finished for protection against erosion. Leading edges of fiber-reinforced plastic radomes, antennae, MAD housings, and other components exposed to the air stream, should be finished with a rain-erosion resistant coating conforming to AMS-C-83231, AMS-C-83445, or MIL-C-85322. MIL-C-85322 requires the use of wash primer conforming to MIL-C-8514. Other methods of protection, such as a boot of erosion and high temperature-resistant material, may be used when approved by the procuring activity. In exterior locations, edges should be sealed with sealant conforming to AMS-S-8802, AMS-3276, AMS-3277, AMS-3281, MIL-PRF-81733, or approved alternative. Transparent components, whether glass or plastic, should not be painted. Plastic parts and surfaces, other than those described above, may be painted for color-matching purposes.

5.5.21 Metal Leading Edges

Exterior surfaces of metallic leading edges exposed to speeds in excess of 500 knots should be finished with rain erosion-resistant coatings in accordance with MIL-F-18264. Exterior surfaces should be aerodynamically smooth.

5.5.22 Helicopter Rotor-Blade Leading Edges

The finishing system used on the leading edges of helicopter rotor blades should prevent deterioration of the underlying surfaces and should be resistant to erosion from rain, sand particles, sea spray, and insects. This type of finishing system is not necessary when the edges are made of corrosion-resistant and erosion-resistant material, such as nickel-plated stainless steel.

5.5.23 Rubber (Natural and Synthetic)

Natural and synthetic rubber should not be painted, greased, or oiled.

5.5.24 Electrical, Electronic or Avionics Systems

Avionic systems and equipment should use NAVMATP-4855-2 and MIL-HDBK-1250 as design guidelines for prevention and control of avionic corrosion.

EMI design requirements often run counter to corrosion protection requirements. In addition, many EMI areas need to be accessed, forcing the use of re-usable conductive seals that are prone to leaking and typically made from highly conductive, noble materials, which create strong galvanic couples with the surfaces they contact. Design of EMI systems should take all possible means to provide corrosion protection in combination with EMI performance requirements.

The following should not be used in avionic systems and equipments:

- RTV that contains acetic acid
- Nickel plated aluminum
- Gold over silver or copper
- Organic materials that outgas, support fungi, absorb moisture or are degraded by maintenance and operational fluids
- An EMI gasket without a seal on both sides of the conductive element
- Hygroscopic materials
- Foam cushioning materials that can deteriorate (revert).

5.5.24.1 Printed Wiring Boards

5.5.24.1.1 General Requirements

The technical baseline for design and construction of electronic equipment should be in accordance to MIL-HDBK-454.

5.5.24.1.2 Cleaning of Printed Wiring Boards

All electronic systems should be thoroughly cleaned to remove all contamination and solder flux prior to the application of conformal coatings and prior packaging. The cleanliness test specified in MIL-P-28809 should be performed to verify the effectiveness of cleaning procedures.

5.5.24.1.3 Conformal Coatings

All PWBs should be coated with a material specified in MIL-I-46058 and coated in accordance with MIL-P-28809. Acrylic, RTV or varnish-type conformal coatings should not be used.

5.5.24.1.4 Printed Wiring Boards Orientation

PWBs should be mounted in a vertical position with the connectors on a vertical edge where design permits.

5.5.24.1.5 Hermetic Sealing

Electronic devices not specifically covered by MIL-M-38510 should be hermetically sealed. Maintaining a maximum internal water vapor content of 500 ppm at 100ºC when tested in accordance with MIL-STD-883, Method 1018.

5.5.24.2 Electrical Connections

The exterior of electrical bonding and ground connections conforming to MIL-STD-464 should be finished in accordance with 5.2 and Table 5 after installation. All permanent electrical bonds, such as jumpers and ground studs, should be sealed after installation with sealant conforming to AMS-S-8802, AMS-3277, MIL-PRF-81733, AMS-3265, AMS-3276, or approved alternative.

5.5.24.2.1 Connectors

All connectors meeting MIL-DTL-38999 should be Class W.

Permanently mated electrical connectors should be sealed after installation with sealant conforming to AMS-S-8802, AMS-3277, MIL-PRF-81733, AMS-3265, AMS-3276, or approved alternative. Electrical connectors not permanently sealed should be internally protected with material conforming to MIL-C-81309, Type III. Preferred corrosion protection method for external connector mating areas, especially for coaxial connectors, is application of a stretch sealing connector tape (such as AvDEC polyurethane Stretch Seal) but protection may be provided by application of MIL-C-81309, Type III. Nickel plated connector shells should not be used.

5.5.24.2.2 Antennas and Static Dischargers

External antennas and static discharger mounting bases should be adequately sealed to prevent moisture intrusion into fuselage surface mating area. The preferred method of sealing is through use of conductive gaskets (such as AvDEC HiTak polyurethane) that provide maximum environmental protection form both internal and external moisture sources without compromising electrical bonding requirements. In areas of high-fluid exposure, a perimeter seal using sealant conforming to AMS-S-8802, AMS-3277, AMS-3276, or approved alternative may be necessary to protect against gasket degradation.

5.5.24.3 Conduits and Boxes

Electrical conduit and junction or relay boxes should receive protection in accordance with section 5.3.6, Tables D-6 and D-7. Plastic coated and braided wire should not be coated.

5.5.24.4 Electrical Pins and Sockets

There are extensive electronics/avionics failures that retest 'OK' or cannot be duplicated when connectors or contact surfaces are demated and remated. These failures are often caused by connector/pin corrosion and can be significantly reduced by the application of a continuous coat of MIL-C-81309 Type III or MIL-L-8177A on pins and pin receptacles prior to mating the connector halves. The connector shells should also be coated with MIL-C-81309 Type III or MIL-L-87177A after mating the connector halves. Other corrosion prevention compounds can be used on connector backshells with appropriate engineering approval from the procuring activity. Alternative sealing systems that have demonstrated water tightness and corrosion protection may be used if approved by the procuring agency.

5.6 Verification of Corrosion Design

Aerospace weapon systems are usually designed for specified lifetimes with maintenance according to defined maintenance concepts and plans. A Verification Plan should be provided per the Corrosion Prevention and Control Planning Guideline. Verification may be done by testing, by similarity to existing designs, or by analysis. Experience has shown that verification by analysis or similarity has been inadequate and should only be allowed where testing is not possible. Corrosion testing of the full weapon system is usually cost prohibitive though much useful information can be obtained from proper attention to full scale or subcomponent environmental testing. Where possible, include formal specific corrosion criteria in the environmental test plans to include evaluation for moisture collection, sealing, etc. Specific corrosion testing should be conducted on components and subsystems per ASTM B117 (and ASTM G-85.A4 for Naval systems only). The systems should be corrosion free and functional after 500 hrs of ASTM B117 testing of the assembled production configuration (and 500 hours of ASTM G-85.A4 testing for Naval systems only). Avionics systems should be corrosion-free and function after 336 hours of the cyclic sodium chloride-sulfur dioxide testing (ASTM G85.A4) (Navy systems only). Exposed electronics/avionics components may be tested in lieu of the assembled subsystem and must exhibit 168 hours of corrosion resistance to ASTM B117 testing and ASTM G85.A4 for Naval systems only). Finish and corrosion protection verification should include the cyclic sodium chloride-sulfur dioxide test of ASTM G85.A4 for a minimum of 500 hours (Navy-only systems).

Verification of corrosion protective coatings should comply with Table 9.

Table 9. Corrosion Protective Coatings Verification

Test	Criteria
ASTM D 2247 30 day humidity test	No blistering, softening, loss of adhesion or other film defect
ASTM B117 2000 hours salt spray test with scribed panels	No blistering, lifting of coating nor substrate corrosion.
ASTM G 85.A4 500 hours SO2 salt spray test with scribed panels (Navy Only)	No pitting greater than 1 millimeter in depth.
ASTM D 2803 1000 hours filiform corrosion test with scribed panels.	No filiform corrosion extending beyond 1/4 inch from the scribe.

5.7 Special Considerations

5.7.1 Firefighting Agents

Some firefighting agents used to extinguish fires pose no risk at all to metallic structure; however, many fire-extinguishing agents are corrosive and very quickly produce severe corrosion. Foam and bromochloromethane and, to a slightly less degree, dibromochloromethane type agents are the most notable offenders in this regard. Some of the more commonly used dry powder agents, such as potassium bicarbonate or sodium bicarbonate are in themselves only mildly corrosive, but after exposure to heat, the residue converts to products which are more corrosive to aluminum. These products are hygroscopic and absorb moisture, creating a corrosive deposit on airplane surfaces. Existing decontamination procedures require flushing with generous quantities of water in conjunction with washing/rinsing of all surfaces and components exposed to fire suppressant materials. To the extent possible, designs must minimize areas of potential exposure to these materials and facilitate the flushing and cleaning of those areas exposed.

5.7.2 Chemical Warfare Agents

During periods of war, the system may be required to operate and be maintained in an environment of chemical agents. All removable equipment, unsealed compartments, etc. are susceptible to contamination. In order to survive in the chemical threat environment and be capable of decontamination after exposure, materials must be used that survive the contaminants and the decontamination process so as not to cause corrosion or degradation of the exposed structure and equipment. Efforts should be taken to attempt to minimize corrosion due to contaminants and decontamination procedures.

5.7.3 Wear and Erosion

The design and manufacture of aircraft should include practices to minimize damage by wear and erosion. Wear and erosion prevention practices should be followed on applicable surfaces of metals, polymers, elastomers, ceramics, glasses, carbon fabrics, fibers, and combinations or composites of these materials.

Wear should be considered damage at an interface, generally with progressive loss of material from one or both surfaces, due to relative motion between the surfaces. Wear mechanism include adhesive, abrasive, and fretting wear as well as corrosive and thermal wear. Erosion should be considered progressive loss of material from a surface due to impinging fluid or solid particles. Surface damage frequently is a combination of two or more wear and erosion mechanisms. Wear prevention practices should be applied to all load bearing and load transfer interfaces. These areas include fastened, riveted, bolted and keyed joints; bearings, races, gears, and splines; contact surface of access doors and panels, hinges and latches; contact point of cables, ropes and wires as well as contact areas between metallic and polymeric strands; interference fits; friction clamps, contact points of springs; sliding racks and pulley surfaces, and other surfaces; and other surfaces subject to wear damage. Materials, surface properties system friction and wear characteristics, liquid and solid lubrication systems, surface treatments and coatings, contact geometry, load, relative motion and service environment should be established for procuring activity acceptance.

Apply erosion prevention practices all surface areas including leading edges, radomes, housing and other protrusions as well as to surfaces exposed to particle impingement during take-offs and landings. Include erosion prevention measures in the finish specification.

5.7.4 Lubrication

Provisions should be made for lubrication of all parts subject to wear. The selection of lubricants (oil, greases, solid film coatings, and hydraulic fluids) should be in accordance with MIL-HDBK-275 as specified in MIL-HDBK-838. The fire resistant synthetic hydrocarbon hydraulic fluid, MIL-H-83282, should be use as the aircraft hydraulic fluid. The number of different lubricants required should be kept to a minimum by using multipurpose lubricants such as the wide temperature general purpose grease MIL-G-81322 whenever possible, without compromising performance and reliability. All lubrication fittings should be readily accessible. Components are highly loaded/dynamic and potentially corrosive applications (e.g., landing gear, arresting gear) should make maximum use of lubrication fittings, vice other form of lubricant. Parts subject to immersion in seawater should be designed so as to exclude seawater from bearings.

5.7.5 Support Equipment

All unique Support Equipment procured as a part of the aerospace weapon system acquisition will be IAW the design guidance provided in MIL-HDBK-808. This provides guidance for materials selection, materials processing, cleaning processes, finishing materials and finishing processes and techniques for effective protection against corrosion for support equipment excluding munitions and electronic equipment. This document covers both organic and inorganic finishes. A finish code system is provided for identifying the selected finish on engineering drawings.

5.7.6 Corrosion Susceptibility of Welded Components

The corrosion susceptibility of welded components should be considered when selecting welding as the primary joining method. Differential corrosion rates between the weld, base material, and heat-affected zone may occur. Welding of aerospace components should be performed in accordance with AWS D17.1 or equivalent specification approved by the procuring activity.

5.7.7 Engine Corrosion Susceptibility Testing

Selected materials and coatings should be corrosion tested under simulated engine environmental conditions appropriate to their final usage during operation, handling, and storage of the engine. A new or newly overhauled engine should be selected for the corrosion susceptibility test. Prior to starting the test, the engine should be disassembled sufficiently and an inspection conducted to determine the condition of all parts normally exposed to atmospheric conditions. Detailed photographic coverage of these parts should be provided for comparison with post-test conditions. The engine should then be reassembled, pretest performance calibrated, and subjected to 25 AMT cycles while being injected with a two percent of airflow weight spray solution, consisting of the following materials dissolved with sufficient distilled water to make one liter of salt spray solution:

Chemical designation	Quantity per liter of spray solution
NaCl (c.p.)	23 grams
Na_2SO_4*$10H_2O$	8 grams
Stock Solution	20 milliliters

The stock solution should be composed of the following materials dissolved with sufficient distilled water to make one liter of stock solution:

Chemical designation	Quantity per liter of stock solution
KCl (c.p.)	10 grams
KBr	45 grams
$MgCl_2$ * $6H_20$ (c.p.)	550 grams
$CaCl_2$ * $6H_20$ (c.p.)	110 grams

At specified intervals during the test, the engine should be subjected to internal inspections to detect any evidence of corrosion or progression of corrosion of internal parts. Upon completion of the test, a performance check should be conducted and the engine disassembled and inspected for evidence of corrosion. Detailed photographs should be taken of all parts that show evidence of corrosion. The contractor should present test specimen evidence of metallurgical analyses that completely characterize the types of corrosion found. The test results should be considered satisfactory when the extent of corrosion is not of such a magnitude as to impair structural integrity or component operation, or be a cause of significantly reducing performance, engine durability, or parts.

Appendix E
Navy Ships and Submarines Guidelines

The following is extracted from NSWCCD-61-TR-2005/21, *Corrosion Prevention and Control Plan for Program and Project Managers*, July 2005.

1 Background

1.1 Abstract

The United States Congress has enacted Public Law 107-314 Sec: 1067 titled "Prevention and mitigation of corrosion of military equipment and infrastructure." This law requires the Secretary of Defense to be responsible for the prevention and mitigation of corrosion of military equipment and infrastructure, and the development and implementation of a long-term strategy for corrosion prevention and mitigation. Over the past several years the Department of Defense has required Program/Acquisition Managers to develop and implement a Corrosion Prevention and Control Plan. Acquisition reform has seen a shift from traditionally required military specifications, standards and handbooks to more reliance on commercial and performance specifications. This shift and the requirement for a well defined Corrosion Prevention and Control Plan presents opportunities and challenges for Program/Acquisition Managers. One of the many challenges facing the Program/Acquisition Managers is the ability to develop a meaningful Corrosion Prevention and Control Plan. Corrosion of DoD assets is not only costly in monetary and manpower terms, but degraded availability of assets are unacceptable in these times of high operational tempo and shrinking budgets. Appendix (A) contains a recommended template for Program/Acquisition Managers to develop a useful Corrosion Prevention and Control Plan.

1.2 Introduction

The Department of Defense (DoD) requires[1] Program and Project Managers to include corrosion-related planning in the acquisition process. This document provides guidance for Program Manager's (PM), which will enable them to develop a Corrosion Prevention and Control Plan (CPCP) that will reduce the overall life cycle cost of a system. A properly developed CPCP will enable the PM to specify materials, coatings and design features for structures and equipment, with an emphasis on corrosion control, and provide a tool to reduce maintenance costs through proper design. The initial draft of the CPCP should be completed prior to Milestone B. Appendix A of this document provides a draft CPCP template to help the PM with this process. The authors have previously published and provided guidance on corrosion wording for acquisition documents to assist Program/Acquisition Managers with corrosion wording for Requests for Proposals and Statements of Work.[2,3]

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[1] Department of Defense (2002). "Corrosion Prevention and Control Planning Guidebook," PDUSD (AT&L). UNCLASSIFIED.

[2] Hays, R.A., and E.B. Bieberich, "Corrosion Wording for USMC Acquisition Documents," CARDIVNSWC TR-61-05 (July 1999).

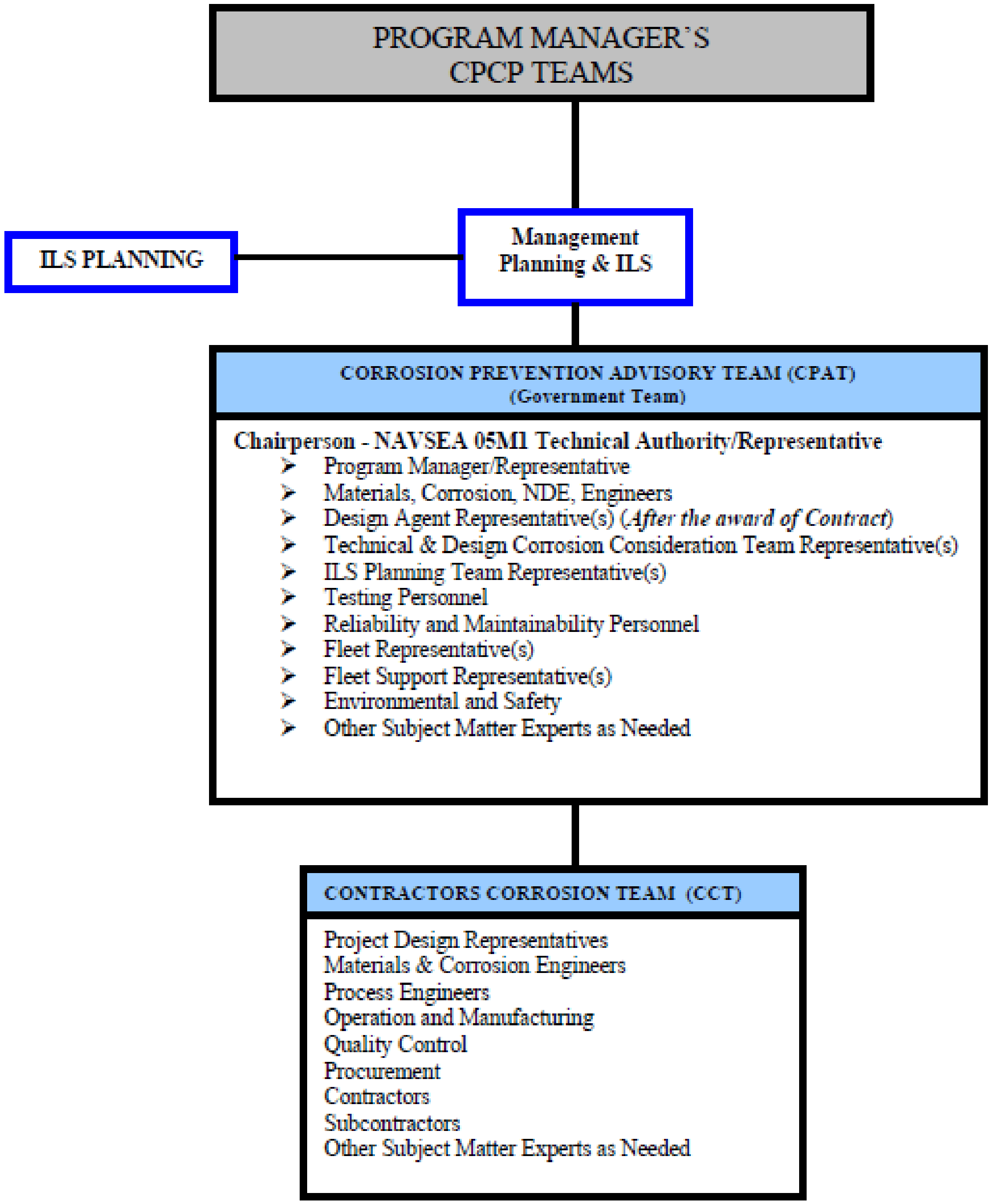
2 Corrosion Prevention and Control Plan

While corrosion prevention and control planning actually begins before the Request for Proposals (RFP) or specification development, the majority of the activity associated with the CPCP occurs after contract award. The initial CPCP requirements should be drafted by the Program Managers Corrosion Prevention Advisory Team (CPAT) before the development of a RFP, to guide the inclusion of the program's CPCP into the RFP. After the award of the contract, the CPCP should be maintained by the Contractors Corrosion Team (CCT) and any revisions should be approved by the PM and CPAT. The CPCP is a fluid document and should be revised as required. Proper documentation of changes to materials and processes being used for corrosion prevention and control must be maintained. Figure 1 shows the CPAT and CCT team structures and provides recommendations for team membership. The Program Managers and Design Agents first draft (prior to Milestone B) of the CPCP guides the initial performance specification development and, at a minimum, should provide:

- Organization, procedures and responsibilities for the Contractor's Corrosion Team (CCT);
- The roles and responsibilities of the contractor's quality assurance (QA), process control, production operations, manufacturing planning, environmental compliance, personnel safety, and other contractor organizations for corrosion prevention and control efforts;
- Discussion of corrosion prevention techniques employed in design and how the design will perform when exposed to the projected environmental spectrum;
- Specifications that outline the application of coatings and other corrosion prevention compounds as well as personnel training and qualifications, materials inspections, surface preparation, and coating or compound application procedures;
- Test data developed for materials, coatings or other corrosion related processes;
- Identification of coating/substrate combinations for which testing is not to be performed, with an assessment of risk level in the absence of testing;
- Recommended specific corrosion control maintenance.

[3] Conrad, R.K., R.A. Hays, and D.A. Davis, "Corrosion Wording for USMC Acquisition Documents, Part 2," NSWCCD-61-TR-2002/14 (August 2002).

Figure 1. Team Structure and Recommended Membership of the Teams



3 CPCP Team Development & Responsibilities

The Program Manager must address the following items in order to adequately develop the CPCP.

3.1 Establishment of the Corrosion Prevention Advisory Team (CPAT)

The CPAT membership (government only or support contractors) should include Program Manager representation, NAVSEA 05M1 Technical Authority representation (should be the Chairperson), and subject matter experts. (i.e., materials engineers, operations and testing personnel and Fleet end-user and ship support personnel). This team must interface with the Contractor's Corrosion Team (CCT) after the award of the contract. In order to evaluate the adequacy of the contractor's efforts in corrosion prevention and control, the PM retains authority to conduct scheduled periodic reviews of the contractor's design and facilities where critical parts and assemblies are being fabricated, processed, assembled and readied for shipment.

The CPAT's Functions Include:

- The CPAT must be actively involved and review all design considerations, materials selections, cost, and documentation that may affect corrosion prevention and control throughout the life of the system;
- The CPAT provides advice and guidance to the PM on corrosion-related issues, and identifies risks as well as corrosion prevention opportunities and the adequacy of the corrosion maintenance documentation;
- The CPAT must review and resolve corrosion, materials and coating discrepancies from QA and coating inspections submitted by the PM;
- The CPAT must review materials issues and determine if a Material Selection Review (MSR) is required;
- The CPAT elevates unresolved issues to the OSD Integrating IPT;
- The CPAT's meeting schedule should be set by the CPAT chairperson and the PM at a frequency that ensures adequate time to address issues with the CCT. This would allow those issues to be resolved in a timely manner such that negative impact on scheduling is avoided;
- The CPAT must outline the CCT duties that should be included in the contract and define the appropriate documentation required by the CCT;
- The CPAT chairperson and appropriate representatives should attend all CCT meetings and advise the PM on technical issues that need to be resolved.

3.2 Establishment of the Contractors Corrosion Team (CCT)

The prime contractor's CCT will be made up of authoritative representatives. The scope of the CCT is to work with the CPAT to ensure proper materials, processes, QA, testing and treatments are selected and properly applied and maintained from initial design through final construction and delivery.

The CCT should include knowledgeable representatives from project design integrated process teams, materials and process engineers, operations and manufacturing, quality control, process control, design, reliability, maintainability, supportability, production operations, manufacturing, hazardous materials, safety, environmental, Integrated Logistics Support (ILS), procurement, test and evaluation, to include contractors and subcontractors. The specific responsibility of the CCT should be:

- Develop, document and maintain the Corrosion Prevention and Control Plan (CPCP);
- Establish process/finish requirements;
- Establish corrosion testing requirements for procured items in conjunction with the Integrated Products Teams (IPTs);
- Establish regular meetings and initiate special meetings if required to address corrosion prevention and control and materials issues;
- Coordinate and interface with the government PM and CPAT chairperson;
- Coordinate and document materials selection guidelines for corrosion protection/avoidance;
- Coordinate and document coating selection guidelines for corrosion protection/avoidance;
- Coordinate the documentation of corrosion design guidelines;
- Coordinate corrosion prevention polices and procedures;
- Review corrosion, materials and coatings test results for process/finish qualifications;
- Identify corrosion specialists within the materials/coatings IPTs;
- Resolve any impasse in determining the preferred process or treatments for corrosion control at any team site.

4 Documentation

4.1 Corrosion Prevention and Control Plan

The corrosion prevention and control plan assists the PM in establishing a management approach to corrosion prevention and control during system acquisition. This plan should describe the specific anticipated CPCP measure to be implemented. This document should be initially drafted by the CPCP and provided to the PM for inclusion as part of the draft RFP no later than Milestone B. After the award of the contract, this document will be maintained by the contractor but any changes must be approved by the PM and CPAT. Copies of major revisions to this document should be formally submitted to Defense Technical Information Center (DTIC).

The CPCP should:

- Define the Corrosion Prevention and Control Program Management Approach by providing guidance or requirements for:
    - Organization, procedures.
    - Responsibilities of the CPAT.
    - Responsibilities of the CCT.
    - Role and responsibilities of QA.
    - Role and responsibilities of Process Control.
    - Role and responsibilities of Production Operation
    - Role and responsibilities of Manufacturing Planning.
    - Role and responsibilities of Environmental Compliance.
    - Role and responsibilities of Personnel Safety.
    - Role and responsibilities of Contractor and Sub-contractors.
- Document corrosion related design needs.
- Provide information for corrosion prevention techniques employed.
- Provide information on meeting projected environmental spectrum.
- Provide test data developed for coating or corrosion preventive compound.
- Provide test data needed for coating or corrosion preventive compound.
- Provide process/finish specification:
    - Coating
    - Corrosion prevention compounds
    - Personnel training and qualifications
    - Materials
        - Metallic
        - Non-metallic
    - Materials inspections
    - Surface preparation
    - Coating application procedures
    - Corrosion prevention compounds application procedures
- Identify materials and corrosion control methods for use in manufacture or construction.
- Identify where corrosion and material tests are not required and provide related risk assessment data.

- Provide recommendations for specific corrosion control maintenance.
- Provide information or copies of applicable ship specifications.

5 Abbreviations

CPCP	Corrosion Prevention and Control Plan
CPAT	Corrosion Prevention Advisory Team
CCT	Contractors Corrosion Team DoD Department of Defense
DTIC	Defense Technical Information Center
ECP	Engineering Change Proposal
ILS	Integrated Logistics Support
IPT	Integrated Product Team
MSR	Material Selection Review
NSWCCD	Naval Surface Warfare Center Carderock Division
OSD	Office of the Secretary of Defense PM Program Manager
RFP	Request for Proposals
QA	Quality Assurance
QC	Quality Control

6 Corrosion Prevention and Control Plan Template

The following document is the Corrosion Prevention and Control Plan Template.

CORROSION PREVENTION

and

CONTROL PLAN

for

Program Title

NOTE: For each specific program CPCP,
the Blue type areas will require program data input.

Table of Contents

Figures

1 Introduction

The primary function of this (Program) Program Office Corrosion Prevention and Control Plan (CPCP) is to provide a process that will develop and resolve corrosion requirements and discrepancies for (Type of Ship/Asset). Through this plan, the costs due to materials and coating selections, corrosion, scale, and microbiological fouling will be addressed and reduced. Compliance with the law and regulations of the Environmental Protection Agency, Department of Transportation, Occupational Safety and Health Administration, and other applicable guidance will be met.

2 Corrosion Prevention Advisory Team Organization

2.1 Corrosion Prevention Advisory Team (CPAT)

The Corrosion Prevention Advisory Team (CPAT) primary function is to draft the initial Corrosion and Control Plan (CCP) and interface with the Contractor Corrosion Team (CCT) to insure the established goals of this plan are attained. The CPAT should monitor all activity during design, engineering, test and production. This team will advise the Program Manager on the corrosion related concerns and identify risks/opportunities. The Program Manager and NAVSEA Technical Warrant Holders (TWH) for the specific area are responsible for the assignment of members to this CPAT Team. The membership of the CPAT is government only or support contractors to the Program office (members can't come from potential contract bidders) and will be as follows:

CPAT Chairperson:	Requested from NAVSEA 05M1 (TWH)
Program Office Representative:	Assigned by PM
Corrosion Lead:	Assigned by NAVSEA 05M1 (TWH)
Non-Destructive Evaluation Issues:	Requested from NAVSEA 05ME
Metallic Materials Issues:	Requested from NAVSEA 05M2 (TWH)
Non-metallic Materials Issues:	Requested from NAVSEA 05M4 (TWH)
Corrosion Issues:	Assigned by NAVSEA 05M1 (TWH)
Coating Issues:	Assigned by NAVSEA 05M1 (TWH)
Reliability and Maintainability Issues:	Assigned by PM
Environmental and Safety Issues:	Assigned by PM

Testing Issues:	Assigned by PM
Design Agent Representative:	Assigned by PM
Fleet Representative:	Requested of Fleet by PM
Fleet Support Representative:	Requested of Fleet by PM
Contractor Representative:	Assigned by PM (Normally the COR)
Technical & Design Corrosion Consideration Team Chairperson:	As required
ILS Planning Team Chairperson:	Assigned by PM
Other Subject Matter Experts:	Assigned by PM or NAVSEA Code
Prime Contractor Representative:	Only after the award of the contract.

2.2 Corrosion Prevention Advisory Team (CPAT) Responsibilities

The CPAT for the (Type of Ship/Asset) shall have the following responsibilities:

2.2.1 General CPAT Oversight and Management

- Ensure that the CPAT members will be government employees only or Program Office support contractors that will act as the liaison between the Navy, the Design Agent and the Contractor's Corrosion Team (CCT) for materials, coatings and corrosion issues. Once the contract is awarded an authoritative representative of the prime contractor's organization should be part of the CPAT.
- Draft the anticipated Corrosion Prevention and Control Plan to be implemented. This document must be initially drafted and provided no later than Milestone B. After award of the contract the prime contractor maintains and executes the CPCP in accordance with the guidelines detailed in the Corrosion Prevention and Control Planning Guidebook, issued by PDUSD (AT&L).
- Reviews all Interface Control Documents for corrosion control issues.
- Provide guidance/resolution for the PM on all corrosion control issues as required in both design and application of materials, coatings, and fasteners/hardware through the development of the (Type of Ship/Asset).
- Assists all IPT's and the CCT to establish resolutions to materials/coatings and corrosion control issues. The methodology shown in Figure 1 will be used for adjudication of corrosion discrepancies, and document using the form in Enclosure 1.
- Recommend the appropriate level of analysis and documentation for discrepancies.
- Identify risks associated with new technologies and designs intended for use on (Type of Ship/Asset).

- Ensure life cycle costs and logistic support changes are reflected and ensure any changes are warranted.
- Draft proposals/justifications for corrosion control/material improvements as required.
- Review equipment corrosion test reports resulting from testing required by the (Type of Ship/Asset) system operating and non-operating environments specification.
- Establishes an ECP/Change Control Document Review Board.
- Coordinate review of appropriate corrosion control documentation by the proper organization, e.g., NAVSEA, PEO's, OPNAV, and EPA.
- The CPAT will maintain the action item list and meeting schedule. Meeting quarterly or as required.
- Additional responsibilities as identified and needed can be added.

2.2.2 Design

- Reviews applicable American Bureau of Shipping (ABS), Naval Vessel Rules (NVR) and NAVSEA technical publications for information that will assist in developing contract design requirements.
- Establishes the Design Decision Memorandum Process.
- Address corrosion concerns and issues as part of the Design Decision Memorandum (DDM) process.
- Provide CPAT, CCT, and any other reports to the design teams as required.
- Ensure that adequate corrosion prevention and control requirements are implemented in accordance with the Corrosion Prevention and Control Plan, contract, design plans, and specifications.
- Reviews applicable (Type of Ship/Asset) specification sections and approved modifications for information that will assist in developing contract design requirements.

2.2.3 Quality Assurance

- Address and establishes the guidelines for QA/QC audits and the responsibilities of the CPAT, prime contractor, subcontractors, and third party inspectors.
- Establishes the schedule and team to perform QA audits.
- Reviews the contractors/third party's QA plan for coatings application to include qualification, checkpoints, and required remedial actions.
- Verify that the contractor or subcontractors personnel providing surface preparation or coating application meet the certification requirements defined in the Corrosion Prevention and Control Plan.

2.2.4 Materials and Coatings

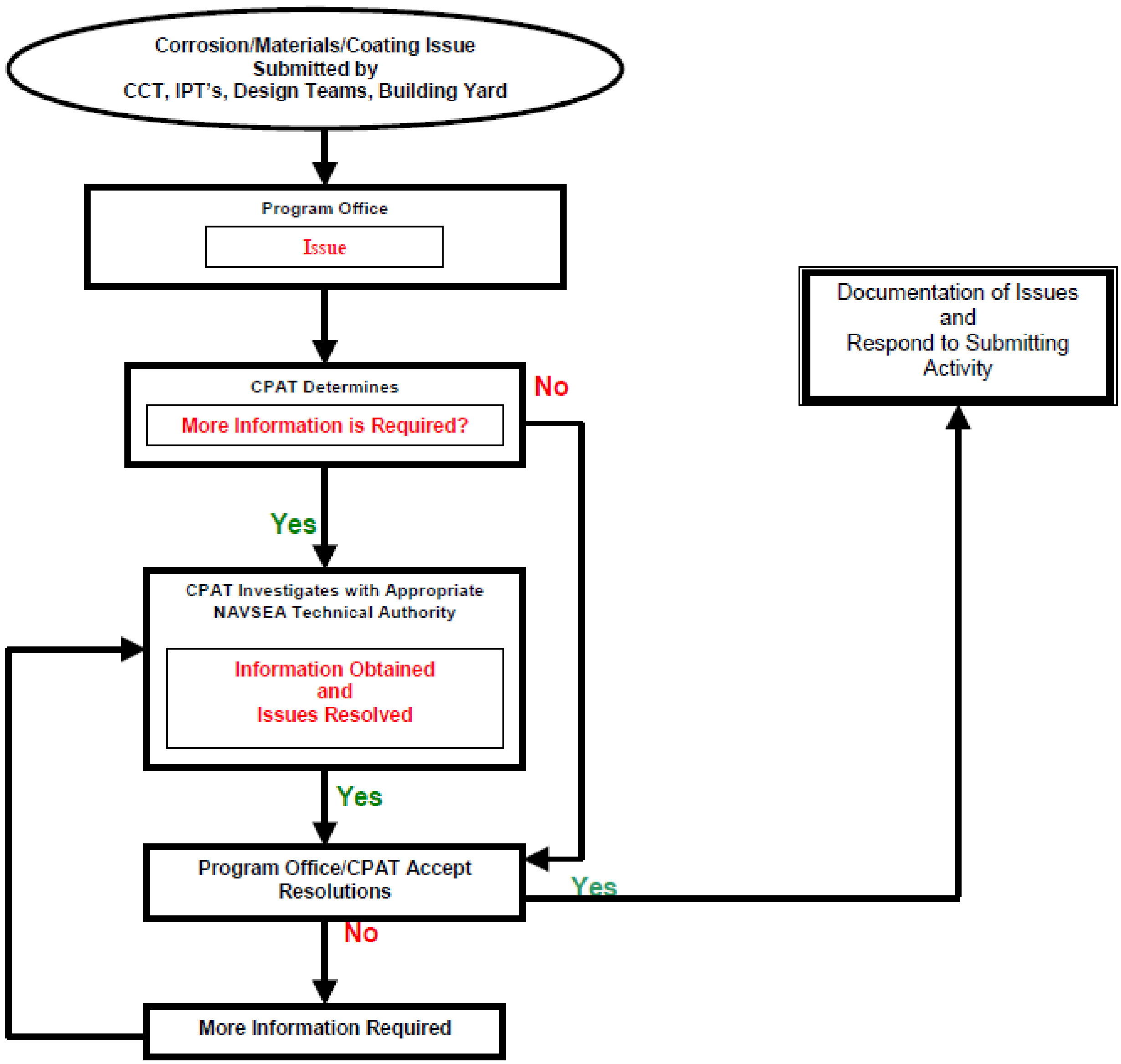
- Evaluate materials to determine if a Material Selection Review (MSR) is required.

- Evaluate Design Agent's trade-off studies affecting materials, coatings and corrosion performance.
- Reviews and comments on the paint procedures and schedules at least six months prior to any painting operations.
- Participates on the Engineering Materials Review Board.
- Addresses any coating deficiencies from previous systems and recommends potential corrective actions to the appropriate design team.
- Recommends corrosion and materials validation testing as appropriate.
- Invite and involve corrosion/material/coating advisors as required.

2.2.5 Reliability, Maintainability, and Supportability

- Ensures the Contractor's plan specifies a Life Cycle Maintenance Corrosion Control Document for the (Type of Ship/Asset).
- Reviews and approves the Life Cycle Maintenance Corrosion Control Document.

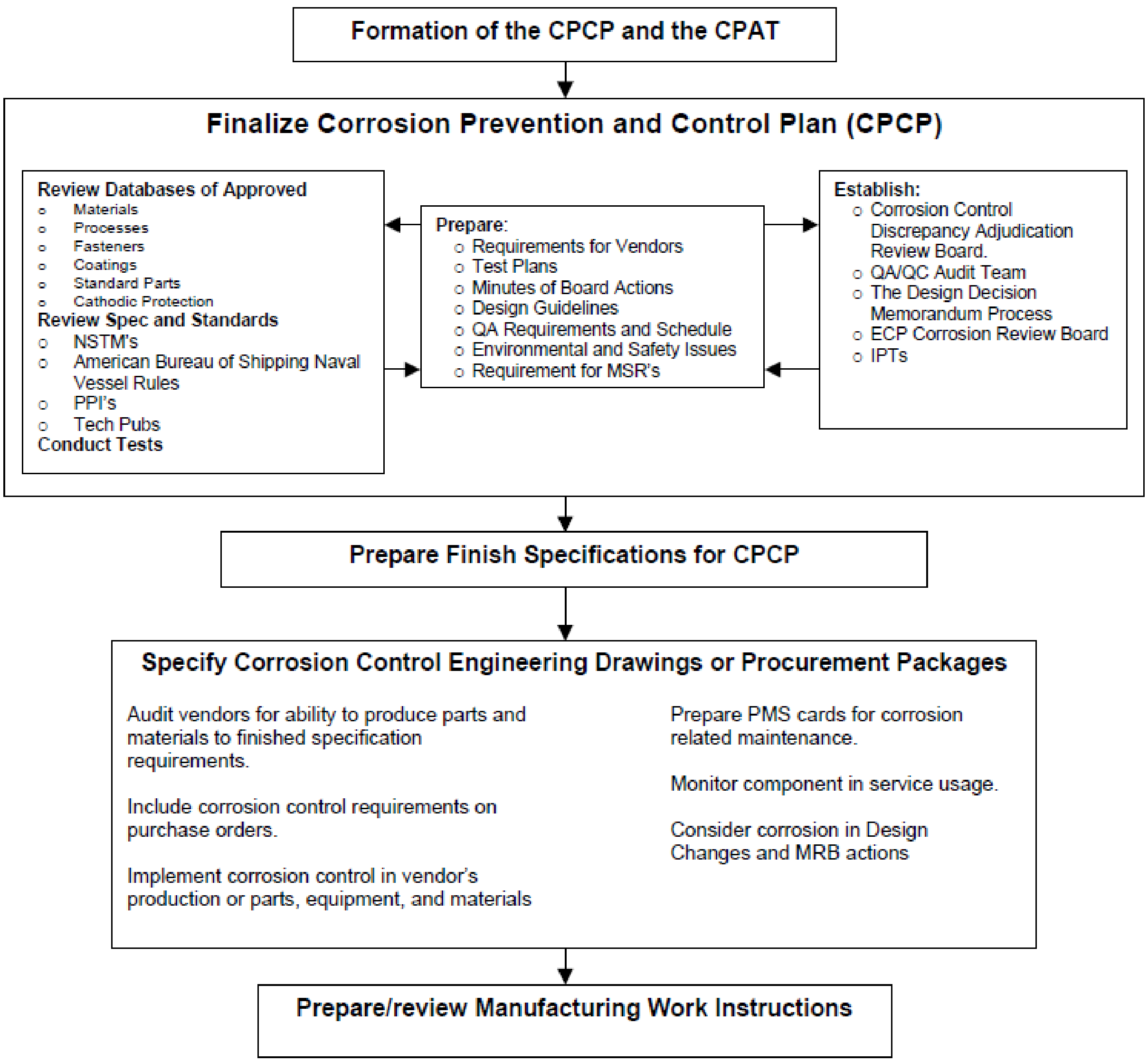
Figure 1. CPAT and CCT Corrosion Control Discrepancy Adjudication Process



3 Corrosion Prevention and Control Plan (CPCP)

This plan describes the corrosion control tasks and outlines who has responsibility for the system and support equipment. A Contractor Corrosion Team (CCT) will be established at the prime contractor to oversee the Corrosion Control Prevention and Control Plan (CPCP) and to provide a forum for the coordination of the Corrosion Prevention and Control Plan tasking assigned to each organization. The prime contractor will ensure that copies of major revisions to this document will be formally submitted to DTIC. Suppliers and vendors that have been granted design authority will actively participate in the CPCP process by formulating their own CPCP's that follow the guidelines set forth in this document and will participate in the CCT meetings as required. The flow diagram presented in Figure 2 illustrates the flow of tasking.

Figure 2. Corrosion Prevention Control Plan Tasks



4 Contractor Team Coordination and Corrosion Control

The CCT will include at least one Program representative from each of the team companies and be chaired by the company IPT Corrosion Control Specialist. This team will provide coordinated and consistent corrosion prevention and control policy. The CCT will guide, direct and instruct the prime and subcontractors on corrosion prevention and control measures and will verify all measures implemented on the program are necessary, adequate, timely, and cost effective. The following are the responsibilities of this team:

a. Develop, document and maintain the Corrosion Prevention and Control Plan (CPCP).

b. The CCT chairperson will be the primary liaison with the government CPAT on all corrosion issues.

c. The CCT will establish a regular meeting schedule and call additional meetings when needed and notify the CPAT chairperson of each CCT meeting date, meeting topic, and any decisions resulting from the CCT meeting.

d. The CCT will establish an Engineering Materials Review Board that documents material/corrosion concerns and reports to the CPAT Chairperson.

e. The CCT will monitor and investigate industrial developments for processing and/or process/finish improvements related to corrosion prevention and for cost effectiveness of, or compliance with, environmental regulations.

f. The CCT will coordinate the documentation of corrosion design guidelines and will provide technical input to corrosion control and other related technical publications and review/approve the related documents.

g. The CCT will coordinate corrosion prevention policies and procedures with other IPT policies and practices, as applicable.

h. Establish criteria for identification of corrosion specialists within

i. The CCT will conduct quarterly CCT meetings to ensure implementation of this plan and to coordinate solutions for problems that arise during the development, design, and manufacturing phase. Additional CCT meetings will be conducted as required. Close communication between the CCT chairperson, company team leader, and CPAT chairperson will be maintained.

j. The CCT will maintain a log of problems, solutions and actions they have addressed or are addressing.

k. The CCT will make field site inspections of systems when requested by the CPAT or on a schedule established by the CPAT.

l. The CCT will review and document the prime and subcontractors internal controls to ensure that corrosion prevention and control techniques are established, implemented, and maintained.

m. The CCT will review training programs to ensure that the required corrosion prevention and control techniques, as well as safety, QA/QC, and Environmental issues, are properly addressed.

n. The CCT will review corrosion test results developed for process/finish material qualifications.

o. Review coating procedures, specifications and qualifications.

p. Establish corrosion test requirements for procured items in conjunction with the cognizant IPT's.

q. The CCT will conduct failure analyses as required and provide corrective action for corrosion problems. These analyses will be conducted and documented by the appropriate Failure Analysis Group. Results will be reported to the Engineering Materials Review Board and recorded in the corresponding corrosion control engineer's log.

r. The CCT will incorporate environmental resistance requirements and verification methods into the testing and selection of materials (metallic and non-metallic) and coatings. Environment is defined as natural, and man-made or operational environments.

s. The CCT will incorporate corrosion prevention and control measures into electromagnetic environment effects, low observable technology, biological/chemical vulnerability and other related technologies.

t. The CCT will ensure that a balance is maintained between electrical bonding/grounding needs and corrosion control approaches.

u. Establish and maintain team-common process/finish requirements.

v. Resolve any impasse in determining the preferred process/treatment method for corrosion control at any team site.

w. Maintain a log of problems, action items and corrective actions. This log will include the status of each of these items for all contractor and subcontractor sites.

x. Creates and maintains an interface with the government CPAT and PM.

y. Establishes the Life Cycle Maintenance Corrosion Control Document.

z. Additional Responsibilities as identified and needed should be added.

4.1 Contractors Corrosion Team (CCT) Functional Tasks

A CCT will be established at the prime contractor and each of the subcontractors that have design responsibilities and will provide coordination among the organizational and technical disciplines responsible for, or involved in, corrosion control tasks. Each CCT will consist of knowledgeable personnel who represent, at a minimum, the following disciplines necessary to implement the CPCP:

4.1.1 Design

- The CCT Chairperson will work with the CPAT to incorporate Program and Team CCT decisions into the product designs.
- The CCT Chairperson will coordinate corrosion-related design problems with the CPAT and Team CCTs.
- The CCT will review drawings for conformance to standard corrosion prevention design practices.
- The CCT will participate in design trade-off studies during all phases of design development.
- The CCT will provide guidance to the CPAT on corrosion prevention procedures based on experience.

4.1.2 Materials and Processes

- The CCT will write and maintain a process/finish specification for the engineering and manufacturing development and production models.
- The CCT will serve as a design consultant for the selection of materials, processes and finishes. The CCT will review and approve engineering drawings, systems, and the components specifications and technical manuals related to corrosion prevention and control.
- The CCT will initiate changes to materials and process specification and design as required.
- The CCT will submit logs of corrosion problems and solutions/actions to the CCT chairperson and CPAT.
- The CCT will maintain records of all inputs.
- During the system development, demonstration and production phases, the CCT will work with the PM to resolve materials and corrosion prevention concerns and document actions taken.
- The CCT will monitor the development in processing or finish requirements relative to the CPCP for design incorporation.
- The CCT will review and recommend approval of cleaning materials, solutions, and chemicals for use on the system, parts, and components not covered by approved specification.
- The CCT will review and recommend approved surface preparation and coating application methods.
- The CCT participates in, or assists with, as applicable, the Engineering Material Review Board for materials and process technical disciplines.
- The CCT participates in the development of MSR’s.
- The CCT reviews NVR and NSTM’s for compliance with specifications and regulations.

4.1.3 Reliability, Maintainability, and Supportability

- The CCT will ensure the incorporation of reliability, maintainability and supportability (RM&S) into materials, corrosion prevention, finish selection and development.
- The CCT will ensure corrosion-related supportability design-to-requirements is current and available to the designers. This includes design reviews to ensure hidden or inaccessible areas are addressed.
- The CCT will develop and recommend corrective and preventive procedures based on Reliability and Maintainability analyses of field data on similar in-service equipment.
- The CCT will document maintenance procedures and applicable logistic resources
- The CCT will provide shop/manufacturing surveillance and support to assure compliance with specification requirements.

4.1.4 Production Operations

- During production operations the CCT will review and analyze corrosion-related problems in all departments. Consultations with materials and process corrosion engineers will be conducted as required during this process.
- The CCT will request changes to engineering documentation in order to correct finishing procedures or implement new procedures.

4.1.5 Quality Assurance

The CCT quality assurance authority consists of process control and quality control items.

4.1.5.1 Process Control

- The CCT will maintain a record of all engineering specifications or design changes.
- The CCT will monitor compliance of process parameters with applicable engineering or government specifications.
- The CCT will maintain records and prepare test reports on compliance with appropriated specifications.
- The CCT will initiate corrective actions for all nonconforming processes.
- The CCT will perform initial and subsequent subcontractor audits, as required, to verify their capability in applying the finish systems specified.

4.1.5.2 Quality Control

- The CCT will verify that parts and assemblies are properly protected from corrosion during manufacture, in storage, and when packaged for shipping.
- The CCT will verify that parts are processed in accordance with the applicable specifications and standards.

- The CCT will verify that all applied coatings and finishes conform to pertinent designs, specifications and standards.
- The CCT will reject any materials, parts, coatings, or finishes that have been damaged or are not in compliance with applicable specifications or standards.

4.1.6 Manufacturing

- The CCT will translate processing and finishing requirements of engineering data onto planning documents.
- The CCT will provide requirements to ensure in-process corrosion protection of the materials and parts during manufacturing.
- The CCT will revise planning documents when changes to engineering design or specifications require those alterations, then inform the CPAT and PM of those changes.

4.1.7 Hazardous materials, Environmental and Safety Compliance

- The CCT ensures that materials and processes will comply with all federal and state regulations.
- The CCT will document and report compromises to the CPCP due to Environmental or Safety requirements.
- The CCT will serve as the focal point for coordination and distribution of new regulations, including those regarding materials and processes.

5 Corrosion Prevention and Control Processes

5.1 General Requirements

In this section of the CPCP, the Program Manager prepares his “REQUIREMENTS OF CPCP” that comply with the latest version of the Corrosion Prevention and Control Planning Guidebook, issued by PDUSD (AT&L). This section of the plan should address corrosion prevention and control requirements and considerations for system definition, design, engineering development, production and sustainment phases that are consistent with the design life of the system. Within this section, requirements should be provided for materials, processes, finishes, surface preparation, coatings and sealants to be used. The following sections should be compiled by the PM and CPAT:

5.2 Process/Finish Specifications

5.3 Materials

5.3.1 Metal/Alloy (Name of metal/alloy i.e. Steel, Stainless Steel, Aluminum, etc)

5.3.1.1 Application

5.3.1.2 Limitations/Trade-offs

5.3.1.3 Welding Specifications

5.3.1.4 Testing and Evaluation Requirements

5.3.1.5 QA/QC Requirements

5.3.1.6 Certifications and Training

5.3.2 Non-metallic (Name of the non-metallic material)

5.3.2.1 Application

5.3.2.2 Limitations/Trade-offs

5.3.2.3 Testing and Evaluation Requirements

5.3.2.4 QA/QC Requirements

5.3.2.5 Certifications and Training

5.3.3 Determine if Material Selection Review (MRS) requirements Apply.

5.4 Coatings (Name of coating)

5.4.1 Surface Preparation & Application

5.4.2 Limitations/Trade-offs

5.4.3 Testing and Evaluation

5.4.4 QA/QC Requirements

5.4.5 Certifications and Training

5.5 Sealants

5.6 Bonding and Grounding

5.7 Cathodic Protection Systems

5.7.1 ICCP

5.7.2 Sacrificial

5.8 Quality Assurance Requirements

5.8.1 Third Party QA/QC

5.8.2 Contractors/Subcontractors QA/QC

5.9 Wear and Erosion

5.10 Stress Corrosion Factors

5.11 Limitation on Use of Protective Metallic Coating

5.11.1 Cadmium

5.11.2 Nickel-cadmium

5.11.3 Chromate conversion coatings

5.12 Surface Considerations

5.13 Galvanic Corrosion

5.14 Lubrication

(Add sections as needed)

6 Operational Environment

This section is presented as background information on the operational environment. The operational environment is defined in the Environmental Criteria Document. Within this part of the CPCP, define the expected environmental conditions that should be considered in the design and construction phase in order to reduce life cycle cost and maintenance burdens such as:

(NOTE—ADD OR DELETE OPERATIONAL ENVIRONMENTS AS NEEDED. This is the section you define the operating environment expected to operate in.)

6.1 Breathing and Condensation

Breathing will occur in enclosures when a cyclic flow of air goes in and out of the enclosure primarily due to atmospheric pressure changes during temperature fluctuations. In temperate tropical zones, breathing will occur during daily temperature changes in the morning and evening hours, when the outside air heats or cools. Depending on the design area, breathing will vary; however, breathing most likely will occur in enclosed areas open to the outside through unsealed joints in unpressurized areas and in instruments and electronic equipment boxes.

6.2 Atmospheric Salt

Normal sea breezes can carry from 10 to 100 pounds of salt per cubic mile of air. Although the salt-laden air may travel inland on sea breezes for a distance of up to 12 miles, the major amount of salt fallout occurs within the first half mile of the beach. In the northern, cooler latitudes, the salt content of air is much less of a problem than in temperate and equatorial regions.

6.3 Seawater Immersion

Natural seawater covers more than 70 percent of the earth's surface and is the most abundant natural occurring electrolyte. Most metals and alloys used for ship construction are attacked by seawater. In addition to the corrosion of the metal by the electrolyte, biofouling will occur. The major concerns in this environment are pH, salinity, oxygen, biological activity, pollution, and temperature.

6.4 Alternate Immersion

Materials exposed in an alternate immersion are almost continuously wetted with well-aerated seawater. Materials commonly used to fabricate tanks, carbon and low carbon steels, do not form a thin tenacious passive film and suffer severe corrosion if not coated properly. The alternate immersion environment is the most aggressive of the marine environments.

6.5 Sulfur Oxides

Sulfur oxides are normally associated with industrial and large urban areas. In the past, sulfur-containing fuels, such as coal, can produce enormous quantities of byproducts. Within the past ten or so years, there has been considerable reduction in emission output due to federal and state laws which require smoke stack scrubbers, catalytic converters, etc. Even though there have been reductions in sulfur oxides, the levels are still high enough, particularly onboard ship behind the stacks, that they mix with moister and sea spray to form a strong sulfurous acid which can cause corrosion and attack to metals, non-metals and coating systems.

6.6 Firefighting Agents

Many fire-extinguishing agents such as Aqueous Fire Fighting Foam (AFFF) are corrosive and can very quickly produce severe corrosion.

6.7 Soot

Soot from a fire or from normal engine operation is primarily carbon, but can include a variety of combustion byproducts and sulfur oxides, depending on what has been burned. Soot is both corrosive and hygroscopic. It imbeds itself into painted surfaces and is very difficult to clean off. When pain chips off of an aluminum structure, you can have a small anode (aluminum exposed through chipped paint) and a large anode (soot) in contact with each other in the presence of moisture. This can result in severe corrosion.

6.8 Sand and Dust

Blowing sand and dust can cause erosion of coatings and severe damage to metals. When damp sand and dust (poultice) form against the structure, corrosion can result. Furthermore, even though the climate may otherwise be acceptable in some desert regions, many deserts sands contain a significant amount of salt.

6.9 Rainfall

Rainfall provides some benefit in corrosion prevention by washing away some contaminants. During periods of high acid rain activity, the beneficial effects of rain will be somewhat diminished. In either case, improperly sealed joints, open cavities, and trap areas will allow corrosion initiation to occur.

6.10 Volcanic Ash

Volcanic ash contains corrosive substances such as sulfur compounds, fluoride, and chloride salts, as well as strong inorganic acids. These chemicals are often carried on the surface of ash particles, which are highly abrasive bits of pulverized rock and can cause erosion of coating and metal surfaces.

6.11 Solar Radiation

Although ultra violet radiation (sun light) is not corrosive, it will cause chalking of paint, hydrolysis of chlorinated organics, and degradation of exposed plastics and elastomers. Deterioration of these materials will allow an electrolyte, usually in the form of moisture and its corrosive constituents, to have free access to the underlying metallic surface.

6.12 Chemical

Maintenance chemicals, such as deicers, cleaners, acids, paint strippers, solvents, etc., can present many different problems as long as these chemicals are being used. Paint strippers, solvents, and some cleaning agents can, when improperly used, deteriorate paint, plastics, and elastomers. Some paint strippers, some cleaners, and most acids are corrosives. Designers should select materials or impose preventive measures to minimize the damage from chemical attack caused by of the cleaning agents. Additionally, maintenance personnel should be thoroughly familiar with the chemicals they use while performing maintenance.

6.13 Damage by Personnel

While damage by personnel is not a corrosive, that deterioration can greatly contribute to corrosion on the system. Walking on surfaces and dropped tools and equipment can sufficiently damage a coating system to allow corrosion to initiate.

6.14 Chemical Warfare Agents

During periods of war, the system may be required to operate and be maintained in an environment of chemical agents. All removable equipment, unsealed compartments, etc., are susceptible to contamination. The system should be able to survive in the chemical threat environment and be capable of decontamination after exposure. Contaminants and the decontamination process should not cause corrosion of the exposed structure and equipment.

7 Deliverables

- Documentation of material/corrosion deficiencies, as required. Complete Enclosure (1) following the adjudication of any issues and file as appropriate.
- Life Cycle Maintenance Corrosion Control Document.
- Review and comment on design issues. Provide technical justification as required.
- Resolve materials and corrosion issues identified by the various IPT's.
- Resolve design issues related to materials corrosion control and coatings identified by the Design Agents.
- Review of (Type of Ship/Asset) Specifications, providing updates for current technologies.
- Periodic review and update of the CPCP.

8 Reference Material

- Steel Structures Paint Council–Surface Preparation Standards
- American Bureau of Shipping Naval Vessel Rules
- NSTM Section 074–Castings and Welding
- NSTM Section 075–Threaded Fasteners
- NSTM Section 078—Materials Requirements
- NSTM Section 505–Piping System Requirements
- NSTM Section 630–Corrosion Prevention and Control
- NSTM Section 631–Preservation of Ship in Service NSTM Section 632–Metallic Coatings
- NSTM Section 633–Cathodic Protection NSTM Section 634–Deck Coverings
- NAVSEA Approved Preservation Process Instruction (PPI's)
- Tech Pubs
- Military Specifications and Standards
- www.corrdefense.org (DoD corrosion website)
- www.NSTCenter.com

Enclosure (1) Corrosion Control Discrepancy Documentation Form

NAVSEA CORROSION PREVENTION
AND
CONTROL PLAN FOR
(type of ship or asset)

(Type of ship/asset) CORROSION CONTROL DISCREPANCY DOCUMENTATION FORM

This form is use to document the resolution of any corrosion control discrepancies reviewed by the NAVSEA Corrosion Prevention Advisory Team (CPAT) or their designated representative(s). Complete information will be available in any documents referenced below

Date: ______________________

Performing Activity

Activity Name: ______________________ Code: ______________________

TPOC: ______________________ Phone: ______________________

Description of Corrosion Control Issue:

Description of Resolution:

Reference Documentation (Where complete problem resolution can be found):

NAVSEA CPAT Review

☐ Accepted ☐ Rejected

Name: ______________________ Phone: ______________________

Activity: ______________________ Date: ______________________

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PORT HUENEME CA 93043-4307 1

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FOR EXPEDITIONARY FIGHTING VEHICLES
WORTH AVE TECHNOLOGY ANNEX
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14041 WORTH AVE
WOODBRIDGE VA 22192-4123 1

DIRECT REPORTING PROGRAM MANAGER
FOR EXPEDITIONARY FIGHTING VEHICLES
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14041 WORTH AVE
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CRANE DIVISION
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300 HWY 361
CRANE IN 47522 2

COMMANDING OFFICER
NAVAL SURFACE WARFARE CENTER
CRANE DIVISION
ATTN CODE 4052 (N MAEGERIEIN)
300 HWY 361
CRANE IN 47522 1

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ATTN CODE 4T4220D (N ANDERSON)
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COMMANDING OFFICER
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NAVSEA LOUISVILLE DETACHMENT
ATTN CODE G51 (D WHITTLE)
160 ROCHESTER DR
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COMMANDING OFFICER
NAVSEA LOUISVILLE DETACHMENT
ATTN CODE 4K22 (G HARLER)
160 ROCHESTER DR
LOUISVILLE KY 40214 1

Internal

CODE 011	1
CODE 0113	1
CODE 0114	1
CODE 28 (R PETERSON)	1
CODE 60	1
CODE 61	1
CODE 6109	1
CODE 611	1
CODE 612	1
CODE 613	5
CODE 613 (CONRAD)	10
CODE 613 (DAVIS)	1
CODE 613 (SHEETZ)	1
CODE 613 (RUEDISUELI)	1
CODE 614	1
CODE 614 (CLAYTON)	1
CODE 614 (DUCKWORTH)	1
CODE 614 (ENG)	1
CODE 614 (KOCH)	1
CODE 614 (MURRAY)	1
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CODE 616 (BOHLANDER)	1
CODE 63	1
CODE 65	1
CODE 66 (DOC PG ONLY)	1
CODE 3452 (TIC/C)	1

Appendix F
Frequently Asked Questions about Corrosion Prevention and Control Planning

Is a corrosion prevention and control plan (CPCP) mandatory and what happens if I don't have a CPCP?

A CPCP is mandatory for all ACAT I programs and is integral to effective corrosion prevention and control planning. CPC planning will be a standard topic and will be reviewed by the Overarching IPT with any unresolved issues raised to the DAB. The DAB will also review and assess the effectiveness of corrosion planning.

Why should I follow the CPC Planning Guidebook*?*

The *CPC Planning Guidebook* has been developed by DoD Science and Technology and Acquisition and Logistics experts who have combined their insight and experience with an understanding of new corrosion prevention and mitigation program requirements to produce this publication. The resulting guidebook, which is posted at www.corrdefense.org, is a compilation of approaches and processes designed to improve readiness, lower life-cycle cost, and improved safety by ensuring successful corrosion prevention and control.

How soon do I need to start considering corrosion and its effect?

Corrosion and its effects should be considered and prevention should be planned as early in the concept refinement phase as possible. Corrosion control planning should be well developed prior to Milestone B, and should continue throughout the life of the program.

What resources do I have available to help plan and execute corrosion-related activities?

Program managers need to establish a Corrosion Planning Action Team (CPAT), as defined in the *CPC Planning Guidebook*, to provide needed assistance regarding corrosion control planning issues. In addition, service materials and processes engineers are available in service corrosion control offices and laboratories. The DoD Corrosion Exchange website lists points of contacts for each of the services. Connect to www.corrdefense.org.

Why worry about corrosion during concept refinement phase, when it happens during operations?

While corrosion and its effects usually appear after a system has been in operation for some time, the mechanisms that initiate and propagate corrosion are most often inherent in the materials selected or caused by manufacturing and assembly processes. Much of the annual $10 billion to $20 billion DoD cost of corrosion is currently spent on detection, assessment, treatment, and repair of corrosion effects that could have been avoided by better design and manufacturing techniques. Initial, up-front investment in corrosion prevention can significantly reduce the total annual cost of corrosion while improving operational readiness and system safety.

Since it is easier to modify existing plans, where can I find examples of a CPC plan that will be of use to my program?

Appendix C of the *CPC Planning Guidebook* (Volume I) contains a sample CPC Plan. You may also be able to access corrosion plans at the various Service system commands.

How detailed must a CPC plan be?

The size and complexity of the design and acquisition program will dictate the level of detail appropriate for corrosion planning efforts. More specifically, types of materials, system structure, projected operating environment, logistic requirements and life-cycle costs will indicate the depth of planning needed in each CPC Plan.

How can I ensure that systems I procure meet requirements for corrosion resistance? What requirements can I impose in a contract?

The request for proposal and accompanying specifications impose procurement requirements. The *CPC Planning Guidebook* provides guidelines for determining corrosion resistance requirements and assessing compliance. The guidebook also prescribes the Corrosion Prevention and Advisory Team, which will be available to review and provide advice concerning design considerations, procurement requirements, materials selection, costs, and documentation that may affect corrosion prevention and control throughout the life of the system or facility.

How are issues resolved when there is disagreement between CPAT members and the program manager as to requirements and actions reflected in the corrosion prevention and control plan?

The CPAT and the program manager should make every effort to resolve issues internally. Unresolved issues will be presented to the overarching integrated product team (OIPT) for adjudication. If this results in no agreement or resolution, the issue may be presented during the DAB Review Process.

Why do I need specific corrosion-related testing during acquisition?

While traditional material and system testing conducted during design and acquisition may reveal some useful data regarding the ability of the system to prevent or resist corrosion and its effects, they often overlook important corrosion mechanisms and characteristics that will have significant impact on system operation and integrity during its service life. Specific corrosion-related testing is essential to verify the effectiveness of the corrosion prevention and control technology selected for the specific design and service environment of the application.

How do I know what corrosion specifications and standards apply to my program?

There are several websites that can provide such information. The ASSIST website at http://assist.daps.dla.mil/online/start/ lists most specifications and standards. The DoD Corrosion Exchange website (www.corrdefense.org) also lists specifications and standards. Commercial specifications and standards associated with corrosion may be found on the NACE website at http://www.nace.org/nace/index.asp.

How do I justify up-front funding for corrosion prevention?

Much of the annual cost of corrosion is currently spent on detection, assessment, treatment and repair of corrosion effects that could have been avoided by better up-front design and manufacturing techniques. Initial investment in corrosion prevention can significantly reduce the total annual cost of corrosion while improving operational readiness and safety of the system being procured.

What factors should I consider in planning for sustainment?

The objective of early planning for corrosion prevention and control is to reduce sustainment effort and costs by investing in materials and processes that prevent or resist corrosion. When it is clear that downstream corrosion control efforts will be required, capitalization of maintenance facilities; recurring costs of maintenance processes; and logistics requirements, such as replacement parts, material storage and transportation, should be considered.

How will a facility's corrosion prevention and control plan be integrated with weapon systems' plans?

Each facility CPCP reflects materials and methods to prevent, resist, or minimize corrosion and its effects on facilities and other infrastructure items. In those cases where facilities directly support weapon systems and warfighting capability, weapon system maintenance concepts and other support requirements may dictate facility requirements. While the facility CPCP will reflect such requirements, integrating the facility CPCP requirements with weapon system plans is outside the scope of the facility CPCP itself.

Equipment Sustainment

Volume II Equipment Sustainment
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Figures

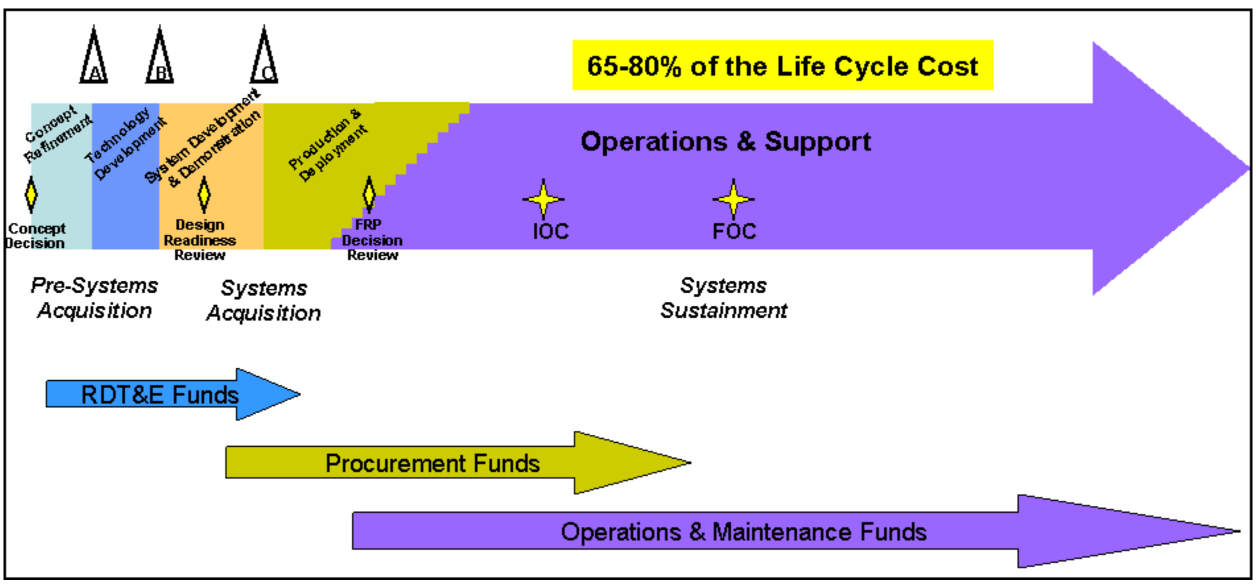
1. Life-Cycle Logistics

1.1 Overview

A fundamental element of DoD policy (Total Life Cycle Systems Management [TLCSM]) is the designation of the program manager (PM) as the life cycle manager, responsible for effective and timely acquisition *and sustainment* of the system throughout its life cycle. The PM provides the needed product support capability to maintain the materiel readiness, sustainment, and operational capability of a system. Emphasis is placed on increasing reliability and reducing logistics footprint in the systems engineering process, and providing for effective product support using performance-based logistics (PBL). In support of the total system level responsibilities of the PM, PBL strategies may be applied at the system, subsystem, or major assembly level, depending upon program-unique circumstances and appropriate economic or business case analysis. By employing PBL, TLSCM becomes the overarching DoD framework for implementing the Title 10 requirement to provide sustained materiel readiness to the warfighter.[1] This volume focuses on the sustainment responsibilities of the PM and, more specifically, the importance in mitigating or preventing corrosion.

DoD continues its efforts to conduct operations in a more effectively and with greater fiscal responsibility. Under the Total Life Cycle System Management approach, the sustainment aspects of a weapon system's life cycle receive increased attention by service leadership and program managers. Based on simple analysis of operations and support (O&S) costs compared to total ownership costs, the life-cycle impact is plain to see, as shown in Figure 1-1.

Figure 1-1. Life-Cycle Impact



[1] *Defense Acquisition Guidebook*, Chapter 5, paragraph 5.0.1, https://akss.dau.mil/dag/DoD5000.asp?view=document, accessed 5 July 2007.

1.1.1 Total Life Cycle Systems Management

TLCSM is the implementation, management, and oversight by the designated program manager of all activities associated with the acquisition, development, production, fielding, sustainment, and disposal of a DoD weapon or materiel system across its life cycle. With TLCSM, major system development decisions are made based upon how the decision will affect operational effectiveness and logistics affordability. TLCSM encompasses, but is not limited to, the following:

- Single point of accountability for accomplishing program logistics objectives, including sustainment
- Evolutionary acquisition strategies, including product support
- An emphasis on life-cycle logistics (LCL) in the systems engineering process
- Sustainment as a key element of performance
- Performance-based logistics strategies
- Increased reliability and reduced logistics footprint
- Continuing reviews of sustainment strategies, including end-to-end materiel readiness value chain planning, assessment, and execution
- Proactive consideration of diminishing manufacturing sources and material shortages or obsolescence issues
- Demilitarization and final disposition of the equipment.

Implementation of the TLCSM business approach means all major materiel alternatives and all major acquisition functional decisions can be implemented only after the program manager demonstrates an understanding of the effects on operations and sustainment phase system effectiveness and affordability.

In addition, TLCSM assigns the program manager responsibility for effective and timely acquisition, product support, availability, and sustainment of a system throughout its life cycle. TLCSM applies to all systems in all life cycle phases.[2]

1.1.2 Life-Cycle Logistics

LCL is the planning, development, implementation, and management of a comprehensive, affordable, and effective systems support strategy. Under Total Life Cycle Systems Management, life-cycle logistics must be considered during both the acquisition and operational phases of the weapon or materiel system life cycle. LCL should be carried out by a cross-functional team of subject matter experts to ensure sustainability requirements are addressed comprehensively and consistently with cost, performance, and schedule. Affordable, effective support strategies must meet goals for operational effectiveness, optimum readiness, and the facilitation of iterative technology enhancements during the weapon system life cycle.

[2] *Defense Acquisition Guidebook*, Chapter 5, paragraph 5.1.1.

The PM's responsibility under TLCSM is to provide the warfighter with sustainable weapon systems that meet their requirements remaining fiscally responsible and accountable. PMs should use the best possible analysis at all program stages to assess performance, schedule, supportability, and cost outcomes. These outcomes should be documented to ensure there is a credible foundation based on the analysis that has been conducted. These efforts are critical for both establishing budgetary requirements and tracking execution success over time for either new or legacy programs.

LCL supports sustained materiel readiness by establishing readiness standards (metrics), optimizing life-cycle investment strategies to achieve those standards, implementing and executing materiel readiness plans, and continually assessing performance against the standards.

LCL includes the planning, development, and implementation of performance-based logistics and performance-based life cycle product support initiatives as the preferred approach to systems support (DoD Directive 5000.1). Examples of these initiatives include managing performance agreements, integrating support strategies, and employing diagnostics, prognostics, and logistics chain management approaches to achieve operational effectiveness, proactive Diminishing Manufacturing Sources and Material Shortages (DMSMS) management, system affordability, and a reduced logistics footprint. LCL should be an integral part of the systems engineering process to ensure that sustainment considerations are implemented during the design, development, and production of a weapon system. This process is critical to providing more effective, affordable, and operationally reliable systems by increasing availability and sustainability.

LCL fully supports DoD's strategic goals for acquisition and sustainment logistics as stated in the most recent Quadrennial Defense Review (QDR), Joint Vision 2020, and the Focused Logistics Campaign Plan (FLCP). DoD goals include the following:

- Develop more integrated and streamlined acquisition processes.
- Project and sustain the force with minimal footprint.
- Implement Performance-Based Logistics.
- Reduce cycle times to industry standards.

In addition, LCL helps program managers achieve these goals within the context of TLCSM.[3]

1.1.3 Product Support

Product support is a package of logistics support functions necessary to maintain the readiness, sustainment, and operational capability of the system.

The overall product support strategy, documented in the acquisition strategy, should include life-cycle support planning and address actions to ensure sustainment and continually improve product affordability for programs in initial procurement, re-procurement, and post-production support.

[3] *Defense Acquisition Guidebook*, Chapter 5, paragraph 5.1.2.

Support concepts satisfy user-specified requirements for sustaining support performance at the lowest possible life-cycle cost for each evolutionary increment of capability to be delivered to the user, including the following:

- Availability of support to meet warfighter-specified levels of combat and peacetime performance;
- Logistics support that sustains both short and long-term readiness;
- Minimal total Lifecycle cost to own and operate (i.e., minimal total ownership cost);
- Maintenance concepts that optimize readiness while drawing upon both organic and industry sources;
- Data management and configuration management that facilitates cost-effective product support throughout the system life cycle; and
- Diminishing Manufacturing Sources and Material Shortages Management process that ensures effective, affordable, and operationally reliable systems in increasing availability and sustainment.

Performance-based logistics, the preferred DoD approach to product support, serves to consolidate and integrate the support activities necessary to meet these objectives.[4]

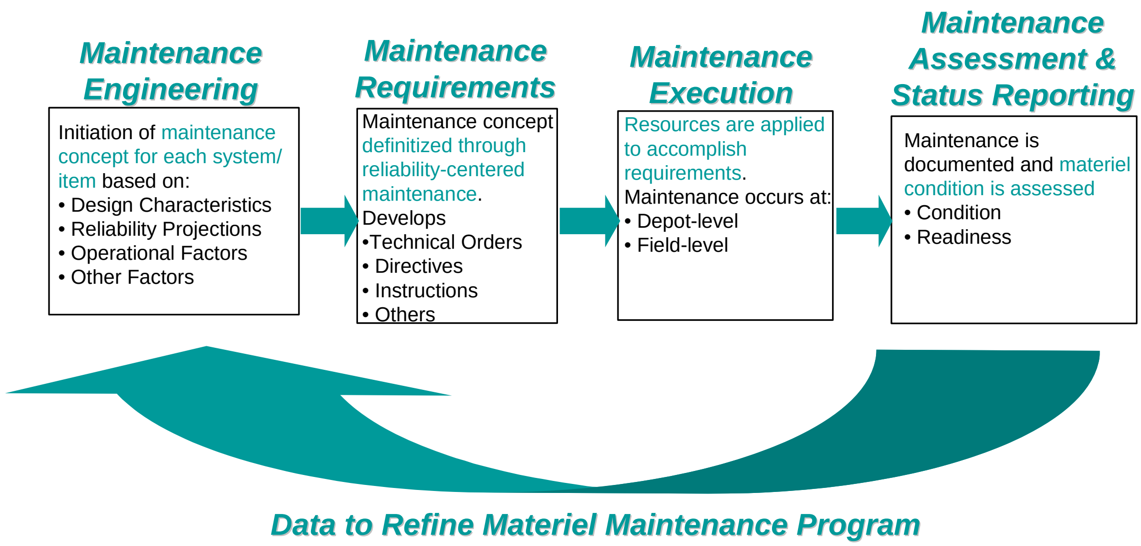
1.2 Sustaining Fielded Weapon Systems

As weapon systems are fielded, program managers shift their sustainment activities from planning to execution. While sustainment encompasses a wide-range of logistics functions, including supply and transportation, this volume focuses on the effects of corrosion on weapon system maintenance and, by extension, weapon system readiness.

Figure 1-2 depicts a standard materiel maintenance program. Corrosion, as a significant driver of maintenance requirements, needs to be considered during each phase—maintenance engineering, maintenance requirements, maintenance execution, and maintenance assessment and status reporting.

[4] *Defense Acquisition Guidebook*, Chapter 5, paragraph 5.1.3.1.

Figure 1-2. Standard Materiel Maintenance Program



The first two steps, maintenance engineering and maintenance requirements, are accomplished in both the acquisition and sustainment phases. For example, the maintenance concept (in the maintenance engineering step) is initially developed during weapon system acquisition based on the factors depicted in the graphic. However, the maintenance concept is reviewed and adjusted (if necessary) based on data collected during the operational and sustainment phases. Because corrosion prevention and repair are essential maintenance functions, they are embedded in each of the materiel maintenance stages as follows:

- Maintenance engineering, particularly when addressing technical and design considerations, is an indispensable step in preventing or mitigating corrosion during operational use; however, corrosion mitigation actions can occur during maintenance activities (especially during depot maintenance or ship availabilities) as well as modification and RESET.
- Maintenance requirements (such as inspection intervals, component replacement schedules, and maintenance procedures) are developed initially during the acquisition phase and based on such factors as expected failure rates, potential safety effects, and subsystem mission criticality of the weapon system. While some corrosion-related maintenance requirements are anticipated and, therefore, included in the initial maintenance concept, adjustments are routinely made once operational (i.e., failure) data becomes available.
- Maintenance actions are executed by more than 640,000 DoD military and civilian maintainers who, along with several thousand commercial firms, support 280 ships, 14,000 aircraft, 800 strategic missiles, and 330,000 ground combat and tactical vehicle. Corrosion-related activities are accomplished by numerous skill sets (career fields) but structural repair (a combination of the previous corrosion and sheet metal career fields) is the most prominent.

- Maintenance assessment and status reporting is perhaps the key to maintenance (and corrosion) prevention and mitigation in the sustainment phase. Unless a catastrophic condition occurs, corrosion is usually not discretely identified in maintenance documentation as a cause of a deficiency. Although not uniquely identified, if a degradation occurs, it is expected to be remedied in accordance with published technical manuals/orders.

1.3 Linking Corrosion into Key Maintenance Initiatives

Corrosion occurs throughout the sustainment phase in equipment components as well as the basic structures. It is attacked at both field and depot levels of maintenance using both preventive and corrective actions.

Because corrosion permeates maintenance activities, its prevention and mitigation must also permeate key maintenance initiatives, such as Continuous Process Improvement (CPI), Condition-Based Maintenance Plus (CBM+), and Reliability-Centered Maintenance (RCM).

1.3.1 Continuous Process Improvement

Continuous Process Improvement (CPI) is an OSD initiative focused on "continuous process improvement to maximize weapon system readiness while minimizing materiel flows and in-process inventories." The goal is to optimize reliability and cycle time while striking a reasonable balance with costs across the total life cycle value chain, employing

- Lean to eliminate all types of waste,
- Six Sigma to optimize process variation, and
- Theory of Constraints to alleviate process bottlenecks.

MIT defines Lean as the "elimination of waste and efficient creation of enterprise value," and includes "optimization of value delivered to all stakeholders and enterprises in value chain." According to the Lean Aerospace Initiative:

> Lean thinking is a dynamic, knowledge-driven, customer-focused process by which all individuals within an enterprise—indeed, the enterprise itself—continuously eliminate waste and expense, maximize resources and streamline operations, and create a total enterprise transformation endowed with added value. Lean tools and practices have been consistently shown to help target, identify, define, and implement improvements across a broad spectrum of enterprises.[5]

1.3.2 Condition Based Maintenance Plus

CBM^+ is the application and integration of appropriate processes, technologies, and knowledge-based capabilities to improve the reliability and maintenance effectiveness of DoD systems and components. CBM+ is based on maintenance performed based upon the evidence of need obtained from real-time assessments, reliability-centered maintenance analysis, embedded sensors, and external measurements. CBM+ uses a systems engineering approach to collect

[5] Lean Aerospace Initiative, https://acc.dau.mil/CommunityBrowser.aspx?id=22426, accessed 11 July 2007.

data, enable analysis and support the decision-making processes for weapon system acquisition and sustainment or operations. [6]

1.3.3 Reliability Centered Maintenance

RCM is an analytical process to determine the appropriate failure management strategies, including preventive maintenance requirements and other actions that are warranted to ensure safe operations and cost-wise readiness. The process of developing preventive maintenance requirements with an auditable documentation package is based on the reliability of the various components, the severity of the consequences related to safety and mission if failure occurs, and the cost effectiveness of the task.

The objective of the RCM process is to identify ways to avoid or reduce the consequences of failures, which, if allowed to occur, will adversely affect personnel safety, environmental health, mission accomplishment, or economics. Preventive maintenance is only one way failures can be mitigated. A preventive maintenance task should be implemented when it is appropriate to do so; but that might not be the best solution in all cases. An RCM analysis might indicate, for example, that the best solution is to simply allow the failure to occur, then perform corrective maintenance to repair it. Or analysis might indicate that some other action is warranted, such as an item redesign, a change in an operational or maintenance procedure, or any number of other actions that will effectively reduce the consequences of failure to an acceptable level.[7]

1.3.4 Set Life-Cycle Sustainment Metrics

In creating the strategy for CBM+ implementation, it is important to identify strategic changes that are required to transition to the desired condition-based maintenance environment. Life-cycle sustainment metrics provide the quantitative tools to track CBM+ implementation and operation. As the implementation effort progresses, high-level performance and cost metrics should be developed, and supporting or diagnostic metrics should be determined.

Diagnostic metrics are measures that relate to specific elements of the maintenance process that must be quantified, managed, and improved to ensure overall performance and cost goals are met. Initially, however, the CBM+ implementation team should identify higher-level metrics required to monitor overall maintenance performance, costs and results. The CBM+ implementation team should begin with metrics developed through recent research that uses the "balanced scorecard" approach.[8]

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[6] Draft DoD Policy Issuance, *CBM+ DoD Instruction*.

[7] From http://logistics.navair.navy.mil/rcm/index.cfm, accessed 11 July 2007.

[8] Robert S. Kaplan and David P. Norton, "The Balanced Scorecard—Measures that Drive, Performance," *Harvard Business Review*, vol. 70, no. 2, January–February 1992.

Generally, a quantitative baseline using past experience or estimated metrics targets should be developed. The balanced scorecard approach requires measures in the following areas:

- Meeting the strategic needs of the enterprise
- Meeting the needs of individual customers
- Addressing internal business performance, and
- Addressing process improvement initiative results.

Implementation of CBM+ requires a structured approach to measuring both the progress of implementation and the performance and costs once the condition-based maintenance process is in operation.

2. Corrosion Programs for Weapon System Sustainment

2.1 Introduction and Approach

Corrosion programs for systems in the acquisition phase have been reasonably well defined. Initially the DoD Corrosion Program focused on this phase because proper design and production can significantly reduce the effect of corrosion throughout the life cycle of a system. Some materials and processes can make a system vulnerable to corrosion. This chapter identifies the elements of an effective corrosion program for systems in the sustainment phase of their life cycle. It does not attempt to capture fine details of unique programs; rather, it captures general practices and corrosion program elements applicable to those programs in the sustainment phase. Interviews with those responsible for those corrosion programs identified unique challenges that some programs face, and "lessons learned" were subsequently captured.

2.2 Requirements

Specific requirements for addressing corrosion in systems in the sustainment phase have been limited in the past. Furthermore there have been only limited metrics by which to measure the success of a corrosion program. In addition to such requirements established by the individual services, a pending DoD Instruction on corrosion (DoDI 5000.rr, *Prevention and Mitigation of Corrosion on DoD Military Equipment and Infrastructure*) promulgates corrosion-specific requirements (see paragraph 2.2.2) The procedures in the pending DoD Instruction indicate that each system have a corrosion prevention action team (CPAT). In a similar manner the Defense Federal Acquisition Regulation Supplement (DFARS) requires corrosion planning for all contracts over $5 million, which includes many sustainment efforts. Key requirements are contained in the following issuances.

2.2.1 Defense Federal Acquisition Regulation Supplements

The DFARS requires discussions of corrosion prevention and mitigation plans for all contracts that require acquisition plans.

- DFAR 207.103, Agency-Head Responsibilities, Part 207.103(d)(i):

  Prepare written acquisition plans for

  - acquisitions for development, as defined in FAR 35.001, when the total cost of all contracts for the acquisition program is estimated at $10 million or more; and
  - acquisitions for production or services, when the total cost of all contracts for the acquisition program is estimated at $50 million or more for all years or $25 million or more for any fiscal year.

- DFAR 207.105, Contents of written acquisition plans, Part 207.105(b)(13)(ii), Logistics considerations:

  Discuss the mission profile, reliability, and maintainability (R&M) program plan, R&M predictions, redundancy, qualified parts lists, parts and material qualification, R&M requirements imposed on vendors, failure analysis, corrective action and feedback, and R&M design reviews and trade-off studies. Also discuss corrosion prevention and mitigation plans.

2.2.2 Pending DoD Instruction 5000.rr

Specific requirements for addressing corrosion in systems in the sustainment phase have been limited in the past. There also have been only a few metrics by which the success of a corrosion program could be measured. To add to any requirements established by the individual services, pending DoD Instruction 5000.rr currently dictates that corrosion prevention and control programs and preservation techniques must be established throughout the life cycle of each system. It also states that corrosion prevention and control reporting systems should allow for data collection, archiving, and feedback, and conclusions and recommendations drawn from this information should be used to address corrosion prevention and control, as well as related logistics and readiness issues. The procedures in this pending DoD instruction indicate each system should have a corrosion prevention action team.

2.2.3 The Services' Policies and Directives Related to Corrosion Prevention and Control

Each service has its own established policies and regulations to effectively manage CPC programs for all systems, equipment, and components (See Attachment 5).

2.2.4 Maintenance Work Program Requirements

Program and maintenance managers should determine corrosion prevention and mitigation related information/guidances on weapon systems, end items, and their components that require a level of maintenance work or are planned for assignment to a maintenance activity, a government agency, or the private sector. Examples of maintenance work and activity include program (e.g. modernization/recapitalization) and periodic maintenances and other generated work packages that may evolved from new program requirements that result from modifications, retrofits, or refurbishments of a weapon system.

2.2.5 Commercial Standards

In addition to formal DoD requirements, some commercial off-the-shelf systems (COTS) or commercial derivatives have corrosion programs because they are maintained in accordance with commercial standards. Those corrosion requirements often are not as rigorous as what is defined in this *Guidebook*; however, when applicable, the commercial requirements should be maintained as a minimum. Likewise, systems supported by contractor logistics support, or systems for which the contractor retains engineering authority, must work through the contractor to ensure they meet the requirements of DoDI 5000.rr.

2.3 Sustainment Corrosion Program Elements—Corrosion Plan

Although formal corrosion prevention and control plans have been required for acquisition programs for many years, programs have relied on engineering and technical data alone to address corrosion issues during a system's sustainment phase. This has resulted in a reactive response to corrosion with many unexpected problems which could have been anticipated had there been a more planned approach.

A sustainment phase corrosion prevention and control plan:

- Explain the philosophy and strategy to address corrosion for the remainder of the planned life of the system.
- Be formally accepted and signed by the program manager as an official program document.
- Define CPC requirements in accordance with existing technical data. These requirements should take into account operating environments and system-peculiar corrosion vulnerabilities. Based on materials and protective systems, their age and condition, the operating environment, and experience, a prevention and mitigation strategy should be clearly defined with a clear link to requirements.
- Define data systems, collection, analysis, and reporting of corrosion data in accordance with pending DoDI 5000.rr. Required corrosion data storage and tracking with reporting frequencies should be established. In many cases, corrosion records have not been retained, thus precluding the identification of trends and the anticipation of problems. Corrosion may occur long after the causative action, so long-term record keeping may be warranted.
- List applicable technical data, specifications, and standards.
- Define the relationship and role of corrosion in other system programs or plans, such as reliability, RCM, condition-based maintenance, maintainability, supportability, system master plans, structural integrity plans, etc. If corrosion is an element or subset of a separate focus, it may not receive the needed attention without specific advocacy within that program. This should be reflected in the corrosion plan to ensure the necessary resources are available.
- Establish the management structure to be used for the peculiar system including a CPAT.
- Define the competency level, duties, roles, responsibilities, and authority of the system corrosion manager. This should include procedures for review of all contracted and organic maintenance efforts, drawings, etc.
- Prescribe a CPAT charter with the approving signature level, the membership, and organization of the CPAT. The charter should describe basic duties of team members and define operating procedures. The CPAT charter should also define detailed working procedures as defined in Section 2.4.2 below.
- Define processes for addressing corrosion in all contracted and organic maintenance efforts.
- Outline sources of funding and procedures to be used to obtain funding for corrosion prevention and mitigation and the necessary engineering support.
- Establish processes and procedures for review of drawings, statements of work, maintenance planning documents, etc. for materials and processes or other content that might affect CPC.
- Establish responsibility and procedures for corrosion quality assurance audits of maintenance activities, storage facilities, etc.

- Define corrosion training requirements and identify sources of such training for system program engineers and CPAT members.
- Establish appropriate metrics and goals for corrosion performance.
- Identify corrosion technology acquisition and technology implementation procedures, field testing procedures, and resources to ensure current technologies and materials are specified. Corrosion conferences and the information provided on the DoD Corrosion Exchange website (www.corrdefense.org) are excellent ways to keep abreast of new corrosion technologies and materials.
- Establish methods for fleet or system corrosion assessments and assessment frequencies. Fleet surveys should be considered in conjunction with data system analysis, failure analyses, user field reports, and analytical condition inspections of representative assets.
- Identify methods to track fleet or individual asset environmental exposure as required for maintenance and corrosion prevention and mitigation actions.
- Be updated at least every 2 years.

2.4 Corrosion Prevention Action Team

2.4.1 Establishment and Scope

Programs in the sustainment phase should already have and established CPAT. In the event a CPAT does not exist, it should be established as soon as possible in accordance with DoD guidance.

The CPAT will play an important role in providing the guidance and expertise necessary to implement the corrosion prevention and control plan. The CPAT advises the program manager on corrosion-related issues, the adequacy and execution of the various elements of the plan, and alternative organizational avenues for addressing corrosion-related issues.

2.4.2 Charter

The CPAT charter provides the authority for the CPAT and its activities. The charter should be signed by the program manager as the one responsible for the specific system. It should define the purpose of the team and include the scope and responsibilities of the CPAT. The charter also should include organizational membership and specify a minimum meeting frequency (once per year) with more frequent meetings as required. The charter should define both member roles and responsibilities and CPAT activities in support of the system’s CPC plan.

2.4.3 Membership

The corrosion manager/POC for the system typically chairs the CPAT. In some cases, users or other involved members might serve as co-chair. Many systems now have contractor support for the CPAT activities. Membership should include representatives from system users, program or project engineering, service corrosion program offices, technical authorities or the equivalent, and subject matter experts, which may include individual service laboratory materials engineers, information analysis center personnel (such as AMMTIAC), and personnel from both organic and contractor maintenance organizations.

Systems that are still in production or that will likely have variants produced should also have representatives from the original equipment manufactures (OEMs) as non-voting members. Every effort should be made to maximize user participation, especially from activities with specific corrosion responsibilities.

2.4.4 CPAT Duties

2.4.4.1 CPAT Chair Responsibilities

- Scheduling regular CPAT meetings as defined by the charter or more often as required
- Preparation of meeting agenda, including calls for action items prior to the final agenda
- Assembling pertinent information and data, along with appropriate resource persons, to address agenda and action items
- Tracking of all action items with assignment of responsibility for resolution
- Maintenance of CPAT records and action items.

2.4.4.2 CPAT Member Responsibilities

- Participation in CPAT meetings
- Input of action items, corrosion issues, or discrepancies for inclusion in the agenda
- Providing requests for technical presentations relating to corrosion issues
- Addressing of corrosion issues through individual member organizations as appropriate
- Assisting CPAT Chair as requested
- Activities/Responsibilities.

2.4.5 CPAT Activities/Responsibilities

- Addressing action items
- Reviewing and resolving discrepancies
- Conducting process audits and fleet assessment surveys as required per the CPC plan
- Providing advice to the program or project manager on corrosion-related issues, risks, technology, and proactive measures to prevent or mitigate corrosion
- Reviewing and making recommendations for corrosion technical manuals, procedures, and guidance
- Reviewing of corrosion data, analysis, and trends with recommendations for action
- Reviewing and making recommendations to responsible organizations regarding facilities, training, technology, and other issues that affect corrosion on the specific system

- Working through or with other cognizant organizations, such as service corrosion program offices, laboratories, other services, etc., to resolve common corrosion issues
- Providing expertise and assistance to CPAT Chair as needed
- Evaluating technologies, policies, regulations, and other issues with the potential of impacting corrosion of the system for which the CPAT is responsible
- Reviewing and recommending changes and updates to the CPC Plan
- Reviewing and evaluating corrosion related test data with recommendations

2.5 Assessments and Surveys, Feedback, and Monitoring

2.5.1 Field Assessments and Surveys

The importance of fleet corrosion assessments and surveys cannot be overemphasized, although such assessments and surveys tend to be very infrequent for most systems in the sustainment phase of their life cycle. While the data systems provide some indication of corrosion activities, and CPAT input from the users reflect specific problems, corrosion condition and the effects of corrosion are often not clearly and comprehensively identified. Many sustainment system corrosion program managers have very limited insight into actual conditions and related corrosion issues.

One weapon system studied in this effort conducted periodic (every 5 years) fleet surveys. These surveys provide the backbone for CPAT activities, as previously unidentified corrosion items became formal CPAT action items and were subsequently addressed and tracked. As the result of an OSD-funded project, another sustainment corrosion program manager, along with contractor support personnel, visited multiple user sites to accomplish on-equipment testing. During the testing, multiple, previously unknown, corrosion problems were discovered and found to be prevalent across the fleet. These discoveries became one of the primary sources of CPAT actions for the next several years, and they may mean significant problems could be otherwise avoided.

Limited budgets often preclude such assessments and surveys, but they should be a part of the CPC plan. Once conducted, the corrosion program manager should quantify the benefits and track associated actions.

2.5.2 Feedback

Other feedback mechanisms are available to access corrosion problems. These include results of “lead-the-fleet” weapons system assessments, materials and quality deficiency reports, consumable and reparable parts history, and newer parts usage and trend analysis.

2.5.3 Monitoring

The insertion and adaptation of developed technologies such as corrosion monitoring sensors can provide valuable information related to corrosion prevention and control. Monitoring sensor results can accurately predict impacts of specific environments on the expected corrosion. Prediction and active monitoring may result in such examples as determining frequency of washing or rinsing and avoidance/extension of periodic maintenance.

2.6 Sustainment System: Corrosion Manager Duties

The duties for a Corrosion manager for a system in the sustainment phase of its life cycle may include, but are not be limited to, the following:

- Serve as CPAT Chair (see Section 2.4.4).
- Draft reviews and updates to the CPC plan at least every 2 years.
- Review all drawing packages, engineering change proposals (ECPs), statements of work, maintenance work packages, modifications for correct materials, and processes for corrosion prevention and mitigation
- Identify corrosion training needs and opportunities for program office engineers and technicians in accordance with the CPC plan.
- Participate in corrosion conferences and corrosion-related technical seminars to maintain technical and programmatic awareness.
- Review, monitor, and analyze corrosion data for trends and indications of needed mitigation actions.
- Review and update corrosion technical data and maintenance programs to ensure compliance with policy directives and regulations and to ensure the best technologies are being used.
- Regularly interact with the system operators and maintainers to address corrosion issues as they occur.
- Identify funding sources and provides budget input for corrosion funding requirements for sustaining engineering, technology implementation, and costs associated with implementing the CPC plan.
- Serve as the advocate for corrosion in other program office engineering activities.
- Identify and elevate unresolved corrosion issues to program office management for resolution.
- Request and assist in quality assurance audits of maintenance processes as needed to ensure compliance to specifications and requirements.
- Arrange for and lead fleet corrosion assessments and surveys in accordance with the CPC plan.
- Maintain corrosion documentation, CPAT minutes, action items, corrosion-related discrepancy files, and material and quality deficiency reports.
- Develop and manage field testing of corrosion related materials and processes.
- Serve as system focal point for corrosion-related issues that involve other organizations, services, DoD, industry, etc.

2.7 Personnel

2.7.1 Personnel Resources and Expertise

Program managers should devote adequate manpower to address corrosion issues. While individual programs are charged with this responsibility, increased external emphasis is also needed to assure proper focus. In many cases, the responsibility for corrosion is "another duty as assigned" and the individual is not given the time, resources, or authority to adequately address corrosion. Likewise, this assignment is many times given to less experienced individuals with little or no formal training. The DoD Corrosion Policy and Oversight (CPO) Office retains a list of subject matter experts, which can be made available to those who are in need of consultation or information.

2.7.2 Education and Training

All CPAT members should be encouraged or required to take the Corrosion Prevention and Control Overview (Continuous Learning Module 038) and subsequent corrosion education courses available at the Defense Acquisition University website (https://learn.dau.mil/html/clc/Clc.jsp). Education and training classes are also offered by other institutions such as NACE International and the Society for Protective Coatings.

2.7.3 CPAT Workshops

All CPAT chairs and contractor corrosion control support personnel should be encouraged or required to participate in at least one CPAT workshop each year. Such attendance would greatly enhance the CPAT chair's effectiveness. CPAT workshop schedules will be made available on the DoD Corrosion Exchange website (www.corrdefense.org).

2.8 Corrosion Metrics and Performance Measures for Sustainment Programs

2.8.1 Corrosion Performance

One of the more difficult aspects of establishing an effective corrosion program for sustainment programs is how to measure success. How bad is too bad, or nothing is ever good enough and there are always things left to do? How does a sustainment corrosion program manager decide between investments in prevention and repair?

Excessive investment in prevention will result in diminishing returns on investment. Managing corrosion strictly via repairs will result in much larger costs than would have been incurred had simple prevention techniques been used.

This is best illustrated with the story of two salesmen of corrosion inhibitor systems being called to the customer's facility to view the annual internal inspection of the boiler. The inevitable corrosion had occurred over the last year, and the salesman whose system was currently in use declared how wonderful it had worked, since corrosion was limited to what they saw. The hopeful competitor looked aghast and declared how terrible it was and how much better it would have been if his system had been used. Such is the difficulty of measuring the success of a sustainment corrosion program. Likewise, when effective corrosion measures are taken, how long does it take to see the results?

2.8.2 Monetary Impact of Corrosion

The DoD Corrosion Program, with direction from Congress, is addressing one aspect of this problem by conducting a cost-of-corrosion baseline study (by equipment platforms and infrastructure facility asset categories), which will provided detailed information and a searchable database of the elements that incur a corrosion-related cost. Like corrosion itself, these costs initially provide a snapshot of where we are; however, how a system is doing will only become apparent as subsequent studies establish trends in cost progression. With the detail of this database, each program manager can gain some insight into the corrosion performance of a specific program by comparing it with similar systems and systems of similar age, usage, etc.

It should be noted that economic cost is only one factor; it should not be used alone as a corrosion performance metric, because costs can be misleading if not properly understood and used in context. Corrosion maintenance costs, for instance, can be reduced over a given period simply by deferring the maintenance, but after a time the same maintenance costs will be much greater. Likewise, investments in prevention can prove very costly initially but will yield large returns on the investment over the life of the system. Unfortunately, corrosion programs can fall victim to budgets, so program managers must use other information to support requirements for addressing the corrosion issues in a timely fashion.

2.8.3 Readiness and Safety Impact of Corrosion

In addition to monetary costs, the effects of corrosion on readiness and safety should be considered by sustainment corrosion program managers. Corrosion-related safety incidents may be the result of anomalous situations, and are difficult to influence; but they should be tracked, analyzed, and targeted for elimination.

Corrosion-related safety trends can be another indicator of performance. Asset availability or readiness is carefully tracked for most systems. When corrosion can be identified as the cause for an unavailable asset, readiness becomes an important measure of performance. Again this is often not specifically identified or tracked, but it parallels to cost may be available from existing data systems and should be explored as one of the corrosion performance measures.

Corrosion-related trends in readiness, in conjunction with cost and safety, can be indicators of the effectiveness of the corrosion program. These factors can be even more indicative when compared to other systems with similar attributes of usage, design, etc.

2.8.4 Data Requirement to Ascertain Impacts of Corrosion

Of the systems investigated in this study, some had better data systems than others in the ability to directly record and provide visibility into corrosion issues. The AIRCAT system used by the USAF C-130 allows direct input of requests for engineering assistance and other corrosion information. All engineering responses and actions are recorded such that unique corrosion concerns and actions are easily visible. However, even this system does not assure that routine field corrosion activities or depot corrosion maintenance is recorded. However, this does allow insight into trends and unique problems. Under an OSD-funded project, the C-130 is also monitoring environmental exposure across a representation portion of the fleet such that corrosion inspection and maintenance can be tailored to the severity of exposure rather. This has allowed increases in wash intervals in mild environments with no impact to corrosion performance. Suffice it to say that there must be accessible data before performance can be measured. Specific corrosion information cannot easily be obtained from generic maintenance data systems across the services. Where possible, corrosion program managers should determine what specific corrosion information is available for that system and develop their own metrics using that information.

2.8.5 Impact of Subsystem on Corrosion Performance Metrics

Of special concern to the corrosion program manager of complex weapon systems, is the impact of the corrosion of systems and subsystems for which the weapon system corrosion manager has no responsibility or control. Every effort should be made to track and report this corrosion performance and its impact since these subsystems often affect multiple fleets. The delineation of responsibilities for corrosion performance is critical to effectively addressing the larger DoD corrosion as well as enhancing the performance of the individual system. The tracking of Defense Logistics Agency (DLA) and other supplied parts for corrosion performance in terms of cost, safety, and readiness is a necessary metric for the overall weapons system performance.

2.8.6 Need for Performance and Metrics Tracking

As systems age, corrosion obviously will become more of a problem as it grows, is identified, and begins to impact mechanical performance. Much has been mentioned about trends but absolute values of corrosion associated metrics may also indicate performance where these can be compared to those of other assets with similar attributes. Absolute corrosion impacts or the corrosion impact as a percentage of the overall metric at a given point in the life of the system may provide insight into readjustments that are required in the corrosion approach. This can then be reflected in the CPC Plan. Initially corrosion inspection and maintenance frequencies are based on expected performance as indicated by design requirements, test data, etc. However, with experience, corrosion inspection and maintenance should also, be shifted to reflect experience. In many systems this has not occurred because no one has actually looked at the years of corrosion experience for incorporation into the corrosion program. In one case, a major corrosion problem has recurred every seven or eight years over the last 25 years and required a fleet wide inspection with major repairs to corrosion damaged assets. While the repairs have been made, there has been little or no attempt to identify or address the cause of this corrosion failure since its occurrence typically exceeds the span of a single corrosion manager’s assignment.

2.9 Alternative Sustainment Corrosion Program Funding Sources

Sustainment Corrosion Program Managers are often constrained by lack of funding from the specific weapons system program. However, other funding sources may be available and should be pursued where specific corrosion needs are applicable from those sources. Many of the programs reviewed during this study applied for and received Pollution Prevention (P2), Environmental Security Technology Certification Program (ESTCP), and Strategic Environmental Research and Development Program (SERDP) funding as part of their environmental efforts which involve materials and processes with significant impact on corrosion prevention and control. Likewise, Global War on Terrorism (GWOT) funding has provided significant help in addressing corrosion which has occurred as a result of exposure resulting from deployments related to the war efforts. Programs may also make use of alternative sources of funding for RDT&E needs such as the sponsoring of topics for the Small Business Innovative Research (SBIR) program, etc. Likewise funding may be available from the Commercial Technologies for Maintenance Activities Program (CTMA), Value Engineering, and other OSD sponsored efforts including OSD corrosion project funding where projects meet the defined criteria. Information on such funding is available at www.corrdefense.gov.

2.10 Conclusions

A review of the DoD weapon systems in the sustainment phase of their life cycle, with successful participation in the OSD Corrosion Policy and Oversight Program, provided a template for corrosion programs for systems in this phase. Some of these systems were no longer in production, others were well into the sustainment phase as production continued; either way, the corrosion issues related to production should be addressed during acquisition.

Acquisition corrosion programs are much more fluid with changing needs and focus as the programs move through the milestone development process while sustainment corrosion programs have a more permanent and fixed focus. While the sustainment programs require significant flexibility to address ever-changing corrosion challenges, the programmatic approach and focus can be more constant. Sustainment corrosion programs have fewer automatic review points or defined corrosion performance metrics but they offer an increased opportunity to tailor programs in the long term to meet specific program needs.

Table 2-1. Corrosion Template for Systems in Sustainment Phase

Requirements	CPC elements	Lessons learned	Resources	Metrics
Policies and regulations	CPC plan	Cost of corrosion	Education opportunities and workshops	Documentation and tracking
Service instructions	CPAT	Analysis report Failures Lead-the-Fleet	Technology strategy and funding sources	User feedback Deficiency reports CTR reports
Program-specific guidelines	Corrosion manager duties	Consumable/ reparable parts history and trends	Subject matter experts	Assessments and surveys
Joint programs	Plan review		SSQP	New technology applications (e.g. sensors)

Appendix A
Equipment Cost-of-Corrosion Baseline Studies

In this appendix, we summarize the results from recent DoD cost-of-corrosion baseline studies. DoD's cost-of-corrosion studies are important for two reasons:

- They measure the annual cost of corrosion for various categories of weapon systems, facilities, and infrastructure.
- They identify corrosion cost reduction opportunities for the military services and DoD.

Introduction

According to two separate studies—including one by the Government Accountability Office (GAO)—the cost of corrosion to DoD equipment and infrastructure is estimated to be between $10 billion and $20 billion annually. Although the spread between these estimates is large, both studies confirm that DoD corrosion costs are significant.

Congress, concerned with the high cost of corrosion and its negative effect on military equipment and infrastructure, enacted legislation in December 2002 that directed the Secretary of Defense to appoint a DoD Corrosion Official to report to the Under Secretary of Defense for Acquisition, Technology and Logistics (USD[AT&L]). The Secretary of Defense was also directed to inform the Congress within 60 days, the structure of the office and who the office would report to. Modifications have been made, and the USD(AT&L) is the Corrosion Executive with a direct reporting Corrosion Office. To perform its mission of corrosion prevention and mitigation, fulfill congressional requirements, and respond to GAO recommendations, USD (AT&L) established the Corrosion Prevention and Control Integrated Product Team (CPC IPT), a cross-functional team of personnel from all the military services as well as representatives from private industry.

In response to a GAO recommendation to "develop standardized methodologies for collecting and analyzing corrosion cost, readiness and safety data," the CPC IPT created a standard method to measure the cost of corrosion for its military equipment and infrastructure. Because the data-gathering effort is large and complex, the CPC IPT plans to measure the total DoD cost of corrosion in segments. In April of 2006, the CPC IPT published the results of its first study using the standard corrosion cost estimation method.

Table A-1 presents the results of the initial five studies and the timeline for future cost-of-corrosion studies.

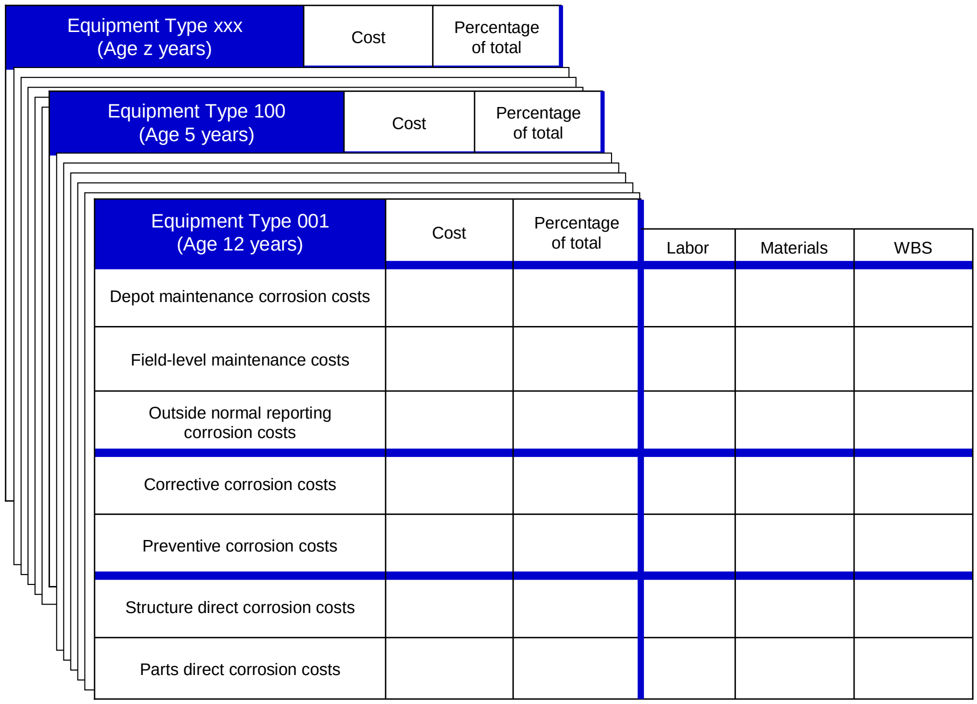
Table A-1. Cost-of-Corrosion Baseline Studies to Date and Future Efforts

Study year	Study segment	Annual cost of corrosion	Data baseline
2005–2006	Army ground vehicles	$2.0 billion	FY2004
	Navy ships	$2.4 billion	FY2004
2006–2007	DoD facilities and infrastructure	$1.8 billion	FY2005
	Army aviation and missiles	$1.6 billion	FY2005
	Marine Corps ground vehicles	$0.7 billion	FY2005
2007–2008	Navy, Marine Corps, and Coast Guard aviation and Coast Guard ships		
2008–2009	Air Force and repeat 2005–2006		
2009–2010	Repeat 2006–2007		
2010–2011	Repeat 2007–2008		

Based upon their general source of funding and level of maintenance, materiel corrosion costs are segregated into three categories: depot-level, field-level (both intermediate and organizational maintenance), and outside normal reporting. Outside normal reporting costs cover corrosion prevention or correction activities that are not identified in traditional maintenance reporting systems. Examples of these costs include the time an aviation crew member with a non-maintenance skill specialty spends inspecting the aircraft for corrosion damage, or the cost of corrosion-related training.

To accommodate the anticipated variety of decision makers and data users, a corrosion cost data structure that maximizes analysis flexibility was designed. Figure A-1 outlines the data structure and different methods of analysis.

Figure A-1. Data Structure and Methods of Analysis



Using this data structure, weapon system managers and other decision makers can analyze the data against the following:

- Equipment type
- Age of equipment type
- Corrective versus preventive cost
- Depot, field-level, or outside normal reporting
- Structure versus parts cost
- Labor costs
- Material costs
- Work breakdown structure (WBS).

Corrosion Shares of Various Maintenance Costs

The cost of materiel maintenance that is attributable to corrosion prevention or correction varies by service and type of equipment. For example, corrosion-related maintenance costs were 14.0 percent of depot maintenance costs for Army ground vehicles in FY2004; but corrosion-related maintenance costs were a much higher share of depot maintenance costs for Army aviation and missiles and Navy ships (28.4 percent and 28.0 percent, respectively).

Table A-2. Corrosion Shares of Depot Maintenance Costs

Service	Systems	Fiscal year	Cost (then-year dollars in millions)		Share
			Depot maintenance	Corrosion-related	
Army	Ground vehicles	2004	1,956	274	14.0%
Army	Aviation and missiles	2005	1,861	529	28.4%
Navy	Ships	2004	4,812	1,345	28.0%
Marine Corps	Ground vehicles	2005	521	119	22.8%

Source: LMI cost-of-corrosion studies for DoD.

Corrosion-related costs as a share of field maintenance costs are generally lower than at the depot level, as well as being more tightly grouped. Corrosion-related maintenance costs were 20.4 percent of field maintenance costs for Marine Corps ground vehicles in FY2005, and this is the clear outlier in this set of data.

Table A-3. Corrosion Shares of Field Maintenance Costs

Service	Systems	Fiscal year	Cost (then-year dollars in millions)		Share
			Field maintenance	Corrosion-related	
Army	Ground vehicles	2004	6,980	1,045	15.0%
Army	Aviation and missiles	2005	6,505	1,028	15.8%
Navy	Ships	2004	5,892	779	13.2%
Marine Corps	Ground vehicles	2005	1,862	379	20.4%

Source: LMI cost-of-corrosion studies for DoD.

Corrosion-related maintenance costs for Marine Corps ground vehicles also represented the highest share of the materiel maintenance costs for the military services and types of equipment studied to date. Note that Table A-4 does not include outside-normal-reporting corrosion costs and therefore differs from Table A-1, which does include them.

Table A-4. Corrosion Shares of Materiel Maintenance Costs

Service	Systems	Fiscal year	Cost (then-year dollars in millions)		Share
			Field + depot maintenance	Corrosion-related	
Army	Ground vehicles	2004	8,936	1,319	14.8%
Army	Aviation and missiles	2005	8,366	1,557	18.6%
Navy	Ships	2004	10,704	2,124	19.8%
Marine Corps	Ground vehicles	2005	2,383	498	20.9%

Source: LMI cost-of-corrosion studies for DoD.

Top Five Lists—Corrosion Maintenance Costs

Data from the cost-of-corrosion baseline studies can also identify weapon systems that incurred the highest corrosion maintenance costs either in aggregate or on average. Top five lists for the four categories of systems studied to date are presented below in Tables A-5 through A-12. Studies of naval aviation and Air Force platforms have not been completed and, therefore, are not reflected.

Army Ground Vehicles

Table A-5. Top Five Army Ground Vehicles by Total Corrosion Maintenance Cost in FY2004

Line item number	Nomenclature	Corrosion cost (in millions)	Maintenance cost (in millions)	Share (%)
T61494	Truck utility: cargo/troop carrier	$222.3	$1,087.0	20.4
T13168	Tank combat full tracked: 120mm gun	$134.5	$758.0	17.6
X40009	Truck cargo: 2-1/2 ton	$89.3	$325.5	27.4
X40794	Truck cargo: drop side	$51.5	$251.3	20.5
W95811	Trailer cargo: 1-1/2 ton	$50.3	$84.7	59.4

Table A-6. Top Five Army Ground Vehicles by Average Corrosion Maintenance Cost in FY2004

Line item number	Nomenclature	Corrosion cost (in millions)	Inventory	Average cost
F60564	Infantry fighting vehicle: M2A3	$9.5	265	$35,779
T13168	Tank combat full tracked: 120mm gun	$133.5	4,243	$31,475
A80593	Antenna mast group component truck	$3.5	131	$26,976
T13169	Tank combat full tracked: 105mm gun (M60A3)	$5.4	216	$25,135
L46979	Launching station: guided missile	$8.8	476	$18,493

Army Aviation and Missiles

Table A-7. Top Five Army Aviation and Missile Systems by Total Corrosion Maintenance Cost in FY2005

Line item number	Name	Corrosion cost (in millions)	Maintenance cost (in millions)	Share (%)
H30517	Helicopter cargo transport:CH-47D	$352.0	$1,782.2	19.8
K32293	Helicopter utility: UH-60A	$335.3	$1,706.8	19.6
1H32361	Helicopter utility: UH-60L	$243.0	$1,630.6	14.9
H148918	Helicopter attack: AH-64D	$171.4	$859.8	19.9
A21633	Helicopter aerial scout: OH-58D	$127.2	$678.1	18.8

Note: The two sub-components may not add to the total because of rounding.

Table A-8. Top Five Army Aviation and Missile Systems by Average Corrosion Maintenance Cost in FY2005

Line item number	Name	Corrosion cost (in millions)	Inventory	Average cost
H30517	Helicopter cargo transport: CH-47D	$352.0	413	$852,000
H32361	Helicopter utility: UH-60L	$243.0	544	$447,000
H48918	Helicopter attack: AH-64D	$171.4	429	$400,000
K32293	Helicopter utility: UH-60A	$335.3	903	$371,000
A21633	Helicopter aerial scout: OH-58D	$127.2	357	$356,000

Navy Ships

Table A-9. Top Five Navy Ship Categories by Total Corrosion Maintenance Cost in FY2004

Ship type	Corrosion cost (in millions)	Maintenance cost (in millions)	Share (%)
Amphibious	$767	$2,232	34.4
Surface warfare	$604	$3,538	17.1
Carriers	$449	$2,129	21.1
Submarines	$225	$2,300	9.8
Other ships	$77	$505	15.2

Table A-10. Top Five Navy Ship Categories by Average Corrosion Maintenance Cost in FY2004

Ship type	Corrosion cost (in millions)	Inventory	Average cost (in millions)
Carriers	$449	12	$37.4
Amphibious	$767	37	$20.7
Surface warfare	$604	105	$5.8
Submarines	$225	72	$3.1
Other ships	$77	30	$2.6

Marine Corps Ground Vehicles

Table A-11. Top Five Marine Corps Ground Vehicles by Total Corrosion Maintenance Cost in FY2005

TAMCN	Name	Corrosion cost (in millions)	Maintenance cost (in millions)	Share (%)
E0846	Landing vehicle, tracked	$175.6	$538.4	32.6
D1158	Truck, utility	$80.2	$579.4	13.8
D1156	Truck, guided missile	$58.5	$404.1	14.5
E1888	Tank, combat, full tracked	$58.3	$262.2	22.2
E0947	Light armored vehicle	$26.4	$119.1	22.2

Note: TAMCN = Table of Authorized Materiel Control Number.

Table A-12. Top Five Marine Corps Ground Vehicles by Average Corrosion Maintenance Cost in FY2005

TAMCN	Name	Corrosion cost (in millions)	Inventory	Average cost
E0846	Landing vehicle, tracked	$175.6	780	$225,139
E1888	Tank, combat, full tracked	$58.3	305	$190,997
E0796	Landing vehicle, tracked	$7.5	60	$124,417
E0947	Light armored vehicle	$26.4	292	$90,464
E0942	Light armored vehicle	$5.4	69	$77,955

Note: TAMCN = Table of Authorized Materiel Control Number.

Volume III Infrastructure
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Figures

1. General Project Management Requirements

> It is simply good sense and good management to prevent corrosion through better design and selection of materials, and to reduce treatment costs by detecting corrosion earlier and more precisely. Fighting corrosion is just one of the things that we need to constantly do so that we are always ready to perform the fundamental mission of the Department, which is to maintain our national security.[1]
>
> —DoD Corrosion Executive

1.1 Introduction

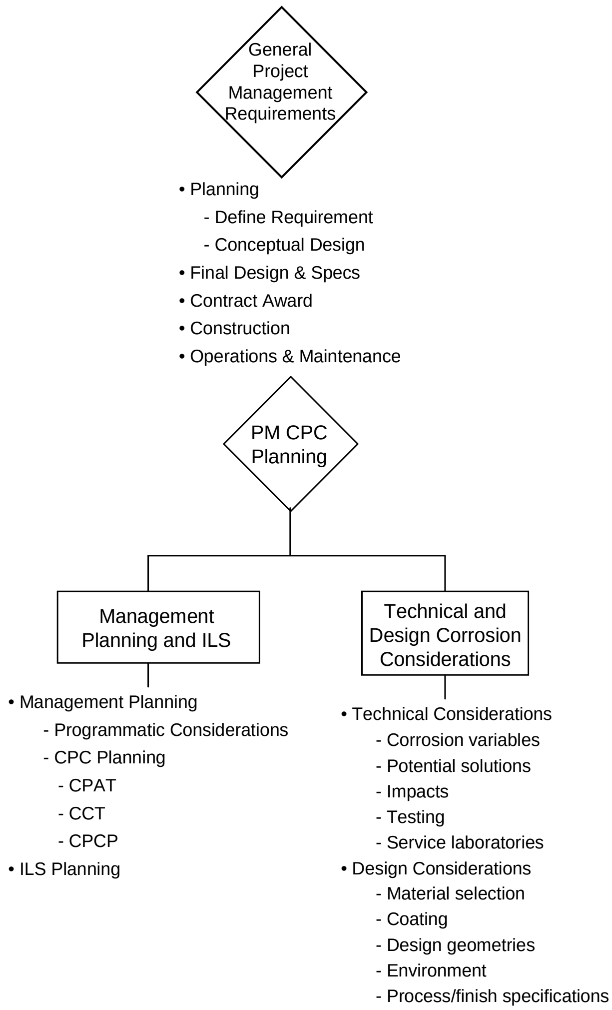
Project managers—perhaps more than any other group—greatly influence DoD's corrosion-related costs, safety, and reliability issues, regardless of whether it is in the design and construction of infrastructure or in their sustainment.[2] That is why this *Corrosion Prevention and Control Planning Guidebook* is targeted to them. It identifies the materials, processes, techniques, and tasks required to integrate an effective corrosion prevention and control program during all phases of DoD infrastructure development and sustainment. The objective is to minimize the effects of corrosion on life-cycle costs, readiness, reliability, supportability, safety, and structural integrity. Following the guidance in this Infrastructure Volume, in conjunction with applicable project and technical documentation, will result in the best possible balance between construction and sustainment costs for DoD infrastructure.

Figure 1-1 outlines the structure of this volume. The remainder of this chapter explores the corrosion requirements as they relate to facility managers and planners, project managers (PMs), and designers. It also identifies general project manager requirements. Chapter 2 outlines specific corrosion-related planning requirements. Chapter 3 focuses on technical and design considerations that may impede or eliminate corrosion.

[1] *AMMTIAC Quarterly*, Volume 7, Number 4, Winter 2003, p. 9.

[2] Per 10 USC 2228, the term "infrastructure" encompasses "all buildings, structures, airfields, port facilities, surface and subterranean utility systems, heating and cooling systems, fuel tanks, pavements, and bridges."

Figure 1-1. Volume III Organization



1.1.1 Intended Use

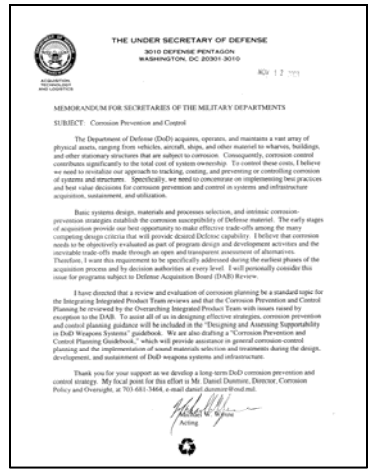
The content of this document is based on broad, in-depth military and industry experience regarding the protection of infrastructure from corrosion and its effects. This document

- provides tools and techniques for implementing sound material/process selection practices, finish treatments, and corrosion protection systems during all phases of DoD infrastructure development;
- provides guidance on facility project management that can be implemented in organizations to address corrosion issues and develop corrosion control plans; and
- describes requirements and methods for
  - establishing and managing a corrosion prevention action team (CPAT) that is appropriately integrated into all design integrated product teams (IPTs) (where applicable), and
  - developing and implementing a corrosion prevention and control plan (CPCP) as described in this document.

1.1.2 Applicability

This infrastructure volume is applicable to all DoD procuring activities and their respective contractors involved in the planning, design, and procurement of new DoD infrastructure as well the activities responsible for the sustainment of existing infrastructure.

1.1.3 Policy/Guidance


THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION, TECHNOLOGY AND LOGISTICS

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS

SUBJECT: Corrosion Prevention and Control

The Department of Defense (DoD) acquires, operates, and maintains a vast array of physical assets, ranging from vehicles, aircraft, ships, and other materiel to wharves, buildings, and other stationary structures that are subject to corrosion. Consequently, corrosion control contributes significantly to the total cost of system ownership. To control these costs, I believe we need to revitalize our approach to tracking, costing, and preventing or controlling corrosion of systems and structures. Specifically, we need to concentrate on implementing best practices and best value decisions for corrosion prevention and control in systems and infrastructure acquisition, sustainment, and utilization.

Basic systems design, materials and processes selection, and intrinsic corrosion-prevention strategies establish the corrosion susceptibility of Defense materiel. The early stages of acquisition provide our best opportunity to make effective trade-offs among the many competing design criteria that will provide desired Defense capability. I believe that corrosion needs to be objectively evaluated as part of program design and development activities and the inevitable trade-offs made through an open and transparent assessment of alternatives. Therefore, I want this requirement to be specifically addressed during the earliest phases of the acquisition process and by decision authorities at every level. I will personally consider this issue for programs subject to Defense Acquisition Board (DAB) Review.

I have directed that a review and evaluation of corrosion planning be a standard topic for the Integrating Integrated Product Team reviews and that the Corrosion Prevention and Control Planning be reviewed by the Overarching Integrated Product Team with issues raised by exception to the DAB. To assist all of us in designing effective strategies, corrosion prevention and control planning guidance will be included in the "Designing and Assessing Supportability in DoD Weapons Systems" guidebook. We are also drafting a "Corrosion Prevention and Control Planning Guidebook," which will provide assistance in general corrosion-control planning and the implementation of sound materials selection and treatments during the design, development, and sustainment of DoD weapons systems and infrastructure.

Thank you for your support as we develop a long-term DoD corrosion prevention and control strategy. My focal point for this effort is Mr. Daniel Dunmire, Director, Corrosion Policy and Oversight, at 703-681-3464, e-mail daniel.dunmire@osd.mil.

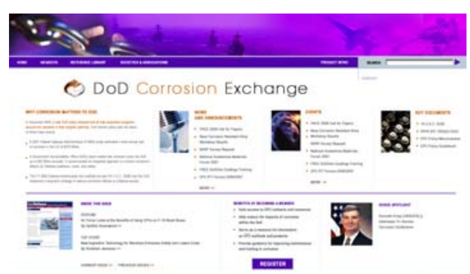
Michael W. Wynne
Acting

DoD corrosion policy recognizes that "the early stages of acquisition provide our best opportunity to make effective trade-offs among the many competing design criteria that will provide desired Defense capability." This guidance is in accordance with the DoD *Corrosion Prevention and Control* policy letter, signed by the Acting Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]), 12 November 2003 (see Attachment 1) and the *Facility Corrosion Prevention and Control* memorandum, signed by the Deputy Under Secretary of Defense for Installations and Environment, 10 March 2005 (see Appendix F). Program and project management requirements include the following:

- Make corrosion prevention and control planning an explicit part of performance-based acquisition as well as performance-based logistics, as defined in DoD Directive 5000.1.
- Assess and evaluate corrosion planning during the programming, design, and construction review processes.
- Adhere to the corrosion prevention and control guidance in the Unified Facilities Criteria and Unified Facilities Guide Specifications.
- Implement best business practices and best-value decisions for corrosion prevention and control in system and infrastructure acquisition, sustainment, and utilization.

1.1.4 Applicable Documents

Corrosion-related documents from government, industry, other non-government agencies, and standards organizations are available on the DoD Corrosion Exchange website (www.corrdefense.org) and the Whole Building Design Guide (WGDG) website (www.wbdg.org). The following are examples of applicable documentation:



- DoD's corrosion report to Congress,[3]
- DoD's corrosion points of contact (POCs) (included as Attachment 4)
- The military services' corrosion policies
- Links to corrosion-related laws and regulations
- Links to corrosion-related criteria specifications and standards

[3] DoD Report to Congress, *Long-Term Strategy to Reduce Corrosion and the Effects of Corrosion on the Military Equipment and Infrastructure of the Department of Defense*, December 2003.

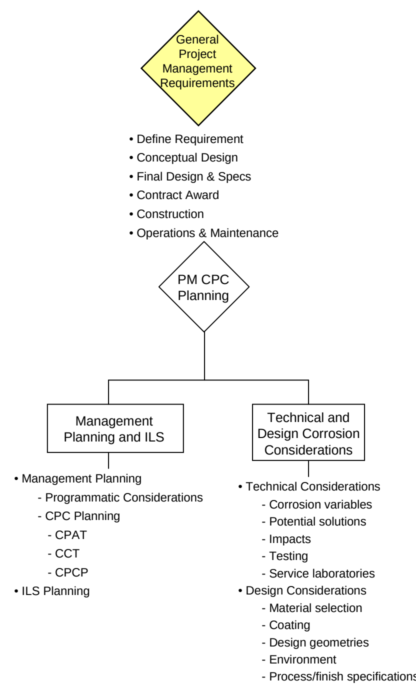
- Copies of minutes from pertinent conferences and symposia
- Advanced Materials, Manufacturing and Testing Information Analysis Center (AMMTIAC) publications.

1.1.5 Definitions

The term "corrosion" means the deterioration of a material or its properties due to a reaction of that material with its chemical environment.[4] Other key definitions are as follows:[5]

- Corrosion prevention and control is the rigorous application of engineering design and analysis, quality assurance (QA), nondestructive inspection (NDI), manufacturing, operations, and support technologies to prevent the start of corrosion, avoid functional impairment due to corrosion, and define processes for the tracking and repair of corrosion problems.
- Integrated product teams (IPTs) are an integral part of the defense acquisition oversight and review process. An IPT is a multifunctional team assembled around a product or service, and responsible for advising the project leader on cost, schedule, and performance of that product. There are three types of IPTs: program IPTs, working-level IPTs, and overarching IPTs.
- The Defense Acquisition Board advises the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD (AT&L)) on critical acquisition decisions. DAB reviews focus on key principles, such as interoperability, time-phased requirements related to an evolutionary approach, and demonstrated technical maturity.

1.2 General Project Management Requirements



Effective and viable CPC planning/programming by facility managers is critical to ensure requirements are included in the infrastructure design. DoD policy requires project managers to accomplish corrosion-related planning during construction proceedings. Management for corrosion prevention and control planning specifically applies to infrastructure projects. The need for viable CPC planning is critical to project success.

Effective and viable CPC planning should be smoothly and seamlessly integrated. The initial phases of the construction cycle should consider the effects of corrosion on the infrastructure and should be reflected in the appropriate documentation. A corrosion prevention and control plan describes how a particular project will implement CPC planning.

[4] Section 1067 of the Bob Stump National Defense Authorization Act for Fiscal Year 2003, Public Law 107-314,
enacted 10 U.S.C. 2228.

[5] Acronyms are defined in Attachment 2. A complete list of defense acquisition acronyms and terms can be found at http://www.dau.mil/pubs/glossary/preface.asp.

1.2.1 Facilities and Infrastructure

1.2.1.1 Facilities Community

Facility managers and project programmers should identify corrosion prevention and control requirements and include such requirements in the DD Form 1391 or other applicable project documentation to ensure the requirements are included in the design. The construction team, particularly the project manager and the prime contractor, should translate the requirements into an RFP, final designs and plans, contract specifications, and CPC planning. Figure 1-2 reflects the process to implement corrosion control during a classic design-bid-build construction project. Figure 1-3 reflects the process to implement corrosion control during a classic design-build construction project. An expanded discussion of the processes is at Appendix C.

Figure 1-2. Process to Implement Corrosion Control During a Classic Design-Bid-Build Project

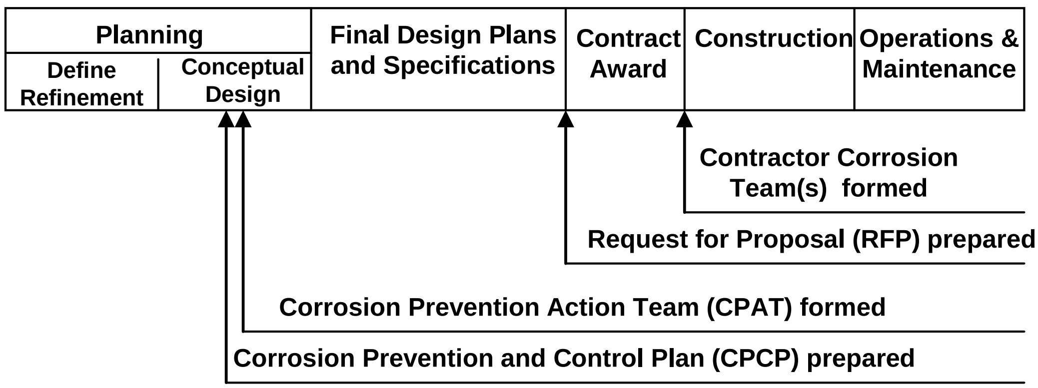
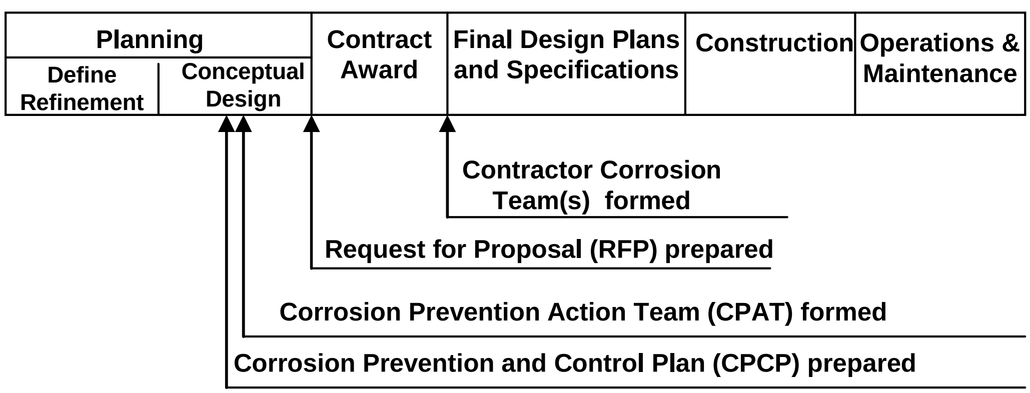


Figure 1-3. Process to Implement Corrosion Control During a Classic Design-Build Project



An infrastructure CPCP must reflect the following:

- The formation of the Corrosion Prevention Advisory Team
- The integration of corrosion prevention into the project design and plans
- Provisions for the inspection of coatings and cathodic protection during construction.

1.2.1.2 Construction Inspection Plan for Facilities

Corrosion criteria should be included in the construction inspection plan. This plan should include and define the type and levels of corrosion testing to be incorporated in the environmental test and verification plan. Standard government or industry test methods should be used whenever possible. The component/subsystem testing should reflect both the severity and duration of exposures. Success criteria should include both retention of functionality and freedom from required corrosion repair per specified performance requirements.

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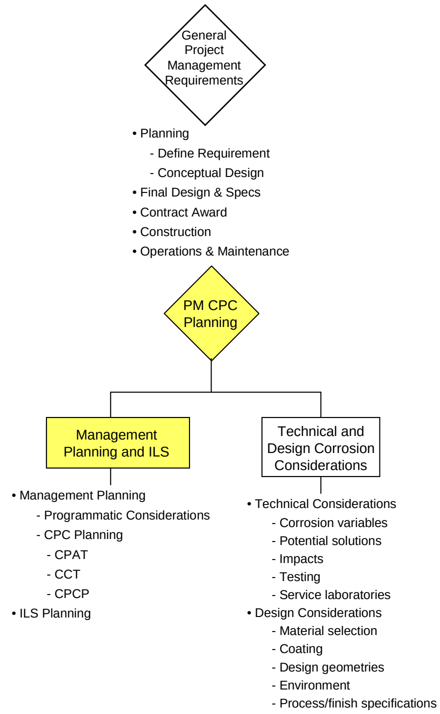
The next chapter covers project management corrosion prevention and control planning.

2. Project Management Corrosion Prevention and Control Planning

2.1 Project Management Requirements



Facility managers, project managers, and procuring agencies should consider corrosion prevention and control a key issue in designing, procuring, and maintaining DoD infrastructure. There are two primary aspects to CPC planning:

- Management of the planning
- Technical and design considerations (requirements, tradeoffs, etc.) that lead to viable CPC planning.

While implementation methods and procedures will vary by system and responsible service or agency, it is critical to maintain the intent of these two requirements. Any viable DoD CPC planning should contain these two basic elements.

The remainder of this chapter covers management planning, while Chapter 3 details technical and design corrosion considerations.

2.1.1 DoD Corrosion Performance Specification Issues

DoD construction reform over the last decade has resulted in a shift from traditional military specifications and standards to more commercial and performance-based specifications and design-build contracts for infrastructure acquisition. This shift challenges the project or engineering manager or designer to develop a meaningful performance specification or request for procurement for corrosion. Several programmatic and technical points must be considered for effective implementation of corrosion performance specifications in DoD construction projects. These are detailed in the Management Planning and Integrated Logistics Support (ILS) sections of this chapter, and the Technical and Design sections in Chapter 3.

2.1.2 Management Planning

2.1.2.1 CPC Planning

To achieve viable CPC planning, facilities managers and project managers should complete the following:

- Prepare a corrosion prevention and control plan as early in the project as possible. Include CPC requirements in the DD Form 1391 or any other appropriate project documentation.
- Implement the CPCP with an accompanying process/finish specification and organize the CPAT.

Figure 2-1. Process to Implement Corrosion Control During a Classic Design-Bid-Build Project

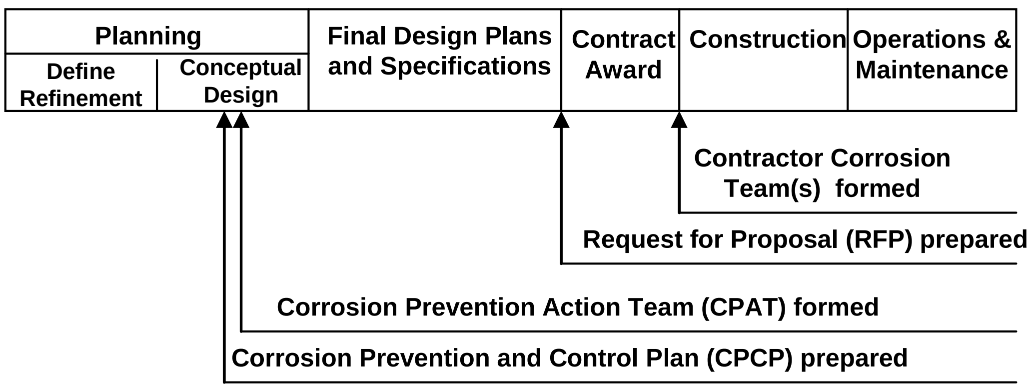
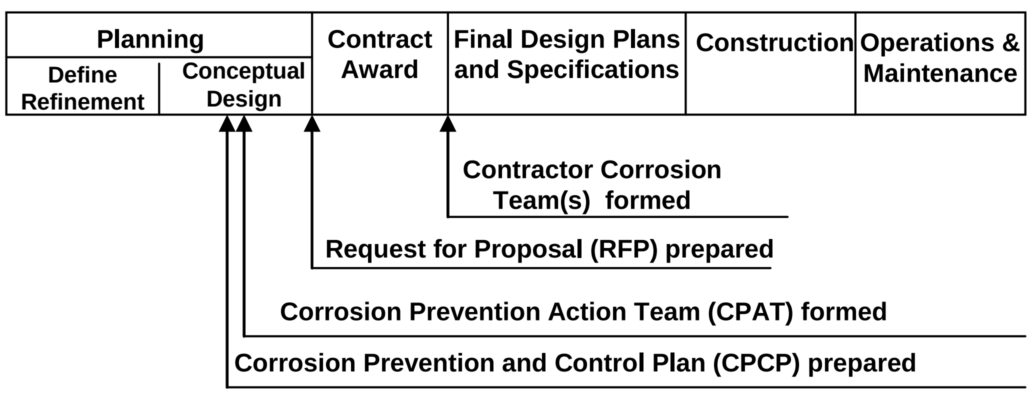


Figure 2-2. Process to Implement Corrosion Control During a Classic Design-Build Project



The corrosion prevention and control plan should

- define CPC requirements;
- list applicable specifications and standards;

- address facility or system definition, design, engineering development, production or construction, and sustainment phases, ensuring they are consistent with the design life and affordability of the system;
- establish the management structure to be used for the peculiar system/facility being designed, procured, and maintained, including a CPAT;
- prescribe the membership and organization of the CPAT, describe basic duties of team members, define operating procedures, and prescribe appropriate specifications and standards used in the systems/facilities;
- include the process/finish specification (materials and processes for corrosion prevention and control)[1] that specify the detailed finish and coating systems to be used on the procured weapon system; and
- address sustainability and logistics considerations.

2.1.2.2 Programmatic Considerations

Programmatic considerations are part and parcel of the DoD acquisition/construction process. These include acquisition cost, warranties, and the priority of corrosion control in construction.

2.1.2.2.1 Acquisition Cost

Implementing effective corrosion control that reduces life-cycle cost may increase the new-unit construction cost.

The project manager should balance the cost of improved design for corrosion against the life-cycle costs for facility. This may be difficult unless objective measures of effectiveness for corrosion control are established.

2.1.2.2.2 Warranties

With a warranty, the seller essentially assures the buyer that the product will perform as represented over a period of time. If the product fails to perform as represented, the seller may be required to provide a new product or satisfactorily repair the existing product. With respect to corrosion in DoD procurements, such agreements are typically hard to enforce:

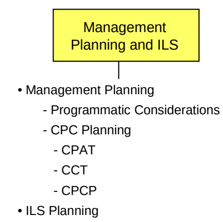
- A warranty has little value in a critical situation. Replacement or repair of a corroded part is meaningless to personnel under fire or when the failure has resulted in property damage, personnel injury, or mission capability degradation.
- The terms of warranties are often complex. This may result in burdensome record keeping and may constrain DoD’s flexibility with respect to maintenance procedures.
- The terms can also be somewhat subjective, such as when corrosion affects appearance and objective measures of performance are not available. Previously, many corrosion maintenance actions were considered discretionary until system functionality was actually affected. Today, however, maintenance concepts and reliability considerations do not allow for deterioration to the point of functional failure.

[1] The specification will be in accordance with CPCP approved process/finish specifications and standards.

2.1.2.2.3 Priority of Corrosion Control in Acquisition/Construction

While logistics support has long been recognized as a critical aspect of any procurement, the life-cycle costs incurred as a result of corrosion have only recently received substantial attention. Strong CPC planning often takes back seat to tactical or strategic capability during budget considerations and definition of constraints.

2.1.2.3 Corrosion Prevention and Control Planning



While corrosion prevention and control planning actually begins before a request for proposal (RFP) or specification is developed, the majority of the activity associated with CPC planning occurs after contract award. The initial CPCP requirements should be developed before the RFP to guide the insertion of the project's corrosion planning into the RFP. The initial CPCP also guides the initial performance specification development. CPC planning consists of the following:

- Establishment of the CPAT, which, along with the contractor corrosion team (CCT), guides the direction of CPC planning; alternatively, and when more appropriate, establishment of processes (including standard procedures, guidance on the processes, and project preparation templates) to ensure CPC is incorporated into projects
- Documentation (outlined above) that implements and reflects the CPC planning—CPC requirements should be included in the DD Form 1391 or other appropriate project documentation
- Actual design, manufacture, or construction, test, and support of the system.

2.1.2.3.1 Corrosion Prevention Action Team

2.1.2.3.1.1 Establishment and Scope

The roles and requirements of when to establish a CPAT vary depending on the type of project. In general, the project manager for a construction project should establish the CPAT during the conceptual design phase of the project.

The CPAT is actively involved in the review of all design considerations, material selections, costs, and documentation that may affect corrosion prevention and control throughout the life of the system or facility. The CPAT advises the project manager on corrosion-related issues and the adequacy of the corrosion maintenance documentation and guidance as they are developed, and elevate unresolved issues to a decision-level authority.

2.1.2.3.1.2 Membership

A representative of the procuring activity should chair the team, which should include representatives from the contractor's organization and from DoD:

- *Prime contractor members* (once the contract is awarded). The contractor's team members should be authoritative representatives of the contractor's organizations. They ensure proper materials, processes, and treatments are selected and properly applied and maintained from the initial design stage to the final hardware delivery or final construction.

- *DoD members*. The DoD team is designated by the project manager and includes all involved military services. Membership from the services should include but not be limited to
  - project engineering and support;
  - individual service corrosion program office, technical authority, or the equivalent; and
  - subject matter experts, which may include
    - individual service laboratory material engineers,
    - corrosion personnel from the user command,
    - information analysis center personnel (such as AMMTIAC), and
    - operational test personnel.

2.1.2.3.1.3 CPAT Duties

DoD team members have several responsibilities:

- Interface with the contractor corrosion team to ensure the goals outlined in this guidebook are attained.
- Monitor all activity during design, engineering, testing, and production.
- Advise the project manager on corrosion-related issues and identify risks as well as corrosion prevention opportunities.
- Attend appropriate CCT meetings.
- Advise the project manager on technical issues that need to be resolved.
- Review and resolve discrepancies submitted by the project manager.
- Schedule reviews as frequently as deemed necessary by the chairperson.

To evaluate the adequacy of the contractor's efforts in corrosion prevention and control, the project manager retains authority to conduct scheduled periodic reviews of the contractor's design and contractor and subcontractor facilities.

2.1.2.3.1.4 Corrosion Technical Manual Guidance and Corrosion Maintenance Concept Definition and Specifics

The CPAT should present its recommendations to the project manager as to the adequacy of the corrosion maintenance documentation and provide guidance as they are developed. Reliability-centered maintenance (RCM) may be used to assess the adequacy of such maintenance documentation and guidance.

2.1.2.3.2 Contractor Corrosion Team

2.1.2.3.2.1 Membership

The membership of the CCT should include representatives from the project design IPTs, material and process engineering, operations and manufacturing, quality control, material (or subcontractor) procurement, and contracts. This representation is intended to be flexible, and the recommended membership may be altered.

A CCT selected chairperson will serve as the manager of the CCT and contractor focal point for the program/project.

2.1.2.3.2.2 CCT Duties

The primary function of the CCT is to ensure adequate corrosion prevention and control requirements are planned and implemented for systems during all phases of the design and construction process. CCT duties should be outlined in the CPCP, which should be part of the initial contract. Specific CCT responsibilities include the following:

- Ensure the appropriate documents outlined under section 2.1.2.4 are prepared and submitted in accordance with the required schedule.
- Obtain the necessary design reviews, clarification, resolutions of any differences in technical position, and final approval of the documentation on a timely basis.

The chairperson or designee should

- establish periodic meetings as required to resolve problems as they occur;
- convene other meetings if a critical or major problem arises that requires action by the team;
- notify all DoD and contractor members of each meeting date, the topics to be discussed, and any decisions resulting from the previous meeting;
- sign off on all production drawings after materials selection, treatments, and finishes are reviewed;
- maintain a continuing record of all action items and their resolutions; and
- establish the principal tasks to be accomplished to implement corrosion prevention and control procedures in all phases of construction, or in the system contractor and subcontractor manufacturing facilities.

2.1.2.4 Corrosion Prevention and Control Planning Documentation

The following document should result from the implementation of the corrosion prevention and control planning.

2.1.2.4.1 Corrosion Prevention and Control Plan

The initial purpose of this plan is to

- set up the CPC program/project management approach,
- document corrosion-related design needs, and
- identify materials and corrosion control methods for use in the manufacture or construction of the system or facility.

The initial draft of the CPCP should be completed before a project's Milestone B or as early as possible in the project during the planning and programming stage. CPC requirements should be included in the DD Form 1391 or other appropriate project documentation. The plan should describe the specific anticipated CPC measures to be implemented. An example of a CPCP for infrastructure is provided at Appendix C.

During the design stage, the project manager should prepare, as soon as possible, a CPCP that describes the contractor's specific corrosion prevention and control measures to be implemented. The CPCP should

- address only the materials and processes to be used in the specific DoD facility being constructed; and
- outline how the contractor will ensure vendor and subcontractor compliance with the corrosion plan approved by the project manager, including installation of government-furnished equipment.

After contract award, the CPCP should be

- maintained by the contractor (or contractor team) and approved by the CPAT and project manager; and
- revised as required to properly record changes to materials and processes being used for corrosion prevention and control.

Copies of the major revisions to the CPCP should be formally submitted to the Defense Technical Information Center (DTIC) so the CPAT's accomplishments are preserved and future projects can benefit from legacy knowledge as they prepare their respective CPCPs.

At a minimum, the CPCP should provide the following information:

- The organization, procedures, and responsibilities for a CCT
- Roles and responsibilities of quality assurance, process control, production operations, manufacturing planning, environmental compliance, personnel safety, and other contractor organizations for the CPC effort
- A discussion of corrosion prevention techniques employed in design and how the design will meet the projected environmental spectrum

- Specifications (process/finish specifications in systems) that outline the application of coatings and other corrosion prevention compounds (if any) and address personnel training and qualification, material inspection, surface preparation, and coating or compound application procedures
- Any test data developed, or to be developed, for coatings or other corrosion-related materials and processes
- Identification of coating/substrate combinations for which no testing is to be performed, with an assessment of risk levels in the absence of testing
- Recommended specific corrosion control maintenance

2.1.3 ILS as It Applies to the CPC Program

For DoD infrastructure, no single, common program office is responsible for the entire corrosion prevention and control process throughout the facility's life cycle. Responsibility for initial planning begins with the installation facility manager. Responsibility for design and construction is often the responsibility of an external design or construction agency or office. Once construction is completed, control reverts to the facility manager for sustainment. Financial resources can be different appropriations through different chains of command (e.g., MILCON for construction managed by the design/construction agent, and O&M for sustainment managed by the installation). The ILS section contained in this Infrastructure Volume is for information only.

2.1.3.1 Integrated Logistics Support Policy

It is Department of Defense policy to include adequate and timely logistics support planning (including corrosion prevention and control planning) in all phases of the acquisition of defense systems and equipment. Specific performance-based logistics (PBL) guidance states

> PMs shall develop and implement performance-based logistics strategies that optimize total system availability while minimizing cost and logistics footprint. Trade-off decisions involving cost, useful service, and effectiveness shall consider corrosion prevention and mitigation. Sustainment strategies shall include the best use of public and private sector capabilities through government/industry partnering initiatives, in accordance with statutory requirements.[2]

Integrated logistics support is realized through the proper integration of logistics support elements (part of the system engineering process) and the application of logistics considerations as they apply to corrosion prevention and control decisions made during the facilities design phase. The optimum balance for facilities/infrastructure is somewhere between its capability and availability to support a specified military requirement. This goal can only be achieved by including logistics support considerations in all stages of the CPCP, from formulation and validation of the concept, through engineering design and development, to construction, and operation. In applying the concept of ILS to facilities/infrastructure, it is important to maintain a proper perspective and remember logistics support is not an end in itself. ILS exists only to support the use of the facility/infrastructure; therefore, it must be considered as the CPCP evolves.

[2] DoDD 5000.1, *The Defense Acquisition System*, Enclosure 1, paragraph E1.17, 12 May 2003.

2.1.3.2 ILS Elements

In addition to integrating support planning into the entire CPCP design and development process, the elements of logistics support (which are listed below and expanded upon in Attachment 3) should be integrated with each other and into the CPCP:

- Maintenance plan
- Support and test equipment
- Supply support
- Transportation and handling
- Technical data
- Facilities
- Personnel and training
- Logistics support resource funds
- Logistics support management information.

When the baseline of any one logistics element is changed—or proposed to be changed—because of a corrosion process application, the effect on all other logistics elements and on the total system/equipment must be considered formally, with the necessary adjustments made.

The key to effective application of the ILS process to the CPCP is a systematic and orderly management process through which the corrosion prevention advisory team can identify logistics actions and requisite decisions quickly and can present them to the project manager.

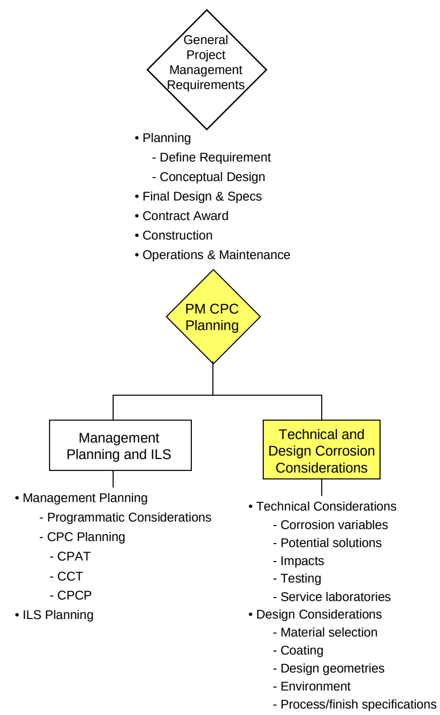
3. Technical and Design Considerations

The design and construction of DoD infrastructure requires the proper blend of safety, affordability, and environmental needs with mission and operational requirements. DoD infrastructure should

- perform reliably,
- require minimum maintenance over a specified lifetime, and
- deteriorate at a rate that permits maximum service life.

Materials, manufacturing methods, and protective treatments that reduce deterioration failures should be considered during the selection of suitable materials and appropriate construction methods that will satisfy system requirements. The following are among the deterioration modes that contribute to failures:

- General corrosion
- Galvanic corrosion
- Pitting corrosion
- Concentration cell corrosion
- Dealloying
- Intergranular corrosion
- Stress corrosion cracking
- Hydrogen embrittlement
- Corrosion fatigue
- Flow-assisted (erosion) corrosion
- Fretting corrosion
- Stray current corrosion
- Fungus growth.



The CPCP and project specifications should detail specific requirements. Fundamentally, the design and design disciplines should allow for the evaluation of the following general approaches:

- Selecting the right materials and manufacturing processes
- Applying protective coatings as necessary
- Using proper corrosion preventative and control designs
- Modifying the environment.

The design should also attempt to eliminate corrosive contaminants. If materials are to be exposed to contaminants, precautionary measures should be taken throughout the design phase to minimize deterioration of individual parts and assemblies (as well as the entire system). Precautionary measures are included in the technical and design considerations discussed below.

3.1 Technical Considerations

Corrosion performance is both an attribute of an entire facility and the sum of the performance of components or individual items. Technical considerations in the implementation of effective corrosion performance specifications are outlined below.

3.1.1 Variables Influencing Corrosion

The following variables influence corrosion:

- The interrelationship between materials and their specific environments
- The effects of design (including configuration and coatings), manufacture or construction, operation, and maintenance
- Corrosion performance specifications for complex systems (These should be addressed first at the component or item level.)
- Corrosion performance specifications for facilities. (These should be addressed first at the conceptual design level.)

3.1.2 Potential Solutions to Corrosion Problems

The large number of variables influencing corrosion performance leads to an equally large number of potential solutions, some of which might not be compatible.

A thorough review of relevant technical literature is essential for making informed decisions for corrosion performance requirements. Written corrosion specifications should be sufficiently flexible to allow the designer and manufacturer to consider the entire range of potential solutions.

3.1.3 Assessments of Corrosion Impacts in Construction and Sustainment

Because corrosion affects both function and appearance, an accurate assessment of its effects is difficult.

- The potential loss of function due to corrosion can often be quantified through physical measurements. These may include plating thickness loss, pit depth measurements, torque measurements, and conductivity measurements. Quantitative assessments are costly and typically applied to critical items only.
- Hidden corrosion is difficult to detect and, therefore , a major problem.

- Degradation in appearance is typically evaluated in very subjective terms through comparison with visual standards, such as those specified in technical manuals and technical society standards.
- Methods and equipment for corrosion monitoring and inspection should be considered in the development of design and maintenance concepts.

3.1.4 Accelerated Corrosion Tests in Acquisition

Corrosion is a time-based phenomenon. As such, accelerated corrosion tests cannot always determine correlations between corrosion and service performance. Some tests can be predictive (for example, exposure of *x* hours in test simulates *y* years of service life), but most tests cannot make exact correlations. Accelerated tests

- are most useful for ranking the relative performance of materials, coatings, etc. in a specific environment and application in comparison to a known system and
- often do not adequately reflect the effects of design changes, substantial material changes, and maintenance cycles.

The design of environmental tests and verification planning should duplicate both the levels and types of damage expected from the environmental spectrum defined for the system. This may be achieved by a combination of environmental tests that capture the critical aspects of the exposure, such as wet-dry cycles, specific corrodents, and geometric configurations.

- Accelerated corrosion testing, in conjunction with mechanical testing, should provide insight into the capabilities of the protective systems and allow projections of damage growth in order to facilitate corrosion management.
- The inspection and testing of facility components should be designed to consider both the levels and types of damage expected from the known environmental spectrum for the facility systems. The following variables need to be considered when developing a plan for inspection and testing:
  - Temperature
  - Exposure
  - Pressure
  - Wet-dry cycling.

3.1.5 Service Laboratories

The service laboratories may be able to provide added technical guidance. Similarly, AMPTIAC may be able to assist in the preparation of CPCPs and provide direct support through the CPAT.

3.2 Design Considerations

There are specifications (e.g., UFC and UFGS) and material selection criteria that should be considered as early in the planning process as possible (and included in the CPCP).

3.2.1 Material Selection

If possible, materials that are unsuitable to the operational environment should be avoided. Consider compatibility when using multiple materials. If dissimilar materials cannot be avoided, isolate those materials from each other. Information about such critical selection can be found at the following:

- The *Cambridge Material Selector* (accessible from Granta Design Limited, Material Information Solutions, http://www.grantadesign.com)
- DoD Corrosion Exchange website (http://www.corrdefense.org)
- Whole Building Design Guide (http://www.wbdg.org/)

3.2.2 Protective Coatings

The CPAT should consider protective coatings to isolate vulnerable materials from the environment.

3.2.3 Cathodic Protection

Cathodic protection is the utilization of the electrical properties of corrosion of metallic substances to provide a system for the protection of steel underground storage tanks (USTs), metallic piping, or any other buried metallic structure to extend their useful life. There are two types of cathodic protection—galvanic protection and impressed current. Cathodic protection is for buried or submerged facilities/infrastructure, particularly where required by law.

3.2.4 Design Geometries

Avoid crevices when possible, and avoid design features that make it difficult for protective coatings to function (sharp corners, for instance), and geometries that unnecessarily trap moisture. Appendix D outlines specific design guidance for facilities and infrastructure.

3.2.5 Environmental Modifications

When it is necessary for a portion of the infrastructure to be exposed to the environment, consider a design that allows for the modification of the environment. Dehumidification and sheltering can be effective means for modifying the environment.

3.2.6 Process/Finish Specification or Equivalent Document in Acquisition

The prime contractor should prepare a process/finish specification or an equivalent document as soon in the design phase as possible. This specification document should identify the specific organic and inorganic surface pretreatments and coatings and other corrosion prevention and control materials and processes intended for use. After it has been approved by the responsible DoD procuring activity, all requirements from the specification document should be included in all applicable production drawings and maintenance documents.

Appendix A
DoD Construction Process

This appendix provides additional background information on DoD's facilities/infrastructure process, which was too detailed to include in Chapters 1, 2, or 3. Readers who require specific facilities/infrastructure information for decision-making are encouraged to consult the following:

- The DoD Corrosion website (http://www.corrdefense.org)
- Service information manuals (e.g., Army/Corps of Engineers [COE] unified facilities criteria, NAVFAC Maintenance and Operations Manual [MO] 307, and Air Force Instruction 32-1054)
- Design criteria
- Operations and maintenance manuals.

Figure A-1 and Figure A-2 depict the implementation process for corrosion control during a DoD construction project. The individual steps of the process are explained below.

Figure A-1. Construction Process and CPC Planning

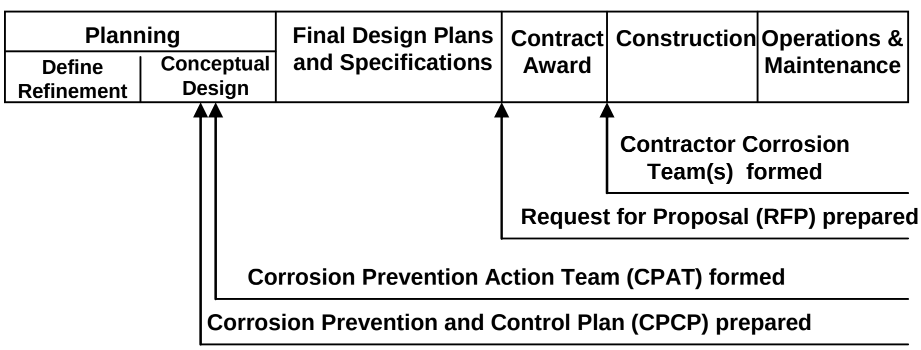
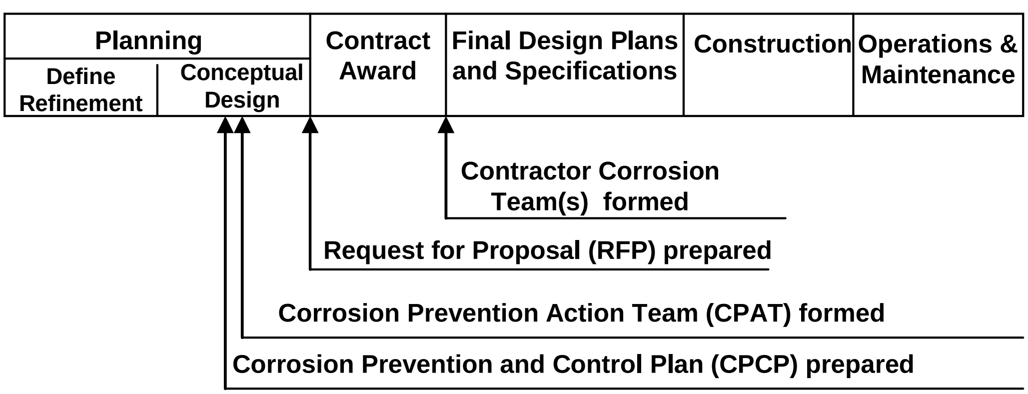


Figure A-2. Process to Implement Corrosion Control During a Classic Design-Build Project



Planning

Requirement Definition

The first step in the process is the definition of the requirement, or the approach to resolve a specific capability gap. This defines the capability gap in terms of the functional areas, the relevant range of military operations, time, obstacles to overcome, and key attributes with appropriate measures of effectiveness (e.g., distance effect, including scale). Facility Managers and project programmers should identify corrosion prevention and control requirements and include such requirements in the DD Form 1391 or other applicable project documentation to ensure this requirements are included in the design."

Conceptual Design

Once the requirements are defined, the facilities managers, engineers and architects assigned to the integrated product team (IPT) responsible for the design of the facility, utilities, or installation should ensure the conceptual design includes corrosion prevention requirements, and incorporate the Corrosion Prevention and Control Plan (CPCP) as early as possible in the conceptual design process.

Final Design Plans and Specification

The project manager will then ensure the

- final design and specifications include corrosion prevention technologies, where required and applicable; and
- corrosion prevention technologies comply with applicable military handbooks, design manuals, engineering technical letters and unified facilities criteria, as well as industry standards, such as those from NACE International (formerly the National Association of Corrosion Engineers and SSPC, the Society for Protective Coatings.

Request for Proposal

An RFP will be distributed to interested contractors and will outline the following:

- What will be expected from the bidders in the development, implementation and management of CPC planning (This is critical when beginning the contracting process for a construction project.)
- The managerial and technical aspects of CPC planning to ensure the contractors fully realize the type of robust CPC planning they are expected to develop and implement
- The CPC planning organization
- Government participation in the planning, contractor responsibilities, and deliverable documents.

Specifications

Finally, facility design plans and specifications will be provided with the RFP when the construction contract is awarded.

Appendix B
Example of Charter for Corrosion Prevention Advisory Team

This appendix provides an example of a corrosion prevention advisory team (CPAT) charter; it is intended to be representative only. The contents of this appendix are not direction. The contents of a program's or project's actual CPAT charter will vary and should reflect the needs of the particular program or project.

1.0 Introduction

Past experience has shown that corrosion in systems can impede operational readiness, impact life cycle cost, and jeopardize system effectiveness. Corrosion, which is defined as the environmental deterioration of any material, metallic or nonmetallic, includes the operating environment's degradation of all materials. DoD *Corrosion Prevention and Control Guidelines* define the objectives and responsibilities aimed at minimizing these threats throughout all phases of a weapons system's life cycle. The guidance recommends that a CPAT be established for each system. The intention is to bring the designer, maintainer, and the user together so they may contribute their unique experience to problem definition, formulate recommendations for solution, and track final resolution. This charter defines the purpose, membership, responsibilities, and procedures of the weapon system.

2.0 Purpose

The CPAT provides assistance and advice to the program/project manager on the most current methods of providing and maintaining an effective corrosion prevention and material compatibility planning for the weapon system.

3.0 Membership

The following organizations constitute the CPAT membership. Each organization identifies, in writing, any changes to their primary and alternate representatives to the CPAT. This charter is reviewed annually by the CPAT to update content and membership, as required.

- Program engineering (chairperson)
- Other concerned program elements
- Prime contractor (co-chairperson)
- Other major contractor participants
- User representatives
- Test and evaluation representatives
- Service program office representatives
- Service R&D laboratory representatives
- Defense contract management representatives.

4.0 Responsibilities

The specific responsibilities of CPAT members are summarized below. These responsibilities are derived from the DoD guidance in addition to contractor support requirements.

4.1 The PM chairperson, as the program or project manager's representative, the contractor team co-chairperson, as the prime contractor, and the Service Corrosion Prevention and Control Office, as corrosion prevention and control program managers will:

4.1.1 Organize the CPAT effort.

4.1.1.1 Establish and chair a CPAT to evaluate the adequacy of corrosion prevention/material compatibility measures included in the design, to review the program's approach to corrosion prevention, and to advise on corrosion prevention and control for inclusion in specifications and technical data.

4.1.1.1.1 Make sure the engineering effort conducted by the integrated product teams (IPTs) during design and fabrication focuses on the prevention and control of corrosion and the compatibility of composites/materials with the system operating environment. This will be done during the Technology Development, Systems Development and Demonstration (SDD), and Production and Demonstration phases.

4.1.1.1.2 Evaluate compliance with applicable standards, specifications, design handbooks, and related technical documentation.

4.1.1.1.2.1 Direct Contractor Corrosion Team (CCT) Quality Assurance members to conduct spot inspections during manufacturing to ensure manufacturing and fabrication processes do not include practices that would eventually cause corrosion and material degradation problems and to ensure approved techniques adopted by the air vehicle IPTs early in SDD are being followed.

4.1.1.1.2.2 Direct CCT Quality Control members to inspect preservation and packaging procedures at the contractor facilities of all materials being delivered to Air Force activities to ensure practices adopted by the IPTs are being followed.

4.1.1.1.3 To the extent they support structural requirements, use standard materials for weapon system sustainment for corrosion prevention.

4.1.1.1.4 Make sure each proposed redesign/modification is evaluated for potential corrosion, material, and environmental compatibility effects and requirements for the prevention and control of corrosion and material are addressed.

4.1.1.1.5 Interface with the chairperson of the major subsystem CPATs to ensure data exchange and resolution of mutual concerns.

4.1.1.1.6 Interface with all team members to ensure data exchange and incorporation of technical advancements into the system.

4.1.1.2 Make sure the results of testing to environments outlined in MIL-STD-810 are reviewed by the CPAT to identify future potential corrosion and material compatibility problems.

4.2 Service Program Office members will:

- Co-Chair the CPAT and assist the PM and user in tracking/resolving action items.
- Ensure the proper requirements for corrosion prevention and control are included in specifications, tailored standards, and procedures; cite newly approved materials in updating specification revisions, design handbooks, and technical data.
- Evaluate the CPCP to confirm it covers the proper steps for preventing corrosion and ensuring material compatibility.
- Identify and help solve corrosion and material compatibility problems in the design, maintenance, and use of the system.
- Periodically review and update technical data; send pertinent information to appropriate training organizations for use in training courses.
- Review modification proposals to ensure proper requirements for corrosion prevention and control are included.
- Review and validate Corrosion maintenance facility requirements documents.

4.3 User members will:

- Serve on the CPAT.
- Take part in contractor reviews and other actions to identify potential corrosion and material compatibility problems.
- Assist in the review of the contractor's effectiveness in preventing corrosion through the design, production, and sustainment phases of acquisition.
- Ensure recommendations for corrective actions or CPAT action items are submitted as early as possible and followed up.
- Ensure field-level support capabilities for corrosion prevention are evaluated by the CPAT.

4.4 Test and Evaluation Organization members will have same responsibilities for corrosion prevention and control as the user during testing and evaluation.

5.0 Procedure

The CPAT will:

5.1 Convene annually as a minimum or as often as required throughout the life cycle of this system at the times and places arranged by the chairperson. The interval will normally be semi-annually during the SDD phase, unless the chairperson determines that more or less frequent sessions are necessary.

5.2 Review corrosion prevention/material compatibility contract requirements and prepare the appropriate design guidance tailored to the unique aspects of this program.

5.3 Advise the CCT to conduct plant site inspections, as appropriate, at contractor and subcontractor facilities to evaluate the adequacy of the design as it relates to corrosion prevention, and to assess the manufacturing, fabrication, engineering liaison, and quality control procedures for corrosion prevention and materials compatibility.

5.4 Advise the CCT to conduct field site inspections at flight test/ground test, demonstration facilities, and operational facilities to evaluate the effectiveness of the corrosion prevention/material compatibility considerations/designs. Discrepancies will be defined and possible solutions proposed.

5.5 The lead contractor will prepare and distribute minutes (no more than 60 days after the date of the CPAT meeting), which assign action items to the responsible agencies for resolution. The lead contractor also will maintain a continuing agenda or log of specific efforts, problems, action items, discrepancies, etc., with the following for each item:

- Definition or description
- Alternatives
- Team recommendation
- Responsible action individual or agency
- Final disposition.

5.6 Make recommendations to the program manager for all changes, corrections, or improvements that require action by a government agency or a contractor.

Note: The CPAT has no authority to direct any government agency or contractor to take any action as a result of its finding. The chairperson will make clear the nonbinding advisory nature of the opinions, findings, suggestions, and recommendation of the team to all parties at all team meetings and activities.

Appendix C
Example of Corrosion Prevention and Control Plan for Facilities

This appendix provides an example of a Corrosion Prevention and Control Plan (CPCP), and is intended to be representative only. The contents of this appendix are not direction. The contents of a program's or project's actual CPCP will vary and should reflect the needs of the particular program/project.

1.0 Objectives

The primary goals of corrosion control planning are to develop and maintain dependable and long-lived structures, equipment, plants, and systems; conserve energy; reduce costs due to corrosion, scale, and microbiological fouling; and ensure compliance with Environmental Protection Agency, Department of Transportation, Occupational Safety and Health Administration, and other applicable regulations and guidance.

2.0 Scope

Corrosion control minimizes the effects of electrochemical or chemical attack on materials by the environment. Planning includes the following:

- Establishment of a corrosion prevention advisory team (CPAT)
- Establishment of a Contractor Corrosion Team (CCT)
- Corrosion control by design and materials selection
- Use of cathodic protection to eliminate electrochemical reactions (corrosion)
- Use of industrial water treatment to reduce corrosion, scale-forming deposits, and biological growths in heating and cooling systems
- Use of protective coatings to reduce atmospheric corrosion or cathodic protection current requirements
- Periodic analysis of logs and records for failure prediction and selection of corrective actions
- Incorporation of corrective actions in repair and construction projects when materials, design, construction, operation, or the environment cause corrosion, scale, or material deterioration.

3.0 Responsibilities

3.1 Air Force Responsibilities

3.1.1 *Headquarters Air Force Civil Engineer Support Agency*. The Air Force Civil Engineer Support Agency (AFCESA) oversees the Air Force's facility corrosion control planning in the Technical Support Directorate, Mechanical/Electrical Engineering Division (HQ AFCESA/CESM).

3.1.2 AFCESA assists HQ USAF (HQ AF/A7C) in formulating corrosion control policy.

3.1.3 AFCESA maintains Air Force corrosion control technical publications and coordination on tri-service technical publications. Develops technical standards, criteria, and procedures with Department of Defense staff elements and other federal agencies.

3.1.4 AFCESA provides specialized field assistance and consultation to Air Staff and major commands on special corrosion control problems, including designs, construction acceptance, and failure analysis.

3.1.5 AFCESA provides corrosion literature searches and delivers any publicly available, but difficult to find, engineering documentation. Through an agreement between HQ AFCESA and the Air Force Research Laboratory, Airbase and Environmental Technology Division (AFRL/MLQ), the Technical Information Center should be contacted for literature or documents. Contact information is:

Technical Information Center
AFRL/MLQ-TIC (FL 7050)
139 Barnes Drive, Ste 2
Tyndall AFB, FL 32403-5323
DSN 523-6285
(904) 283-6286 (fax)
DSN 523-6286 (fax)

3.1.6 AFCESA approves corrosion control methods and equipment not specified in Air Force publications.

3.1.7 AFCESA maintains a list of all corrosion points of contacts at the major command level to include full name, complete mailing address, DSN and commercial telephone and fax numbers, training received, and assigned corrosion duties.

3.1.8 AFCESA compiles each fiscal year a summary of funded projects justified all or in part by corrosion control and a summary of leak records. Catalogs and analyzes these data for trends.

3.2 Army Responsibilities

3.2.1 The Deputy Chief of Staff, G–4 (DCS, G–4) has responsibility for oversight and resourcing the Army CPC Program for fielded systems. The DCS, G–4 will:

a. Coordinate the CPC Program for fielded systems at Headquarters, Department of the Army (HQDA), and provide support to the CPC Program during design and production.

b. Designate a principal point of contact to direct HQDA-level CPC Program activities.

c. Develop, support and defend resources to initiate and sustain an effective Army CPC program.

d. Evaluate the program's effectiveness through routine field sampling and on-site visits.

3.2.2 The Assistant Secretary of the Army (Acquisition, Logistics and Technology) (ASA (ALT)) will:

a. Designate a principal point of contact to coordinate DA-level CPC Program activities with the Army and Department of Defense (DOD) staff, program executive offices (PEOs), U.S. Army Materiel Command (USAMC), and major Army Commands (MACOMs).

b. Designate the Commanding General, U.S. Army Materiel Command (CG, USAMC), as the Army CPC Program Manager.

c. Ensure that CPC is maintained in DA policy and guidance for management of the following:

   i) System acquisition and production.

   ii) Research, development, test, and evaluation (RDTE) programs and activities.

   iii) Equipment standardization programs, including international standardization agreements (STANAGs).

   iv) Logistics research and development initiatives.

   v) Logistics support analysis (LSA) as it relates to integrated logistic support (ILS) in the materiel acquisition process.

3.2.3 The Deputy Chief of Staff, G–1 (DCS, G–1) will:

a. Ensure that CPC requirements for materiel are reflected in DA policies for the formulation, management, and evaluation of personnel and programs for all components of the Army. Particular consideration should be given to:

   i) Personnel utilization and distribution.

   ii) Training and education of military and civilian personnel to develop CPC specialists.

b. Support MACOM CPC programs.

3.2.4 The Office of The Surgeon General (OTSG) will:

a. Ensure that CPC is a consideration in the following:
   i) Drafting of medical materiel requirements documents.
   ii) Direction, evaluation, and coordination of medical materiel.
   iii) Medical materiel maintenance programs.
   iv) Medical materiel life cycle management.
   v) Procurement, operation, and evaluation of all food service materiel and food and potable water contact surfaces.
   vi) Survey of medical materiel during command logistics review and logistics assistance visits.

b. Provide guidance to ensure Occupational Safety and Health Administration (OSHA) and Environmental Protection Agency (EPA) standards threshold-effect levels and regulations for human health and environmental protection are observed during corrosion control practices. This guidance is especially important since volatile organic compounds, heavy metals, and other toxic and pollutant materials are commonly used in corrosion control.

c. Ensure that CPC technologies recommended by the Army CPC Program Manager for use in new weapons systems designs or in sustainment procedures for fielded systems have undergone applicable toxicological clearance and approval test procedures to ensure human health and environmental protection.

3.2.5 The Commanding General, U.S. Army Materiel Command (CG, USAMC) has overall responsibility for planning and implementing the Army CPC Program. The CG, USAMC will:

a. Manage the CPC Program and implement primary program policy and establish the necessary policies, procedures, and techniques to effectively administer the program.

b. Establish a responsible official at HQAMC to oversee the Army CPC Program management.

c. Support and provide assistance to the USAMC major subordinate commands (MSCs) and depots in the establishment and implementation of their individual CPC programs, with resources and technical expertise.

d. Assure that CPC is considered in the following areas:
   i) System acquisition and production.
   ii) Research, development, test, and evaluation (RDTE) programs and activities.
   iii) Equipment standardization programs, including international standardization agreements (STANAGs).
   iv) Logistics research and development initiatives.

v) Logistics support analysis (LSA) as it relates to integrated logistic support (ILS) in the materiel acquisition process.

vi) Collection, distribution, and feedback of system test and equipment maintenance information relating corrosion.

3.2.6 The Commanding General, U.S. Army Training and Doctrine Command (CG, TRADOC) will:

a. Include corrosion and deterioration control considerations in the LSA process early in the materiel acquisition/development phase.

b. Include corrosion training (both initial and follow-on skill) for appropriate military and civilian storage/maintenance/supply and maintenance support/packaging specialists concerning the causes of corrosion, detection, and corrective and preventive measures. This training will include the proper packaging and preservation of unserviceable but repairable items of materiel being returned for maintenance.

c. Develop the curriculums for advanced individual training (AIT) of appropriate personnel in CPC as an expansion skill. These personnel can then become a more effective part of a system's maintenance team.

d. Ensure that appropriate course curriculums and training materials reflect the current CPC information available from USAMC as well as from industry and academia. Included in all corrosion training courses will be the necessary safety, health, and environmental requirements related to the technical content of the training being provided.

e. Disseminate training materials to all participating commands and furnish, on request, the following to:

Commander, USAMC, ATTN: AMCQPS–IEI
9301 Chapek Road
Fort Belvoir, VA 22060–5527:

i) Copies of CPC training materials.

ii) Subsequent major revisions that reflect the incorporation of additional or advanced technical corrosion data or the development of new corrosion courses.

f. Address CPC requirements in appropriate tables of organization and equipment (TOE) to identify skill levels for program implementation and management in the field.

g. Ensure compatibility with nuclear, biological, and chemical (NBC) contamination survivability for Army materiel, as described in AR 70–75.

3.2.7 The Commanding generals of major Army commands, Chief of the U.S. Army Reserve, and Chief of the National Guard Bureau will establish and maintain an effective command level program. Each commander/chief will (as applicable):

a. Appoint from internal sources a CPC manager with a technical background to administer the command-level program.

b. Ensure that all subordinate command activities understand and fulfill their responsibilities under the command program.

c. Program, budget, and fund for the personnel, facilities, and other resources needed to run the command program.

d. Develop a plan that will include corrosion-control-related tasks or projects proposed to support the CPC program.

e. Participate in and provide host support to USAMC survey teams based on survey schedules.

f. Propose and manage training for maintenance, storage, and technical personnel and ensure that their subsequent assignments are appropriate to make full use of this training.

g. Ensure that host–tenant agreements include funding for support and training in CPC, as appropriate.

h. Review and adjust the various periodic system inspection cycles based on operational and environmental factors, to prevent equipment deficiencies due to corrosion.

i. Ensure that the CPC Program complies with Environmental Protection Agency and Occupational Safety and Health Administration standards.

j. Review subordinate command publications that implement the program.

k. Recommend changes to publications, such as technical manuals (TMs), technical bulletins (TBs), and service supportability standards (SSS) to clarify delineation of corrosion duties for the operator/crew, field, and sustainment maintenance.

l. Ensure that Army equipment operators and maintenance personnel in the field are motivated and trained to identify and report corrosion and recognize the importance of employing prescribed corrosion control practices.

m. Ensure that deficiency reports: SF 368 (Product Quality Deficiency Report), SF 364 (Report of Discrepancy (ROD)), and DD Form 1225 (Storage Quality Control Report) on systems and equipment involving corrosion are submitted as specified in DA Pam 750–8, DA Pam 738–751, and AR 735–11–2. A copy of the command survey report should be provided to the appropriate MACOM CPC manager for assignment and subsequent resolution, action, and feedback by the appropriate USAMC major subordinate command (MSC).

n. Participate in the USAMC command surveys. These officials will assist in determining areas that require improved corrosion control and recommend evaluation of specific systems, equipment, or components susceptible to corrosion damage. They will propose action to USAMC, act on assigned action items, and submit quarterly status reports to USAMC until USAMC determines the action complete.

3.2.8 The Commanding General, U.S. Army Tank-automotive and Armaments Command (CG, TACOM) has overall staff responsibility for planning and implementing the Army CPC Program. The CG, TACOM will:

a. Appoint a functional manager for the CPC Program and, on the basis of guidance from the USAMC responsible official, implement Army program policy.

b. Establish a CPC program office to administer the Army CPC Program.

c. Support and provide assistance to the USAMC major subordinate commands (MSCs) and depots in the establishment and implementation of their individual CPC Programs, with resources and technical expertise.

d. Assure that CPC is considered in the following areas:

   i) Collection, distribution, and feedback of system test and equipment maintenance information relating to corrosion, including the following:

      (a) Test incident reports (TIRs).

      (b) SF 364, Report of Discrepancy (ROD).

      (c) SF 368, Product Quality Deficiency Report.

      (d) Logistic Assistance Office (LAO)/Logistic Assistance Representative (LAR) reports.

      (e) Technical field reports (TFR).

      (f) Fielded system reviews (FSR).

      (g) Equipment report of discrepancy (ROD).

      (h) Development test and operation test data (DT/OT).

      (i) DD Form 1225, Storage Quality Control Report.

      (j) Logistic support analysis records (LSARs).

      (k) Sample data collection (SDC) reports.

   ii) Weapons system and ground support equipment acquisition, recapitalization, remanufacture, overhaul, and/or product improvement, including the evaluation of each proposal for a new system, equipment, or component.

   iii) Manufacturing technology and related programs.

   iv) Funded research and development programs.

   v) Administration of system programs or projects by the program or project managers.

   vi) Testing and evaluation on the equipment, processes, and application techniques within the assigned areas of responsibility. (This specifically includes nondestructive testing and evaluation (NDT/NDE) of commercial material, equipment, or processes.)

   vii) Acquisition of nondevelopmental items, equipment, and systems.

   viii) Care of supplies in storage, including preservation, packaging and exercising requirements.

e. Provide information to and support the weapons systems managers.

f. Establish and maintain the Center of Excellence for CPC in cooperation with the MSCs.

g. Develop and provide corrosion training concerning the causes of corrosion, detection, consequences, and corrective and preventive measures, for appropriate personnel involved in the design acquisition and maintenance of Army materiel.

h. Assure that CPC technical information for Army materiel will include necessary safety, health, and environmental protection requirements.

3.3 Navy Responsibilities

3.3.1 Commanders/Commanding Officers should take appropriate actions to minimize corrosion damage and to insure maximum readiness of shore facilities. Support in surveying and identifying CPC systems installed and determining operation and maintenance requirements may be obtained from the NFESC CPC Subject Matter Experts (SME) or NAVFAC Echelon III CPC program managers on a reimbursable basis. NAVFAC Echelon III CPC program managers and the NFESC can assist with the conduct of CP and coating surveys, CPC design reviews, CPC system maintenance and the commissioning of new CP systems on a reimbursable basis.

3.3.2 Activities, Regional Commanders, and Facilities Engineering Commands

a. Revise or establish local instructions/business processes to insure that CPC is effectively established and maintained at the activity level.

b. Analyze facilities, structures and systems for signs of corrosion necessitating some form of corrosion control.

c. Notify the local NAVFAC component and Regional Commanders of corrosion control problems and the need for assistance.

3.3.3 Planning Community

Include corrosion prevention and control requirements as a separate line item in project documentation for the construction of new or the repair/upgrade of existing metallic structures. Include CPC narratives and cost estimates on DD Form 1391 under supporting utilities. Coordinate CPC requirements with the activity corrosion control plan to establish and ensure compatibility with existing systems. The CPAT and/or cognizant NFESC CP SME and NAVFAC Echelon III CPC program manager can assist in determining the system requirements. The CPC requirement must not be eliminated from any project unless approved by the CPAT.

3.3.4 Design Community

Navy engineers and architects in charge of design (EIC/AIC) should ensure that project designs include appropriate corrosion prevention and control measures to comply with appropriate statutes and criteria listed in the annex to this Appendix. Design CPC systems for maintainability. The design of CPC can be a complex technology, and if application problems or other technical questions arise, contact the CPAT and/or NFESC CPC SMEs and NAVFAC Echelon III CPC program manager.

3.3.5 Construction Community. The Navy Facilities Engineering Command and Resident Officer in Charge of Construction (FEAD/ROICC) should:

a. Conduct quality assurance evaluations of the contractor and ensure as-built drawings provide the location of all CPC system equipment, test points, etc. Conduct quality assurance evaluations of the contractors protective coatings surface preparation procedures, coatings materials, and coatings applications procedures.

b. Observe acceptance tests of the CPC systems to ensure they comply with procedures specified in the contract documents. In the absence of a qualified CPC inspector obtain assistance from the CPAT, NFESC CPC SMEs, or NAVFAC Echelon III CPC program manager.

3.3.6 Operation and Maintenance.

Inspect and maintain CPC systems according to appropriate operation and maintenance criteria manuals, Operation and Maintenance Support Information (OMSI) or other specific maintenance manuals; and cognizant NAFAC Echelon III requirements.

3.3.7 NAVFAC Echelon III, NFESC, and Facilities Engineering Commands.

Qualified personnel at these NAVFAC component commands can provide CPAT assistance to activities/regions.

a. Serve as members of or assist CPATs. Assist with the preparation and review of projects for correcting existing corrosion problems or avoiding future corrosion damage. Review designs for CPC technical adequacy.

b. Provide technical assistance during the installation and commissioning of CPC systems or application of CPC measures. Assist the activity in developing maintenance and operation plans to insure that the CPC systems remain effective.

c. Monitor the performance of CPC systems by evaluating records of their performance.

3.3.8 Naval Facilities Engineering Service Center is assigned Navy-Wide Specialized Expertise for Corrosion Prevention Control and can assist in the following:

a. Serve as members of or assist CPATs. Assist with the preparation and review of projects for correcting existing corrosion problems or avoiding future corrosion damage. Review designs for CPC technical adequacy.

b. Provide technical assistance during the installation and commissioning of CPC systems or application of CPC measures. Assist the activity in developing maintenance and operation plans to insure that the CPC systems remain effective.

c. Provide direct technical assistance to the Commander Navy Infrastructure, Navy Regional Commanders, activities and NAVFAC component offices in the investigation of corrosion problems and the development of plans for remedial action.

d. Prepare, review, and update CPC instructions, manuals, specifications and criteria.

e. Assist in the development of training courses and presentation of training programs for activity personnel involved in CPC.

3.3.9 NAVFAC Headquarters.

a. Establishes CPC policy.

b. Provides CPC program oversight.

c. Provides CPC program budget guidance.

3.4 [Major Commands][Regions][Regions]

3.4.1 [Major command civil engineers][Regions][Regions] assist installations and bases in developing and executing corrosion control planning (including aqueous, atmospheric, and underground corrosion) to ensure compliance with Department of Defense and service policy; Environmental Protection Agency, Department of Transportation, and Occupational Safety and Health Administration regulations; and local (including host country) requirements.

3.4.2 [Major command civil engineers][Regions][Regions], or their designated representatives, assign the office of primary responsibility for the planning. Appoint command corrosion engineers to act as the overall focal point in all corrosion control–related matters. Appoint staff engineers as required to work with the command corrosion engineers as technical consultants in the three major areas of corrosion control: cathodic protection, industrial water treatment, and protective coatings.

3.4.3 [Major command civil engineers][Regions][Regions], or their designated representatives, provide installations with technical assistance and guidance on corrosion control. Develop a major command training policy for corrosion control to support budget requests. Past experience indicates some type of annual contact with others involved in corrosion control maintains interest, allows networking on day-to-day problems, and cross-feeds new approaches and solutions. This is significant as most corrosion control positions are one-deep.

3.4.4 [Major command civil engineers][Regions][Regions], or their designated representatives, regard corrosion control as a functional design requirement of all facilities exposed to the environment. Ensure data and justifications are part of each project. This applies to all phases, from planning, project definition, and programming through design and construction to final acceptance. Programming documents should include environmental and safety factors and associated costs. Ensure key corrosion control features of projects have separate design documentation, including drawings, specifications, and design analyses.

3.4.5 [Major command civil engineers][Regions][Regions], or their designated representatives, ensure completion of designs, design reviews, and construction inspection by qualified individuals according to major command policy for Military Construction Program and Operations and Maintenance projects. Past experience indicates design qualifications should include recognition by professional organizations, such as NACE International, or state registration authorities, or 5 years of experience in design and maintenance of the corrosion control measures under review. Consult headquarters, e.g., AFCESA or IMA, for review support when necessary.

3.5 Corrosion Prevention Advisory Team (CPAT)

3.5.1 The CPAT ensures design according to publications referenced in Annex 1 to this appendix.

3.5.1.1 Accomplishes surveys and design before construction contract advertisement or before construction in design-build contracts.

3.5.1.2 Ensures designer or design reviewer meets qualifications according to major command policy for design of corrosion control measures. For example, an experienced NACE International accredited corrosion specialist, NACE International–certified cathodic protection specialist, or a registered professional corrosion engineer accredited or registered in cathodic protection should perform contracted cathodic protection surveys and designs.

3.5.2 CPAT does not delete corrosion control measures from any design without the specific approval of the designer of record and the command corrosion engineer.

3.5.3 CPAT coordinates with the command corrosion engineer and the base corrosion control engineer during preliminary design. This coordination ensures compatibility of design with existing corrosion control systems and maintenance of successful techniques within craftspersons' capability. Installation personnel approve the updating of systems and equipment per designer's recommendations.

3.5.4 CPAT performs failure analysis for replacement projects that did not achieve life expectancy. Ensure complete understanding of the failure and include procedures in the specifications to prevent recurrence. This analysis shall be part of the preliminary design submittals.

3.5.5 CPAT coordinates among design team members to ensure material selections and system designs are compatible with the corrosion control approach selected.

3.5.6 CPAT does not allow the construction contractor to continue with any work until approval of the corrosion control system shop drawings. The technical reviewer, usually the contracting officer's technical representative, shall be knowledgeable in the installation of the corrosion control systems.

3.5.7 CPAT ensures the contractor notifies the contracting officer a minimum of 24 hours prior to installation, testing, or final acceptance of corrosion control systems.

3.5.8 CPAT ensures the construction inspector understands the corrosion control system installation or involves the base corrosion control engineer or craftsperson as technical advisor. This involvement includes construction surveillance during installation, testing, and final acceptance. If the construction agent cannot ensure the presence of an in-house inspector during cathodic protection work, the construction agent will use Title II, Construction Inspection Services, to obtain a full-time qualified inspector.

3.5.9 CPAT ensures the specifications contain acceptance testing to ensure achievement of design criteria and the contractor performs this acceptance testing with installation representatives in attendance.

3.5.10 As-built drawings shall provide the location of corrosion control system equipment, testing points, sampling points, and items requiring periodic maintenance.

3.5.11 CPAT uses field surveys, field tests, and experience of installation personnel in the design.

3.5.12 CPAT specifies the testing necessary for the final acceptance of the corrosion control system. Target values of system operating parameters will be part of this testing to ensure the facility will function within design limits. Ensure the acceptance testing protocol includes procedures if acceptance testing differs from target values. Consult operations personnel, equipment manufacturers, and the construction contractor to determine solutions and set new equipment operating points.

3.5.13 CPAT incorporates operability and maintainability into the overall design of the corrosion control systems. Designs will provide minimum life-cycle cost over the facility life expectancy.

3.5.14 CPAT provides detailed calculations and one-line diagrams at the preliminary design stage to show the magnitude and layout of the corrosion control system. For example, validate the use of pre-engineered tanks with factory installed cathodic protection through appropriate calculations and field tests.

3.5.15 CPAT provides corrosion control system drawings to show location of equipment, test points, sampling points, potential cathodic protection interference, items requiring periodic maintenance, and installation details.

3.5.16 CPAT ensures appropriately qualified and trained personnel develop and execute a comprehensive corrosion control planning, encompassing the three areas of corrosion control. Ensure compliance with applicable Federal, state, local, and host nation laws and regulations, particularly those related to public safety and environmental protection. The planning will include applying and maintaining effective corrosion control methods in design, operations and maintenance, quality assurance, and acceptance testing.

3.5.17 CPAT publishes a [squadron][installation][base] operating instruction for corrosion control planning. Ensure civil engineer [squadron][installation][base] craftspersons receive annual training on the requirements of the [squadron][installation][base] operating instruction.

3.5.18 CPAT develops and manages the [base][installation] corrosion control planning.

3.5.19 CPAT assists programmers in narrative and cost estimates for corrosion control line items on DD Forms 1391, Military Construction Project Data Sheets.

3.5.20 CPAT participates in project design and design review related to corrosion control. Sign all project drawings when corrosion control measures, operability, and maintainability are adequate.

3.5.21 CPAT provides technical advice to the construction inspector during installation, testing, and final acceptance of corrosion control systems.

3.5.22 CPAT coordinates operations and maintenance of corrosion control systems with the operations unit, including preventive maintenance scheduling. Ensure control charts for industrial water treatment detail the frequency and actions for testing and adjustment of each system.

3.5.23 CPAT reviews corrosion control records and takes action to correct deficiencies.

3.5.24 CPAT investigate leaks from corrosion, tuberculation, and scaling in heating and cooling systems, and premature failure of protective coatings. Take corrective action in each case, other than simple repair by replacement.

3.6 The Contractor Corrosion Team (CCT)

3.6.1 The CCT ensures adequate corrosion prevention and control requirements are being implemented in accordance with the project contract, plans, and specifications.

3.6.2 The CCT ensures the implementation of corrosion prevention and control is documented and that documents are submitted in accordance with the required schedule.

3.6.3 The CCT establishes periodic meetings, as required, to resolve problems as they occur. Other meetings should be convened should a critical or major problem arise which requires action by the CCT or CPAT.

3.6.4 The CCT notifies all DoD and contractor members of each meeting date, the topics to be discussed, and any decisions resulting from the previous meeting.

3.6.5 The chairperson or his designees should sign off on all construction drawings after review of materials selection, treatments, and coatings.

3.6.6 The chairperson will maintain a continuing record of all action items and their resolutions.

4.0 Requirements

4.1 *Environmental*. Consult [AFPD 32-70, *Environmental Quality*][AR 200-1, *Environmental Protection and Enhancement*], and associated [Air Force][Army][Navy] instructions [(AFIs)][(AIs)][(NIs)] to understand the impact of corrosion and corrosion control activities on the environment.

4.1.1 The primary environmental impact of cathodic protection is in the prevention of petroleum, oil, and lubricant corrosion-induced leakage into the environment from underground and on-ground tanks and underground piping. Cathodic protection is already a requirement on new tank installations. The goal is to prevent all notices of violation due to corrosion. Ensure compliance with [AFI 32-7044, *Storage Tank Compliance*][DA Pam 200-1, *Environmental Protection and Enhancement*][…]; Title 40, Code of Federal Regulations, Part 280; and applicable state and local requirements.

4.1.2 The primary environmental concern of industrial water treatment is the proper disposal of chemically treated water. Consult [AFI 32-1067, *Water Systems*][DA Pam 200-1, *Environmental*

Protection and Enhancement][…]. Also consult environmental engineering and bioenvironmental engineering prior to selecting any industrial water treatment chemical.

4.1.3 The following environmental laws apply to industrial water treatment. Consult with bioenvironmental engineering and environmental engineering to determine methods of compliance with laws and local practices.

4.1.3.1 *Toxic Substances Control Act* (15 U.S.C. 2601) authorizes the U.S. Environmental Protection Agency to control existing and new chemical substances determined to cause unreasonable risk to the public health or environment.

4.1.3.2 *Clean Water Act* (33 U.S.C. 1251) includes the *Federal Water Pollution Control Act* and amendments. This act establishes limits for the discharge of pollutants to navigable waters, regulations on specific toxic pollutants in wastewater discharges, and control of oil and hazardous substance discharges.

4.1.3.3 *Safe Drinking Water Act* (42 U.S.C. 300) provides for protection of underground sources of drinking water and establishes primary and secondary drinking water standards.

4.1.3.4 *Federal* Insecticide*, Fungicide, and Rodenticide Act* (7 U.S.C. 136-136y) requires the U.S. Environmental Protection Agency to register all pesticides.

4.1.3.5 *Resource Conservation and Recovery Act* (42 U.S.C. 690) addresses the control of solid and hazardous waste. The act defines hazardous waste and controls it by a complex manifest system designed to track a waste from its generation to final disposal.

4.1.3.6 *Comprehensive Environmental Response, Compensation, and Liability Act* (42 U.S.C. 9601), also commonly referred to as “Superfund,” defines procedures for responding to existing uncontrolled hazardous waste sites, establishes the National Priorities List and the National Contingency Plan, and requires the reporting of hazardous substance releases into the air, land, and water.

4.1.3.7 *Clean Air Act* (42 U.S.C. 7401) regulates air emissions from stationary and mobile sources to protect public health and welfare. State and local governments have the primary responsibility to prevent and control air pollution.

4.1.4 Do not use chromates in any industrial water treatment application.

4.1.5 The environmental concerns of protective coatings center upon metal content in the dried paint and volatile organic compounds that evaporate from solvent-based paint.

4.1.5.1 Lead-containing paint has a lead content of more than 0.06 percent lead by weight (calculated as lead metal) in the total nonvolatile content of liquid paint or in the dried film of the paint already applied. Do not use lead-containing paint on any Army, Navy or Air Force facility. Note that nonlead-containing paint must still pass a Toxicity Characteristic Leaching Potential Test or be considered hazardous waste during disposal.

4.1.5.2 The U.S. Environmental Protection Agency restricted the use of mercury-containing fungicides in solvent-thinned, oil-based paint. Exterior water-thinned paints may contain a maximum of 0.2 percent mercury (calculated as metal) in the total weight of the paint. Clear markings indicating the mercury content must be on the container. The U.S. Environmental Protection Agency banned the use of mercury in interior paint applications.

4.1.5.3 The U.S. Environmental Protection Agency identified six major pollutants that may harm the public health and welfare. Ozone is one of these pollutants. Since the presence of Volatile Organic Compounds (photochemically reactive solvents) in the air directly relate to the ozone concentration in the air, VOC's used in the drying and curing of coatings have an environmental impact. National VOC limits have been set by EPA but may also be more stringent in impacted regions of the country and/or vary by end-use surface coating operation.

4.2 *Safety*. Consult [AFPD 91-2, *Safety Programs* and AFPD 91-3, *Occupational Safety and Health*][AR 385-10, *The Army Safety Program*][…] as well as their associated instructions, for guidance to minimize the risk of corrosion and corrosion control activities on facility and worker safety.

4.2.1 For cathodic protection, consult [AFI 32-1064, *Electrical Safe Practices*][DA TM 5-682, *Facilities Engineering: Electrical Facilities Safety*][…]. The Department of Transportation regulates flammable utilities. The *Natural Gas Pipeline Safety Act of 1968*, as amended, and the *Hazardous Liquid Pipeline Safety Act of 1979*, as amended, provide the minimum criteria to ensure safe operation.

4.2.2 Many of the chemicals used to treat industrial water may be harmful to the health of the operator and other base personnel. They range from highly toxic to mildly irritating to the persons handling them. Handle water treatment and testing chemicals with care, following guidance in Occupational Safety and Health Administration directives, manufacturer's recommendations, and the material safety data sheets. Install eye wash stations and safety showers according to ground safety requirements. Consult with unit safety, bioenvironmental engineering, and environmental engineering on potential safety issues and the use of less hazardous substitutes.

4.2.2.1 A cross-connection is a physical connection between a potable water supply system and a non-potable system (such as an industrial water system) through which contaminated water can enter the potable water system. Consult [AFI 32-1066, *Plumbing Systems*][DA TI 814-10, *Wastewater Collection*][…]. Permit only Class III backflow prevention devices (air gap or reduced pressure principle) to provide makeup from a potable water system to an industrial water treatment system.

4.2.2.2 Morpholine, cyclohexylamine, and similar chemicals added to protect condensate lines from corrosion make the steam and condensate unfit for consumption or other uses normally reserved for potable water. Do not use treated steam in direct contact with food or for any direct steam humidification, such as in a gymnasium steam room or humidity control for electronic equipment.

4.2.3 Most paint and protective coatings are hazardous to some degree. All, except water-thinned paints, are flammable; many are toxic; and others can irritate the skin. By following simple precautions, most paints are quite safe during application. Surface preparation also has intrinsic hazards. For example, sandblasting operations generate clouds of blasting media, paint, and substrate material. Dry sanding on lead-containing paint and on certain types of non-lead-containing paint can generate excessive amounts of airborne lead dust. The Occupational Safety and Health Administration controls the permissible exposure limit of these airborne particulates and the personal protective equipment required. Consult unit safety and bioenvironmental engineering for specific information.

4.3 Design

4.3.1 Design, construction, and application of cathodic protection, industrial water treatment, and protective coatings are functional requirements for almost all projects. Designs shall achieve the minimum life cycle cost for the overall facility. [Base][Installation] personnel must be able to operate and maintain the final facility design, including the corrosion control systems, without extensive training or equipment investment, unless this is the best approach to achieve minimum life cycle cost.

4.3.2 Corrosion resistance is not the only criterion for material selection. When selecting a material, investigate all aspects of its physical properties in the application environment, during both normal operation and typical system failure.

4.3.3 Clearly and distinctly document corrosion experience for future reference. This experience should refer to design, material selection, selection of corrosion control technique, or decisions of no requirement for corrosion control. Document all design and selection decisions in project design analyses. Pass this information to the operations and maintenance elements to assist future decisions.

4.3.4 Revisit the design and selection decisions when a system malfunctions or leaks due to corrosion, scaling, or premature failure of the corrosion control system. This is especially important for the rare case when a designer justified no corrosion control being needed.

4.3.5 Ensure new or supplemental corrosion control systems are compatible with existing systems. The construction contractor shall not select the warranty period industrial water treatment.

4.3.6 Construct pipelines in a manner that facilitates use of in-line inspection tools.

4.3.7 Cathodic protection and coatings work together. Ensure these items are part of the design. Do not design submerged or buried coated metallic facilities without cathodic protection and do not design cathodic protection on bare metallic facilities. Recommend fiberglass-clad underground storage tanks be installed with galvanic anodes. This recommendation is made even though many such tanks are EPA-approved for installation without cathodic protection.

4.3.8 Do not use unbonded coatings, such as loose polyethylene wraps. Use of unbonded coatings is a direct violation of Department of Transportation regulations and Air Force, Army and Navy criteria for pipelines.

4.3.9 Provide both cathodic protection and protective coatings for buried or submerged metallic facilities, regardless of soil or water corrosivity, when the facility:

a. Carries flammable product
b. Is mission critical
c. Would be expensive to maintain
d. Would waste energy or impact the environment if corroded
e. Requires corrosion control as identified by major command

4.3.10 For other buried utilities, generally provide cathodic protection and protective coatings if the soil resistivity is below 10,000 ohm-centimeters. Follow the documented recommendations of a qualified corrosion engineer when the soil resistivity is above 10,000 ohm-centimeters. The Army requires cathodic protection regardless of soil resistivity.

4.3.11 Provide both cathodic protection and protective coatings for the following aboveground tanks based upon qualified analysis:

4.3.11.1 All ferrous tanks in contact with the earth, unless built on an oil-filled sand pad with plastic liner underneath.

4.3.11.2 Interiors of steel water distribution storage tanks.

4.3.12 Consider the need for lightning and fault current protection at isolating devices (dielectrically insulated unions and flanges) when designing cathodic protection systems. Consult [AFI 32-1065, *Grounding Systems*][DA TM 5-811-3, *Electrical Design–Lightning and Static Electricity Protection*][…].

4.3.13 Installed cathodic protection systems shall provide protective potentials meeting criteria in NACE International Standard SP0169, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*, Section 6, *Criteria and Other Considerations for Cathodic Protection*. Structure-to-soil potentials are to be potential drop (current times resistance) free.

4.3.14 Special conditions sometimes exist where cathodic protection is ineffective or only partially effective. Corrosion personnel may deviate from this instruction after documenting the achievement of objectives and receiving command corrosion engineer approval.

4.3.15 Industrial water treatment designs or decisions begin with an analysis of the system makeup water. Consult bioenvironmental engineering and [AFI 48-119, *Medical Service Environmental Quality Programs*][…][…] for sampling potable water sources that feed industrial systems. Use [AF Form 2752A, *Environmental Sampling Data*][…][…], for complete analyses to identify the quantity and relationship of water constituents for industrial water treatment purposes.

4.3.16 Acceptance testing of new heating and cooling systems will ensure the industrial water treatment system meets design and operation parameters. Boiler steam purity tests will determine total dissolved solids limits. Correlate the total dissolved solids level selected for boiler operation to the conductivity reading of a typical sample. The Water or Wastewater Laboratory at associated plants or

[Base Supply's Fuels Laboratory][…][…] usually can measure total dissolved solids using American Society for Testing and Materials standard methods. Verify the selected condensate treatment meets design parameters by testing for copper, iron, and pH at near, medium, and far points from the boiler throughout the system.

4.3.17 Indicate locations to install corrosion coupon racks following American Society For Testing and Materials *Standard Test Methods for Corrosivity of Water in Absence of Heat Transfer (Weight Loss Methods*), D26888-92, Test Method B. The coupons are the best confirmation of industrial water treatment effectiveness.

4.3.18 Do not use nonchemical industrial water treatment devices on Army, Navy and Air Force systems either regularly or on a test evaluation basis except as indicated below. This includes the Management and Equipment Evaluation Program.

4.3.18.1 Basic research and application development of nonchemical industrial water treatment devices has been underway since before 1935. However, many variables affect performance, and no criteria and standards have been developed which may be incorporated into guide specifications or statements of work. Such criteria and standards are necessary for standard Army, Navy and Air Force contracting methods to ensure devices will perform as advertised. In addition, because of downsizing and outsourcing, the technical capability to perform installation-specific test evaluations is not available at installation level.

4.3.18.2 Battelle Memorial Institute is researching applications of nonchemical industrial water treatment under the Department of Energy's Federal Energy Management Program. Various energy services companies (ESCOs) are investigating use of these devices for energy and water conservation measures under Energy Savings Performance Contracting (ESPC). Under ESPC, the ESCO provides guaranteed savings that are validated each year to reconcile payments, using an agreed-upon measurement and verification methodology. Because the ESCO has the responsibility for measuring and verifying performance, problems cited in paragraph 4.3.18.1 are overcome. Currently, HQ AFCESA/CESM is developing measurement and verification standards to allow nonchemical devices to be available for use under ESPC.

4.3.19 Light-reflective floor coatings include chemically resistant urethane for existing hangar floors and dry shake metallic floor topping applied to the top layer of freshly poured concrete for new floors. Ensure electrostatic discharge and slip resistance are part of the design. Include the daily cleaning requirements to cover equipment, supplies, and frequency as part of the maintenance instructions provided to the using agency.

4.3.20 Avoid using chemical strippers. If specified, perform effectiveness tests prior to award of any contract. This is especially necessary for removing lead-based paint from wood. Also, specify procedures to confirm neutralization of alkaline paint stripper through chemical testing. Alkaline residue left on the substrate is a recurring paint failure mechanism.

4.4 Maintenance

4.4.1 Perform routine maintenance checks, surveys, and inspections of cathodic protection, industrial water treatment, and protective coating systems. Each installation must have the basic equipment and training to perform tests and measurements of installed corrosion control systems.

Consult associated manuals and tables of allowances for the minimum required field inspection instruments.

4.4.2 Investigate when corrosion control actions do not achieve results. This information provides the basis for selecting corrective actions and ensuring future projects do not continue the same problems.

4.4.3 Select and apply methods for determining voltage drops during cathodic protection testing using sound engineering practices, such as contained in NACE International Technical Report 10A190, *Measurement Techniques Related to Criteria for Cathodic Protection of Underground or Submerged Steel Piping Systems* (see Annex 1).

4.4.4 Cathodic protection situations involving stray currents and stray electrical gradients require special analysis. For additional information, see UFC 3-570-06, O&M: Cathodic Protection Systems, and NACE International Standard SP0169, Section 9, Control of Interference Currents.

4.4.5 Industrial water treatment requires testing at a frequency that ensures the prevention of scale, corrosion, and biological formation in the heating and cooling systems. The time between testing depends on system integrity and operations. A mechanically sound system will require less frequent testing as less chemical leaves the system over time.

4.4.6 Develop and post, in appropriate locations, control charts for each boiler, cooling tower, and closed system showing the treatment chemicals used, the amount to add per operating parameter, the testing required, the limits to maintain in the system, what to do if the chemical levels are above or below the limits, and any other information peculiar to the system.

4.4.7 Perform periodic surveys to ensure effective industrial water treatment.

4.4.7.1 Annually check the capacity of ion exchangers. Do not rely on a timed regeneration cycle.

4.4.7.2 Once at the start of heating season and once at the end of heating season, test the condensate throughout the return system to identify potable water leakage into the condensate return system at heat exchangers. This identifies leaks at the earliest stages.

4.4.7.3 When adding or deleting buildings to a steam system or significantly changing industrial water treatment chemicals, perform the design acceptance tests for the boiler total dissolved solids limit and verify the total protection of the condensate return system.

5.0 Operation, Maintenance, and Recordkeeping

Corrosion control logs and reports are valuable in any failure analysis when problems arise. They provide the facts to make decisions. They also provide managers the status of the systems and the ability to make incremental improvements to achieve the expected life cycle of facilities, equipment, and piping. The goal is to solve the small problems at the operational level before they become so large that a major project is the only solution.

5.1 Cathodic protection recordkeeping, using prescribed forms as explained in UFC 3-570-06, includes the following:

5.1.1 Initial close interval, anode bed, and annual corrosion surveys of installed impressed current and sacrificial systems. Use [AF Form 491, *Cathodic Protection Operating Log for Impressed Current Systems*; AF Form 1686, *Cathodic Protection Operating Log for Sacrificial Anode System*; and AF Form 1688, *Annual Cathodic Protection Performance Survey*][…][…] to record these tests.

5.1.2 Impressed current system checks every 60 days. Use [AF Form 491][…][…] to record these checks.

5.1.3 Initial and annual water tank calibrations of installed systems. Use [AF Form 1689, *Water Tank Calibration*][…][…] to record these tests.

5.1.4 Annual update of the Cathodic Protection Annual Performance Booklet, sent to major command. For the National Guard, booklets will be maintained at the installation and made available upon request.

5.1.5 Use the information captured on [AF Form 1687, *Leak/Failure Data Record*][…][…] to provide justification for system repair or replacement, for installation of corrosion control measures, and for the project narrative on DD Forms 1391. Consult [AFI 32-1069, *Gas Supply and Distribution*][DA TM 5-653 *Steam, Hot Water, and Gas Distribution Systems: Inspection and Preventive Maintenance Service*][…]; UFC 3-230-02, *Operation and Maintenance of Water Supply Systems*; and UFC 3-460-01, *Petroleum Fuel Facilities*, for leak detection and survey requirements on these systems.

5.2 Industrial water treatment records should reflect the minimum entries needed to effectively manage the control of the industrial water treatment program and indicate the need for additional testing. Treatment, testing and reporting procedures are addressed by UFC 3-240-13FN, *Operations and Maintenance: Industrial Water Treatment*. The reverse of prescribed forms explains their use. Associated recordkeeping includes the following:

5.2.1 Accomplish industrial water treatment operating logs based upon one log for each individually treated system (each boiler, each cooling tower bank, and each closed system).

5.2.2 Use [AF Form 1457, Water Treatment Operating Log for Cooling Tower Systems][DA Form 4141, Facilities Engineering Operating Log (Water–General)][…] as a minimum.

5.2.3 Use [AF Form 1459, Water Treatment Operating Log for Steam and Hot Water Boilers][DA TM 5-650, Central Boiler Plants][…] as a minimum.

5.2.4 Keep other industrial water system records on modifications of these forms or a log developed locally for the specific tests required.

5.2.5 Keep the maintenance and history of industrial water treatment, other than that contained in the logs, in a historical record for each system. This book should contain a record (including dates) of occurrences of corrosion and scale, major maintenance and surveys performed on the system, replacements of piping and equipment, accidents, outages, changes in methods of operation and treatment used, and other pertinent data to assist troubleshooting and provide facts for management decisions on process improvement.

5.2.6 Use [AF Form 3222, *Centrifugal/Reciprocating Operating Log*, and AF Form 3221, *Absorption Operating Log*][…][…] to evaluate the mechanical aspects of the equipment and determine the efficiency of the Industrial Waste Treatment (IWT) program.

5.3 Maintain records following MIL HDBK 1110/1, *Paints and Protective Coatings*. Perform evaluations using these records after any paint failure and before any protective coatings contract. These records replace undocumented hearsay experience and allow fact-based decisions with costs and verified life expectancies of completed work to determine the following:

5.3.1 Effectiveness of a particular paint system on different surfaces or in varying environments.

5.3.2 Comparison of different paint systems under similar conditions.

5.3.3 Comparison of different equipment for surface preparation or application.

5.3.4 Frequency of spot painting and repainting.

6.0 Forms Prescribed

6.1 The required forms were listed in the text and in Annex 1.

Annex 1 to Appendix C: Glossary of References and Supporting Information

References

Public Laws

Title 10, U.S.C 2228

Clean Air Act, Title 42, U.S.C., Section 7401

Clean Water Act, Title 33, U.S.C., Section 1251

Comprehensive Environmental Response, Compensation, and Liability Act, Title 42, U.S.C., Section 9601

Federal Insecticide, Fungicide, and Rodenticide Act, Title 7, U.S.C., Section 136-136y

Hazardous Liquid Pipeline Safety Act of 1979, Public Law 96-129, title II, 30 Nov 79, 93 Stat. 1003, (49 U.S.C. 1811, 2001 et. seq.), as amended

Natural Gas Pipeline Safety Act of 1968, Public Law 90-481, 12 Aug 68, 82 Stat 720 (49 U.S.C. 1671 et. seq.), as amended

Resource Conservation and Recovery Act, Title 42, U.S.C., Section 690

Safe Drinking Water Act, Title 42, U.S.C., Section 300

Technical Standards and Corrective Action Requirements for Owners and Operators of Underground

Storage Tanks (UST), Title 40, Code of Federal Regulations (CFR), Part 280, Environmental Protection Agency

Toxic Substances Control Act, Title 15, U.S.C., Section 2601

DoD Publications

Department of Defense Corrosion Website

www.corrdefense.org

Unified Facilities Criteria

UFC 3-190-06, Paints and Protective Coatings

UFC 3-230-02, Operations and Maintenance of Water Supply Systems, July 2001

UFC 3-240-13FN, Operations and Maintenance: Industrial Water Treatment, May 2005

UFC 3-460-01, Design: Petroleum Fuel Facilities, January 2004

UFC 3-570-02A, Cathodic Protection

UFC 3-570-02N, Electrical Engineering, Cathodic Protection

UFC 3-570-06, Operation and Maintenance: Cathodic Protection Systems

Commercial Standards, Recommended Practices (RP) and Technical Reports (TR)

D26888-92, Standard Test Methods for Corrosivity of Water in Absence of Heat Transfer (Weight Loss Methods), Test Method B

American Society for Testing and Materials
1916 Race Street
Philadelphia PA 19103-1187
Phone: Comm (215) 299-5400
RP0169-92, Control of External Corrosion on Underground or Submerged Metallic Piping Systems

TR 10A190, Measurement Techniques Related to Criteria for Cathodic Protection of Underground or Submerged Steel Piping Systems (as defined in NACE International Standard RP0169-83)

NACE International
PO Box 218340
Houston TX 77218
Phone: Comm (713) 492-0535

Society for Protective Coatings

SSPC Good Painting Practices Volume 1

SSPC Systems and Specifications, *SSPC Painting Manual*, Volume 2

SSPC
40 24th Street, 6th Floor
Pittsburgh, PA 15222
Phone: (412)281-2331

Additional References

Public Laws

Lead-Based Paint Exposure Reduction Act, Public Law 102-550, Title X, Subtitle B, 28 Oct 92, 106 Stat. 3924 (29 U.S.C. 671, 42 U.S.C. 4853 et. seq.)

Lead-Based Paint Poisoning Prevention Act, Public Law 91-695, 13 Jan 71, 84 Stat. 2078 (42 U.S.C. 4801 et. seq.), as amended

Unified Facilities Guide Specifications (UFGS)

UFGS 09 90 00, *Paints and Coatings*, October 2005

UFGS 26 42 13.00 20, *Cathodic Protection by Galvanic Anodes*

UFGS 26 42 14.00 10, *Cathodic Protection System* (Sacrificial Anode)

UFGS 26 42 15.00 10, *Cathodic Protection System* (Steel Water Tanks)

UFGS 13112A, *Cathodic Protection System* (Impressed Current), May 2004

UFGS 09 62 50.10, *Thin Film Flooring System for Aircraft Maintenance Facilities*

UFGS 09 62 50.12, *Epoxy Mortar Flooring System for Aircraft Maintenance Facilities*

UFGS 09 97 13.25, *Maintenance, Repair, and Coating of Tall Antenna Towers*

UFGS 09 97 13.26, *Coating of Steel Waterfront Structures*

UFGS 09 97 13.15, *Interior Coating of Welded Steel Petroleum Fuel Tanks*

UFGS 09 97 13.27, Exterior *Coating of Steel Structures*

UFGS 09 97 13.16, *Interior Coating of Welded Steel Water Tanks*

UFGS 09 97 13.17, *Interior Coating of Welded Steel Petroleum Fuel Tanks*

UFGS 09 97 13.28, *Protection of Buried Steel Piping and Steel Bulkhead Tie Rods*

UFGS 26 42 19.00 20, *Cathodic Protection by Impressed Current*

UFGS 26 42 17.00 10, *Cathodic Protection (Impressed Current)*

UFGS 26 42 22.00 20, *Cathodic Protection (Steel Water Tanks)*

UFGS 33 52 80, *Liquid Fuels Pipeline Coating Systems*

Air Force Publications

Policy Directives

AFPD 32-70, Environmental Quality

AFPD 91-2, Safety Programs

AFPD 91-3, Occupational Safety and Health

Instructions

AFI 21-105, Aerospace Equipment Structural Maintenance

AFI 32-1054, Corrosion Control

AFI 32-1064, Electrical Safe Practices

AFI 32-1065, Grounding Systems

AFI 32-1066, Plumbing Systems

AFI 32-1067, *Water Systems*

AFI 32-1069, Gas Supply and Distribution

AFI 32-7044, Storage Tank Compliance

AFI 48-119, Medical Service Environmental Quality Programs

AFPD 32-10, Installations and Facilities

Handbook

AFH 32-1290(I), Cathodic Protection Field Testing

Engineering Technical Letters (ETLs)

ETL 88-4, Engineering and Services Reliability and Maintainability Design Checklist, June 1988, Section 14, "Corrosion Prevention and Control"

ETL 87-2, Volatile Organic Compounds, March 1987

Technical Report

ENM-TR-01, *Industrial Water Treatment Primer*, March 1992 (Available from HQ AFCESA/CESM)

Allowable Standards (AS)

AS 464, Civil Engineer: Operations Flight Support Equipment

Army Publications

Regulations

AR 200-1, Environmental Protection and Enhancement

AR 385-10, The Army Safety Program

Technical Manuals

TM 5-650, Central Boiler Plants

TM 5-653, Steam, Hot Water, and Gas Distribution Systems: Inspection and Preventive Maintenance Service

TM 5-682, Facilities Engineering: Electrical Facilities Safety

TM 5-811-3, Electrical Design–Lightning and Static Electricity Protection

TM 5-811-7, Electrical Design, Cathodic Protection (replaced by UFC 3-570-02A, *Cathodic Protection*)

Technical Instruction

TI 814-10, Wastewater Collection

Pamphlet

Pam 200-1, Environmental Protection and Enhancement

Form

DA Form 4141, Facilities Engineering Operating Log (Water–General)

Corps of Engineers Manual

EM 1110-2-3400, Painting: New Construction and Maintenance, April 1995

Engineer Technical Letters

ETL 1110-3-474, Engineering and Design: Cathodic Protection, July 1995

ETL 1110-9-10 (FR), Engineering and Design, Cathodic Protection System Using Ceramic Anodes, 5 January 1991

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Maintenance and Cathodic Protection Interim Design Guidance

MO-225, Industrial Water Treatment, August 1990

MO-307, *Corrosion Control*, September 1992

Interim Technical Guidance Letter

ITG 94-01, Cathodic Protection Systems

Industry Standards

National Association of Corrosion Engineers (NACE)

RP0187-2005, Design Considerations for Corrosion Control of Reinforcing Steel in Concrete

RP0198-2004; The Control of Corrosion Under Thermal Insulation and Fireproofing Materials—A Systems Approach

RP0285-2002, Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Metallic Liquid Storage Systems

RP0390-2006 Maintenance and Rehabilitation Considerations for Corrosion Control of Atmospherically Exposed Existing Steel-Reinforced Concrete Structures

SP0106-2006, Control of Internal Corrosion in Steel Pipelines and Piping Systems

SP0177-2007, Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems

SP0169-2007, Control of External Corrosion on Underground or Submerged Metallic Piping Systems

SP0207-2007 Performing Close-Interval Potential Surveys and DC Surface Potential Gradient Surveys on Buried or Submerged Metallic Pipelines.

Cathodic Protection.

RP0186-2001, Application of Cathodic Protection for Well Casings

RP0193-2001, External Cathodic Protection of On-Grade Carbon Steel Storage Tank Bottoms

RP0196-2004, Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks

RP0388-2001, Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Tanks

SP0286-2007, The Electrical Isolation of Cathodically Protected Pipelines

SP0290-2007 Impressed Current Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures

SP0387-2006 Metallurgical and Inspection Requirements for Cast Galvanic Anodes for Offshore Applications

SP0492-2006 Metallurgical and Inspection Requirements for Offshore Pipeline Bracelet Anodes

SP0572-2007, Design, Installation, Operation, and Maintenance of Impressed Current Deep Anode Beds

TM0101-2001Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Tank Systems

TM0497-2002 Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems

Industrial Water Treatment

RP0189-89, Online Monitoring of Cooling Waters

RP0281-86, Initial Conditioning of Cooling Water Equipment

Protective Coatings

RP0172-72, Surface Preparation of Steel and Other Hard Materials by Water Blasting Prior to Coating or Recoating

RP0188-90, Discontinuity (Holiday) Testing of Protective Coatings

TR 1E171, Performance Survey of Coatings Used in Immersion Service in Conjunction with Cathodic Protection

TR 6D161, Specification and Format for Surface Preparation and Material Application for Industrial Maintenance Painting

TR 6D163, A Manual for Painter Safety

TR 6D170, Causes and Prevention of Coating Failures

Annex 2 to Appendix C: Abbreviations and Acronyms

AFH	Air Force Handbook
AFI	Air Force Instruction
AFP	Air Force Pamphlet
AFPD	Air Force Policy Directive
AFRL/MLQ-TIC	Air Force Research Laboratory, Airbase and Environmental Technology Division, Technical Information Center
ANG	Air National Guard
AR	Army Regulation
DA Pam	Department of the Army Pamphlet
DA TI	Department of the Army Instruction
DA TM	Department of the Army Technical Manual
ESCO	Energy Services Companies
ESPC	Energy Savings Performance Contracting
HQ AFCESA/CESM	Headquarters Civil Engineer Support Agency, Mechanical/Electrical Engineering Division
HQ USAF/ILE	Headquarters US Air Force, The Office of the Civil Engineer
IMA	Installation Management Agency
MIL-HDBK	Military Handbook
NACE	National Association of Corrosion Engineers
NAVFAC	Navy Facilities
NG	National Guard
RCS	Report Control Symbol
SSPC	Society for Protective Coatings
UFC	Unified Facilities Criteria
UFGS	Unified Facility Guide Specification

Appendix D
Facilities and Infrastructure Design Guidance

This appendix, using the Air Force approach as an example, provides design guidance for DoD facilities and infrastructure.

1. Design, construction, and application of cathodic protection, industrial water treatment (IWT), and protective coatings are functional requirements for almost all projects. Designs should achieve the minimum life-cycle cost for the overall facility. Base personnel should be able to operate and maintain the final facility design (including the corrosion control systems) without extensive training or equipment investment, unless this is the best approach to achieve minimum life-cycle cost.
2. Corrosion resistance is not the only criterion for material selection. When selecting a material, investigate all aspects of its physical properties in the application environment, during both normal operation and typical system failure.
3. Clearly and distinctly document corrosion experience for future reference. This experience should refer to design, material selection, selection of corrosion control techniques, or the decision to not require corrosion control. Document all design and selection decisions in project design analyses. Pass this information to the operations and maintenance elements to assist future decisions.
4. Revisit the design and selection decisions when a system malfunctions or leaks due to corrosion, scaling, or premature failure of the corrosion control system. This is especially important for the rare case when a designer justified the decision to not require corrosion control.
5. Ensure new or supplemental corrosion control systems are compatible with existing systems.
6. The construction contractor should not select the warranty period.
7. Construct pipelines in a manner that facilitates the use of in-line inspection tools.
8. Because cathodic protection and coatings work together, ensure these items are part of the design. Do not design submerged or buried coated metallic facilities without cathodic protection, and do not design cathodic protection on bare metallic facilities. Recommend fiberglass-clad underground storage tanks be installed with galvanic anodes. This recommendation is made even though many of these tanks are EPA-approved for installation without cathodic protection.
9. Do not use unbonded coatings, such as loose polyethylene wraps. Use of unbonded coatings is a direct violation of Department of Transportation regulations and Air Force criteria for pipelines.
10. Provide both cathodic protection and protective coatings for buried or submerged metallic facilities, regardless of soil or water corrosiveness, when the facility
    a. carries flammable product,

b. is mission critical,

c. would be expensive to maintain,

d. would waste energy or affect the environment if corroded, or

e. requires corrosion control as identified by decision authorities.

Other buried utilities generally provide cathodic protection and protective coatings if the soil resistivity is below 10,000 ohm-centimeters. Follow the documented recommendations of a qualified corrosion engineer when the soil resistivity is above 10,000 ohm-centimeters.

1. Based upon qualified analysis, provide both cathodic protection and protective coatings for the following aboveground tanks:

    a. All ferrous tanks in contact with the earth, unless built on an oil-filled sand pad with plastic liner underneath

    b. Interiors of steel water distribution storage tanks.

2. Consider the need for lightning and fault current protection at isolating devices (dielectrically insulated unions and flanges) when designing cathodic protection systems. Consult Air Force Instruction 32-1065, *Grounding Systems*, during the design process.

3. Ensure installed cathodic protection systems provide protective potentials meeting criteria in NACE International Standard SP0169, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*, Section 6, “Criteria and Other Considerations for Cathodic Protection.” Structure-to-soil potentials should be free from potential drop (current × resistance).

4. Under certain conditions cathodic protection is ineffective or only partially effective. Corrosion personnel may deviate from this guidance after documenting the achievement of objectives and receiving command corrosion engineer approval.

5. Because industrial water treatment designs or decisions begin with an analysis of the system makeup water, consult bioenvironmental engineering and AFI 48-119, *Medical Service Environmental Quality Programs*, for sampling potable water sources that feed industrial systems. Consider using AF Form 2752A, *Environmental Sampling Data*, for complete analyses to identify the quantity and relationship of water constituents for industrial water treatment purposes.

6. Acceptance testing of new heating and cooling systems will ensure the industrial water treatment system meets design and operation parameters. Boiler steam purity tests will determine total dissolved solids limits. Correlate the total dissolved solids level selected for boiler operation to the conductivity reading of a typical sample. The water or wastewater laboratory at associated plants or base supply’s fuels laboratory usually can measure total dissolved solids using standard methods developed by the American Society for Testing and Materials. Verify the selected condensate treatment meets design parameters by testing for copper, iron, and pH at near, medium, and far points from the boiler.

7. Indicate locations to install corrosion coupon racks following the American Society for Testing and Materials’ D26888-92, *Standard Test Methods for Corrosivity of Water in*

Absence of Heat Transfer (Weight Loss Methods): *Test Method B*. The coupons are the best confirmation of industrial water treatment effectiveness.

8. Do not use nonchemical industrial water treatment devices on DoD systems either regularly or on a test evaluation basis except as approved in advance. This includes the Management and Equipment Evaluation Program.
9. Light reflective floor coatings include chemically resistant urethane for existing hangar floors and dry shake metallic floor topping applied to the top layer of freshly poured concrete for new floors. Ensure electrostatic discharge and slip resistance are part of the design. Include the daily cleaning requirements to cover equipment, supplies, and frequency as part of the maintenance instructions provided to the using agency.
10. Avoid using chemical strippers. If specified, test product for effectiveness prior to award of any contract. This is especially necessary for removing lead-based paint from wood. Also, specify procedures to confirm neutralization of alkaline paint stripper through chemical testing. Alkaline residue left on the substrate is a recurring paint failure mechanism.

Appendix E
Facilities Cost of Corrosion Results

In this appendix, we summarize some important results from DoD's cost-of-corrosion studies conducted the past 2 years. DoD's cost-of-corrosion studies are important for two important reasons:

- They measure the annual cost of corrosion for various categories of weapon systems, facilities, and infrastructure.
- They identify corrosion cost reduction opportunities for the military services and DoD.

Introduction

According to two separate studies, the cost of corrosion to DoD infrastructure and equipment is estimated to be between $9 billion and $20 billion per year. Although the spread between these estimates is large, both studies confirm that DoD corrosion costs are significant.

Congress, concerned with the high cost of corrosion and its negative effect on military equipment and infrastructure, enacted legislation in December 2002 that created an office with the overall responsibility of preventing and mitigating the impact of corrosion on military equipment and infrastructure. The Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]) was the office designated to fulfill this role. To perform its mission of corrosion prevention and mitigation, fulfill congressional requirements, and respond to Government Accountability Office (GAO) recommendations, the USD (AT&L) established the Corrosion Prevention and Control Integrated Product Team (CPC IPT), a cross-functional team of personnel from all the military services as well as representatives from private industry.

In response to a GAO recommendation to "develop standardized methodologies for collecting and analyzing corrosion cost, readiness and safety data," the CPC IPT created a standard method to measure the cost of corrosion for its military equipment and infrastructure. Because the data-gathering effort is large and complex, the CPC IPT plans to measure the total DoD cost of corrosion in segments.

Table E-1 presents the results of the initial five studies and the timeline for future cost-of-corrosion studies.

Table E-1. Cost-of-Corrosion Studies to Date and Future Efforts

Study year	Study segment	Annual cost of corrosion	Data baseline
2005–2006	Army ground vehicles	$2.0 billion	FY2004
	Navy ships	$2.4 billion	FY2004
2006–2007	DoD facilities and infrastructure	$1.8 billion	FY2005
	Army aviation and missiles	$1.6 billion	FY2005
	Marine Corps ground vehicles	$0.7 billion	FY2005
2007–2008	Navy, Marine Corps, and Coast Guard aviation and Coast Guard ships		
2008–2009	Air Force and repeat 2005–2006		
2009–2010	Repeat 2006–2007		
2010–2011	Repeat 2007–2008		

Method

The method used to estimate facilities corrosion costs[1] focuses on tangible direct material and labor costs as well as some indirect costs (e.g., priority 2 costs) such as research and development (R&D) and training. The corrosion cost estimation is a combined top-down and bottom-up approach. The top-down portion uses summary-level cost and budget documentation to establish spending ceilings for family housing and non-family housing maintenance and construction activity. This establishes a maximum cost of corrosion for each area of activity. The bottom-up portion uses detailed work order records to aggregate actual occurrences of corrosion maintenance and construction. This establishes a minimum level of corrosion costs in each activity area. When necessary, statistical methods to bridge any significant gaps between the top-down and bottom-up figures were used to derive a final estimation for the cost of corrosion in each area.

The cost estimation method also segregates costs by their source and nature, using four schema groups:

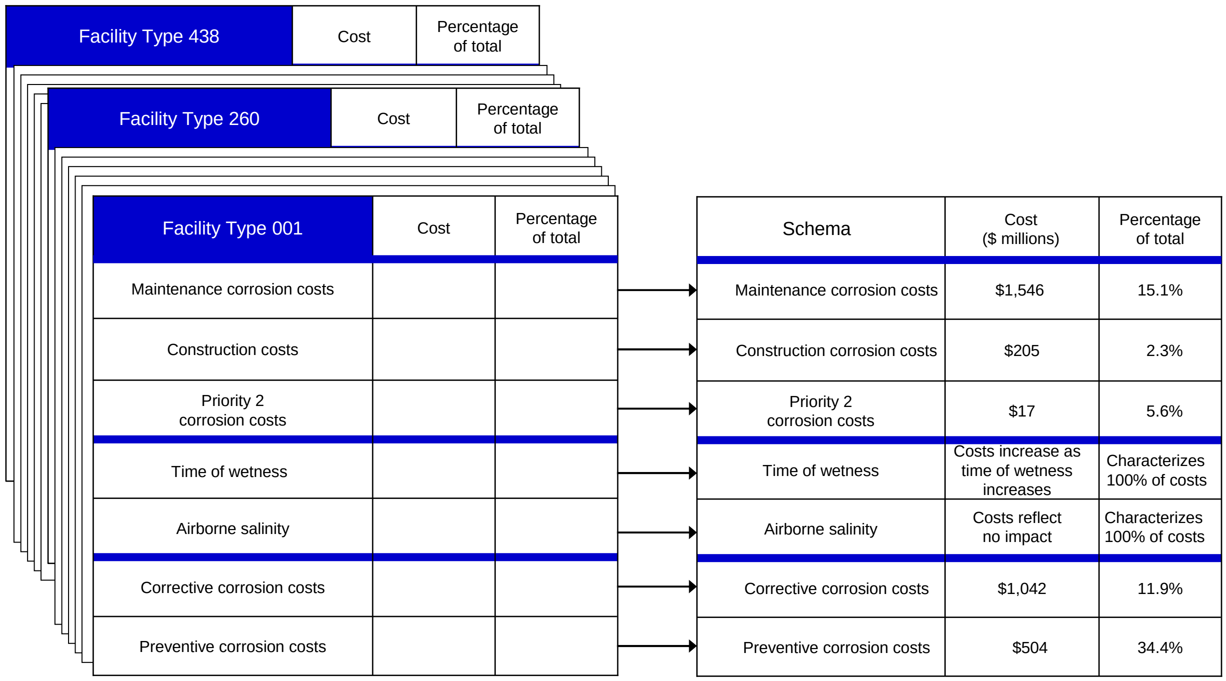
- Group 1 schemas—Maintenance, construction, and priority 2 costs
- Group 2 schemas—Facility analysis categories (FACs)
- Group 3 schemas—Time of wetness and airborne salinity (TOW/S)
- Group 4 schemas—Corrective versus preventive costs.

Results

The total cost of corrosion for DoD facilities in FY05 was estimated to have been $1.768 billion. DoD facilities and infrastructure corrosion costs were estimated according to the four schema groups for each of 438 facility analysis categories. These total more than 1 million facilities at 5,957 installations (see Figure E-1).

[1] "Costs" reflect known or identified actual expenditures.

Figure E-1. Cost of Corrosion for DoD Facilities/Infrastructure (FY05)



Using this data structure, it is possible to analyze the data against the following:

- FAC code
- Installation
- Labor and material costs
- Total cost versus corrosion-related cost
- Maintenance, construction, and priority 2 costs
- TOW/S zone
- Corrective versus preventive maintenance cost
- Family housing (FH) versus non-family housing (non-FH) cost

The highest costs of corrosion occur during performance of facilities and infrastructure maintenance, from both a total cost and percentage of expenditure standpoint. The cost of corrosion for facility and infrastructure maintenance is approximately seven times higher than corrosion costs associated with facility and infrastructure construction. There are two main reasons for this:

- Only construction projects with an existing mission and an existing footprint are eligible to contain corrective corrosion costs; therefore, more than half of the total construction project population was excluded from corrective corrosion costs calculations. This results in a lower ratio of corrosion-related construction cost to total construction cost.

- There is a significantly greater detail available in the descriptions for maintenance actions than for construction projects. As a result, the construction project descriptions may not contain the keywords to flag the work as a corrosion cost.

Priority 2 corrosion costs are small, with research and development being the largest contributor ($16 million).

Maintenance costs due to corrosion generally increase as the time of wetness increases. However, an increase in corrosion costs for installations located within 1 mile of seawater (a measure of the presence of airborne salinity) was not observed.

DoD spent more than twice as much on corrective corrosion maintenance ($1,042 million) as it did on preventive corrosion maintenance ($504 million). However, of the total preventive facility and infrastructure maintenance expenditures, more than one-third are corrosion-related.

Although not shown in Figure E-1, corrosion-related maintenance costs for non-FH facilities ($1.361 billion) are much higher than corrosion-related maintenance costs for FH facilities ($0.185 billion. This is because there are significantly more non-FH facilities than FH facilities. In terms of maintenance percentage, corrosion expenditures for FH facilities equal 17.4 percent of maintenance costs. The same calculation for non-FH corrosion yields a corrosion percentage of 14.9 percent. The slightly higher ratio for FH facilities makes intuitive sense because a significant trigger for facilities corrosion expenditures is deteriorating appearance (rust, scaling, flaking, etc.) as well as potential health impacts (the presence of mold, for example). It is reasonable to conclude that occupants and managers of FH dwellings have a lower tolerance for appearance and health-related problems than users of non-FH facilities. Therefore, potential corrosion issues in FH dwellings may receive earlier intervention and, therefore, a higher percentage of maintenance costs than similar issues in non-FH facilities.

Cost Reduction Opportunities

Facility and infrastructure types that are large in total size are generally the highest contributors to total corrosion costs, but they have a low corrosion cost per unit of size measurement. For example, the three FACs with the highest total corrosion costs from Figure E-2 are also among the three largest FACs in terms of total size (only FAC 4421 is larger); however, each of these three FACs has a fairly low corrosion cost per square foot. The FACs with a high corrosion cost per unit of size measurement, such as ship maintenance dry-dock (FAC 2131) and electrical power substation (FAC 8131), are better targets of opportunity for corrosion cost reduction.

Figure E-2. Top 10 Corrosion Costs by Facility Analysis Category

FAC	FAC description	Total corrosion cost ($ millions)	Total maintenance cost ($ millions)	Corrosion percent	Total size (millions)	Unit of measure	Corrosion cost per unit ($)
7210	Enlisted Unaccompanied Personnel Housing	94	603	15.6%	139	SF	$ 0.68
6100	General Administrative Building	75	545	13.7%	173	SF	$ 0.43
7110	Family Housing Dwelling	54	268	20.1%	230	SF	$ 0.23
8131	Electrical Power Substation	51	199	25.6%	14	KV	$ 3.79
1714	Reserve Training Facility	48	298	16.0%	98	SF	$ 0.49
4421	Covered Storage Building, Installation	46	190	24.2%	156	SF	$ 0.30
4111	Bulk Liquid Fuel Storage	44	311	14.1%	64	BL	$ 0.69
8321	Sewer and Industrial Waste Line	36	131	27.3%	130	LF	$ 0.27
2131	Ship Maintenance Dry-dock	32	73	44.2%	3	SF	$ 9.73
6102	Large Unit Headquarters Building	29	161	17.9%	24	SF	$ 1.19

Throughout the facilities cost-of-corrosion study, a list of corrosion best practices was developed that proved applicable across services, TOW/S zones, and installations. Those best practices are:

- Perform all scheduled recurring work services and maintenance. Doing so will help control costs due to corrosion damage as well as other facilities lifecycle costs.
- Use anti-corrosion water treatment in closed-loop heating and cooling systems.
- Use cathodic protection on steel storage tanks and pipelines. Find adequate resources for the cathodic protection program so that these systems are maintained and function appropriately.
- Choose appropriate corrosion-resistant materials for new construction and repair by replacement.
- When a system (such as a pipeline) begins to fail due to corrosion, make the necessary repairs, then plan and program funds for total system replacement, preferably with a corrosion-resistant material.
- Government staff should review new construction project designs to ensure maintenance is properly considered and preventive measures (such as corrosion-resistant materials, closed system water treatment, and cathodic protection) are not eliminated to bring the project’s cost down.
- Consider treating domestic water when the pH is less than 6.5 or greater than 8.5. This will diminish the effects of corrosion on systems that distribute or use domestic water.
- Consider using corrosion-resistant concrete embeds and equipment mounting brackets in facilities such as water treatment plants, sewage treatment plants, sewage lift stations, swimming pool chlorination rooms, etc. In addition, consider using remote sensing instruments so that only the sensor must be mounted in areas that are humid or have corrosive environments.

Appendix F
Facility Corrosion Prevention and Control Memorandum

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

MAR 1 0 2005

ACQUISITION
TECHNOLOGY
AND LOGISTICS

MEMORANDUM FOR ASSISTANT SECRETARY OF THE NAVY (INSTALLATIONS AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS, ENVIRONMENT AND LOGISTICS)
PRINCIPAL DEPUTY ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS AND ENVIRONMENT)
DIRECTOR, DEFENSE LOGISTICS AGENCY

SUBJECT: Facility Corrosion Prevention and Control

References:
(a) United States Code: Title 10, Section 2228
(b) Under Secretary of Defense (AT&L) Memo, November 12, 2003, Subject: Corrosion Prevention and Control
(c) DODD 5000.1, Operation of the Defense Acquisition System, May 12, 2003
(d) DFARS Change Notice 20040917
(e) Corrosion Prevention and Control Planning Guidebook, Spiral Number 2, July 2004

Corrosion can significantly affect the cost of facility maintenance and the expected service life of DOD facilities. To minimize the impact of corrosion, the Department must apply the proper corrosion prevention practices in the management of facilities. Congress recognized this and enacted legislation, reference (a) which places added emphasis on corrosion prevention and control. Reference (b) issues DOD Corrosion Prevention and Control Policy.

Planning, design, and construction provide the best opportunities to incorporate the necessary corrosion prevention technology into our facilities. References (c) and (d) add corrosion prevention to the areas that must be considered in the acquisition process. Once facilities are in service, corrosion must be controlled through proper maintenance practices and adequate sustainment resources. I am initiating a review of the sustainment program to ensure corrosion prevention is fully incorporated into our program requirements. Results of that review will be used to identify future funding requirements.

Military Departments are directed to review their facility design, construction and maintenance procedures to ensure current corrosion prevention measures and technologies are being incorporated into facilities acquisition and maintenance.

Reference (e) provides guidance to achieve this objective. Any needed policy revisions or procedural changes should be issued not later than six months of the date of this memo with a copy provided to this office.

Thank you for your support to date in development of the long-term DoD Facilities Corrosion Prevention Strategy. My point of contact for this effort is Sonny White. He can be reached at (703) 697-1015, or by e-mail at mahlon.white@osd.mil.

Philip W. Grone
Deputy Under Secretary of Defense
(Installations and Environment)

Attachments

Attachment Contents

Attachment 1 Corrosion Prevention and Control Memorandum

THE UNDER SECRETARY OF DEFENSE

3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION,
TECHNOLOGY
AND LOGISTICS

NOV 12 2003

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS

SUBJECT: Corrosion Prevention and Control

The Department of Defense (DoD) acquires, operates, and maintains a vast array of physical assets, ranging from vehicles, aircraft, ships, and other materiel to wharves, buildings, and other stationary structures that are subject to corrosion. Consequently, corrosion control contributes significantly to the total cost of system ownership. To control these costs, I believe we need to revitalize our approach to tracking, costing, and preventing or controlling corrosion of systems and structures. Specifically, we need to concentrate on implementing best practices and best value decisions for corrosion prevention and control in systems and infrastructure acquisition, sustainment, and utilization.

Basic systems design, materials and processes selection, and intrinsic corrosion-prevention strategies establish the corrosion susceptibility of Defense materiel. The early stages of acquisition provide our best opportunity to make effective trade-offs among the many competing design criteria that will provide desired Defense capability. I believe that corrosion needs to be objectively evaluated as part of program design and development activities and the inevitable trade-offs made through an open and transparent assessment of alternatives. Therefore, I want this requirement to be specifically addressed during the earliest phases of the acquisition process and by decision authorities at every level. I will personally consider this issue for programs subject to Defense Acquisition Board (DAB) Review.

I have directed that a review and evaluation of corrosion planning be a standard topic for the Integrating Integrated Product Team reviews and that the Corrosion Prevention and Control Planning be reviewed by the Overarching Integrated Product Team with issues raised by exception to the DAB. To assist all of us in designing effective strategies, corrosion prevention and control planning guidance will be included in the "Designing and Assessing Supportability in DoD Weapons Systems" guidebook. We are also drafting a "Corrosion Prevention and Control Planning Guidebook," which will provide assistance in general corrosion-control planning and the implementation of sound materials selection and treatments during the design, development, and sustainment of DoD weapons systems and infrastructure.

Thank you for your support as we develop a long-term DoD corrosion prevention and control strategy. My focal point for this effort is Mr. Daniel Dunmire, Director, Corrosion Policy and Oversight, at 703-681-3464, e-mail daniel.dunmire@osd.mil.

Michael W. Wynne
Acting

Attachment 2 Acronyms

AFCESA	Air Force Civil Engineer Support Agency
AFI	Air Force instruction
AFP	Air Force pamphlet
AFPD	Air Force policy directive
AFRL	Air Force Research Laboratory
AMMTIAC	Advanced Materials, Manufacturing, and Testing Information Analysis Center (formerly the Advanced Materials and Processes Technology Information Analysis Center)
AS	allowable standard
CCT	contractor corrosion team
CDD	capabilities development document
CFR	Code of Federal Regulations
CP	Cathodic Protection (System)
CPAT	Corrosion Prevention Action Team
CPC	corrosion prevention and control
CPCP	corrosion prevention and control plan
CPD	capabilities production document
DAB	Defense Acquisition Board
DID	data item description
DoD	Department of Defense
DoDD	DoD directive
DSN	Defense Switching Network
DTIC	Defense Technical Information Center

EM	engineering manual
EPA	Environmental Protection Agency
ESCO	Engineering Services Company
ESPC	Energy Savings Performance Contracting
ETL	engineering technical letters
FOC	full operational capability
FRP	full rate production
HQ	headquarters
IAW	in accordance with
ICD	initial capabilities document
ILS	integrated logistics support
IOC	initial operational capability
IPT	integrated product team
IWT	industrial waste treatment
LRIP	low rate initial production
M&P	materials and processes
MNS	mission needs statement
MRB	Material Review Board
MTBF	mean time between failure
MTTR	mean time to repair
NACE	National Association of Corrosion Engineers
NDI	non-destructive inspection
NEPA	National Environmental Policy Act
NGS	non-government standard
OIPT	overarching integrated product team

ORD	operational requirements document
OT&E	operational test and evaluation
PM	program (or project) manager
PT	product team
QA	quality assurance
R&D	research and development
RCM	reliability-centered maintenance
RCS	report control symbol
RFP	request for proposal
RM&S	reliability, maintainability, and supportability
RP	recommended practice
SDD	system development and demonstration
SRM	sustainment, restoration, and modernization
SSPC	Society for Protective Coatings
T.O.	technical order
TM	technical manual
TPC	Technical Practices Committee
TR	technical report
UFC	Unified Facilities Criteria
UFGS	United Facilities Guide Specifications
U.S.C.	United States Code
USAF	United States Air Force
UST	underground storage tanks

Attachment 3 Principal Integrated Logistics Support Element Definitions

Maintenance Plan

A description of the requirements and tasks necessary to achieve, restore, or maintain the operational capability of a system, equipment or facility. Corrosion prevention techniques and processes should be discussed in this document as they relate to the overall maintenance concept. The maintenance plan normally is a subordinate plan of the integrated logistics support plan (ILSP).

Support and Test Equipment

All mobile or fixed equipment required to support the operation and maintenance of a population of systems, equipment, or facilities at all levels and all locations. Corrosion control and monitoring equipment should be identified and integrated with other support equipment requirements (e.g., portable cleaning machines and fixed wash racks).

Supply Support

All functions and management actions needed to determine requirements for acquisition, cataloging, packaging, preservation, receipt, storage, transfer, issue, and disposal of spares, repair parts, bulk material, clothing, food, and fuel. Corrosion control and monitoring supplies should be identified and integrated with other supply requirements (e.g., cleaners, coatings, and abrasives).

Transportation and Handling

The procedures, equipment, and facilities used for the packaging, movement, transfer, and handling of systems or equipment. Unique corrosion control equipment and supplies should be identified and integrated with other support equipment requirements (e.g., hazardous coatings and liquid cleaners).

Technical Data

All types of specifications, standards, engineering drawings, instructions, reports, manuals, tables, and test results used in the development, production, testing, use, maintenance, and disposal of military items, equipment, and systems. Corrosion control and monitoring manuals, reports, specifications, and standards should be identified and integrated with other logistic requirements and made readily available to users (e.g., specifications available on web).

Facilities

Facilities includes all real property (all buildings and land) and permanent improvements to real property (access roads and railroad spurs, security fencing, utility lines, dedicated spaces, and piers) required for operation and support of a system or equipment. Wash racks and other permanent corrosion control facilities need to be identified early in the development process to adequately budget for the land and associated dedicated improvements.

Personnel

Personnel—in the numbers and with the necessary skills—who operate and support a system or equipment in its operational environment. Corrosion control and monitoring personnel should be identified and integrated with other support personnel requirements.

Training

The processes, procedures, and equipment used to train personnel in the operation and support of a system or equipment. Corrosion control and monitoring training should be identified and integrated with other support equipment requirements (e.g., school house requirements, imbedded training, and training material).

Logistics Support Resource Funds

The money required for the identification, acquisition, and management of logistic resources. Corrosion control and monitoring funding requirements should be identified and controlled to ensure all of the ILS elements are adequately funded.

Logistics Support Management Information

Information used for the analysis and reporting of actions taken or required to be taken in developing or executing logistic support plans (e.g., a centralized website for all corrosion prevention and control reports and documentation available to department and associated commercial users).

Attachment 4 Corrosion Points of Contact—Organization and Personnel

Organization

OSD

Director, DoD Corrosion Policy and Oversight
ODUSD (AT&L), The Pentagon
3000 Defense Pentagon
Washington, DC 20301-3000
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(973) 724-5795
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CEERDC-CFM (Facilities)
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Champaign, IL 61822-1076
(217) 373-6753

U.S. Army, Aviation and Missile Command
AMSAM-RD-PS-AM
Redstone Arsenal, AL 35898
(256) 876-7472
DSN: 746-7472

US Army Natick Soldier Research Development and Engineering Center
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(508) 233-6977
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Office of Naval Research
ONR 332 Materials Division
800 N Quincy Street
Arlington, VA 22217
(703) 696-4309
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Attachment 5 CPC Policy and Regulation Directives

Title 10 and DoD Guidance

Chapter 131, Title 10 USC, Section 2228, National Defense Authorization Act for FY2003*, Military Equipment and Infrastructure: Prevention and Mitigation of Corrosion*

Section 2228 requires the Secretary of Defense to designate an official or organization responsible for the prevention and mitigation of corrosion on military equipment and infrastructure. Section 2228 also requires the development of a long-term strategy for corrosion prevention and mitigation.

Corrosion Policy Memorandum (12 November 2003)

Among recent policy accomplishments, the most important may have been the publication of DoD corrosion prevention and control policy guidance. The policy recognizes that "the early stages of acquisition provide our best opportunity to make effective trade-offs among the many competing design criteria that will provide desired Defense capability."

Program and project management requirements include the following:

- Make corrosion prevention and control planning an explicit part of performance-based acquisition as well as performance-based logistics (PBL), as defined in DoD Directive 5000.1.
- Assess and evaluate corrosion planning during the program IPT and the overarching IPT review processes, with issues raised by exception to the Defense Acquisition Board (DAB) (for programs that are subject DAB to review).
- Adhere to the corrosion prevention and control guidance in the *Designing and Assessing Supportability in DoD Weapons Systems Guidebook*.
- Implement best business practices and best-value decisions for corrosion prevention and control in system and infrastructure acquisition, sustainment, and utilization.
- Formulate and implement a support strategy that ensures system support and life-cycle affordability considerations are addressed and documented as an integral part of the program's overall acquisition strategy. Specific support strategy requirements are contained in the *Interim Defense Acquisition Guidebook.*

Designing and Assessing Supportability in DoD Weapon Systems: A Guide to Increased Reliability and Reduced Logistics Footprint *(29 May 2003)*

This guide provides a template for PMs (when assigned) or responsible activities to use in defining and assessing their program activities to meet QDR objectives and DoD policy requirements throughout the weapon system life cycle. Emphasis is placed on designing for increased reliability and reduced logistics footprint and on providing for effective product support through performance-based logistics strategies.

There are seven references to corrosion within the document. They are primarily contained within the discussion of maintainability and supportability as they pertain to system availability in DoD weapon systems. The following are specific factors to be considered, planned, and provided for:

- Corrosion protection and mitigation planning and analysis for supportability
- Designed-in access for corrosion inspection and mitigation for maintainability
- Specific logistic-related technologies that have potential to improve maintenance and reduce the logistics footprint (e.g., corrosion control)
- Consideration of corrosion mitigation during reliability centered maintenance (RCM) analysis.

DoD Directive 5000.1, The Defense Acquisition System *(12 May 2003)*

Policies in this directive apply to all acquisition programs.

According to Paragraph E1.17, Performance-Based Logistics, PMs must develop and implement performance-based logistics strategies that optimize total system availability while minimizing cost and logistics footprint. Trade-off decisions involving cost, useful service, and effectiveness must consider corrosion prevention and mitigation. Sustainment strategies must include the best use of public and private sector capabilities through government-industry partnering initiatives, in accordance with statutory requirements.

DoD Instruction 5000.2, Operation of the Defense Acquisition System *(12 May 2003)*

This instruction establishes a simplified and flexible management framework for translating mission needs and technology opportunities, based on approved mission needs and requirements, into stable, affordable, and well-managed acquisition programs that include weapon systems and automated information system (AISs).

This instruction contains no reference to corrosion.

CPC IPT Charter (3 September 2003)

The following are specific goals of the CPC IPT:

- Provide strategic review and advice as necessary to deal with the following congressional requirements:
  - Expanded emphasis on corrosion prevention and mitigation
  - Uniform application of requirements and criteria for testing and certification of new corrosion prevention technologies throughout the DoD
  - Development of a coordinated approach to collecting, reviewing, validating and distributing information on proven methods and products

    - Implementation of a coordinated science and technology program that includes demonstration, validation, and transition of new corrosion technologies into operational systems.
- Develop and recommend policy guidance on the prevention and mitigation of corrosion.
- Provide overviews or summaries of the corrosion programs and funding levels proposed and executed by the military departments and agencies.
- Develop a roadmap and monitor the progress of corrosion-related activities.
- Develop strategies to efficiently track corrosion costs and the impact of corrosion on readiness and safety.
- Develop guidance for improving maintenance and training plans.
- Develop guidance to ensure the use of corrosion prevention technologies and the application of corrosion treatments are fully considered throughout the life cycle of system or infrastructure.

Pending DoD Instruction 5000.rr

This Instruction implements policy, assigns responsibilities and prescribes procedures under 10 USC 2228 to:

- Provide guidance by assigning responsibilities for the establishment and management of programs to prevent or mitigate corrosion on DoD military equipment and infrastructure.
- Assign responsibilities for the DoD Corrosion Executive and the Secretaries of the Military Departments.
- Designate a DoD Corrosion Executive responsible to:
    - Develop and recommend corrosion prevention and mitigating policy and guidance.
    - Review corrosion programs and corrosion-related research, development, test and evaluation (RDT&E) funding levels of each Military Department and USD(AT&L) Defense Agency.
    - Oversee and coordinate DoD efforts to prevent or mitigate corrosion during the acquisition and sustainment cycles of military equipment and infrastructure.
    - Monitor acquisition practices to ensure use of corrosion prevention technologies.
    - Develop and implement a long-term strategy to reduce corrosion and the effects of corrosion on military equipment and infrastructure according to the DoD Corrosion Prevention and Mitigation Strategic Plan (Reference (c)).

DoD Directive 4151.18, Maintenance of Military Materiel *(31 March 2004)*

This directive establishes policies and assigns responsibilities for the performance of DoD materiel maintenance, including maintenance of weapon systems, hardware, equipment, software, or nay combination thereof and for both organic and contract sources of repair.

Paragraph 3.3.7 states: "Corrosion prevention and control programs and preservation techniques shall be established throughout the system life cycle. Examples of preventative and control methods may include using effective design practices, material selection, protective finishes, production processes, packaging, storage environments, protection during shipment, and maintenance procedures. Preservation techniques shall be used as a part of maintenance programs when operationally feasible. Corrosion prevention and control reporting systems shall allow for data collection and feedback, and shall be used to address corrosion prevention and control logistics considerations and readiness issues."

DFARS Change Notice 20040917 (12 October 2004)

The Defense Federal Acquisition Regulation Supplement (DFARS) Part 207 was amended to incorporate the requirement to address corrosion and other maintainability issues within the acquisition plan. This change implements Section 1067 of the National Defense Authorization Act for Fiscal Year 2003, which requires DoD to prevent and mitigate corrosion during the design, acquisition, and maintenance of military equipment.

Specifically Part 207.105 (b),13), *Logistics consideration*, states "Performance based logistics that optimize total system availability while minimizing costs and logistics footprint should be considered. Trade-off decisions involving cost, useful service, and effectiveness shall consider corrosion prevention and mitigation."

DoD Corrosion Website

The DoD Corrosion website (www.corrdefense.org, soon to be www.corrdefense.gov) is the heart of a state-of-the-art Corrosion Prevention and Control (CPC) information management and distribution e-portal. The e-portal has been designated as one of the cornerstones in the DoD's long-term strategy for corrosion prevention and mitigation detailed in 10 U.S.C. 2228, which was enacted by the *Bob Stump National Defense Authorization Act* for FY2003. The DoD corrosion website is life cycle–oriented and serves as a leader in corrosion research, industry coordination, and information dissemination to all individuals and organizations in the DoD, academia, and industry who have an interest in corrosion particularly as it relates to DoD weapon systems, equipment, related commercial assets, and infrastructure.

The vision of the DoD Corrosion website is for the DoD, academia, and industry to work together to develop and share corrosion data, information, and knowledge to help reduce the cost of corrosion and its impact on the readiness of DoD weapon systems, equipment, comparable commercial assets, and infrastructure.

The goals of the DoD Corrosion website are as follows:

- Improve and support communication, collaboration, and coordination within the corrosion prevention and control (CPC) community.
- Increase the effectiveness of CPC research and operations
- Develop, maintain, and expand the web-based information aggregation and sharing capabilities of the website.
- Maintain a content-rich, collaborative online environment for all members.

Corrosion Prevention and Control FAQs (29 January 2004)

Frequently asked questions (FAQs) are posted on the DoD Corrosion Exchange website along with the general answers about corrosion prevention and control planning (CPCP). The FAQ's provide information on draft CPC plans, corrosion control–related activities, corrosion-related testing, specifications and standards application, and CPCP integration into weapon system plans.

Strategic Plan for Corrosion Prevention and Mitigation (May 2007)

The DoD *Strategic Plan for Corrosion Prevention and Mitigation* articulates policies, strategies, objectives, and plans that will ensure an effective, standardized, affordable DoD-wide approach to prevent, detect and treat corrosion and its effects on military equipment and infrastructure. These policies, strategies, and objectives specifically address congressional requirements and respond to GAO findings and recommendation.

The DoD *Strategic Plan for Corrosion Prevention and Mitigation* applies to all elements of DoD component services and agencies, including the science and technology, acquisition, operational, and support communities. The plan also applies to segments of the industrial community (including manufacturers, material suppliers, and contract maintenance organizations) that provide products or services affected by or related to equipment and infrastructure corrosion. The plan addresses affordable system and facility design, materials selection, manufacturing, detection, treatment, and repair processes associated with corrosion and its effects. The plan was formally promulgated by the Under Secretary of Defense for Acquisition, Technology and Logistics (USD[AT&L]) and remains in effect until cancelled or superseded. Revisions to the plan will be incorporated and implemented as needed throughout the life of the plan.

Defense Acquisition Guidebook *(17 October 2004)*

The *Defense Acquisition Guidebook* complements DoD Directive 5000.1 and DoD Instruction 5000.2 by providing the acquisition workforce with discretionary best practice that should be tailored to the needs of each program.

Paragraph 4.4.13, "Corrosion Prevention and Control," states, "The program manager should consider and implement corrosion prevention and mitigation planning to minimize the impact of corrosion and material deterioration throughout the system life cycle." Corrosion prevention and mitigation methods include the use of effective design practices, material selection, protective finishes, production processes, packaging, storage environments, protection during shipment, and maintenance procedures. The program manager establishes and maintains a corrosion prevention and mitigation reporting system for data collection and feedback and uses it to adequately address corrosion prevention and mitigation logistic considerations and readiness issues. Corrosion prevention and mitigation considerations are integral to all trade-off decisions for Performance based logistics as required in DoD Directive 5000.1:

> PMs shall develop and implement performance-based logistics strategies that optimize total system availability while minimizing cost and logistics footprint. Trade-off decisions involving cost, useful service, and effectiveness shall consider corrosion prevention and mitigation. Sustainment strategies shall include the best use of public and private sector capabilities through government/industry partnering initiatives, in accordance with statutory requirement.

Other references to corrosion control protection and mitigation are contained in Paragraph 4.4.9, “Supportability,” Paragraph 4.4.15, “Information Assurance,” and Chapter 5, “Life-Cycle Logistics.”

OSD, Report to Congress, Status Update on Efforts to Reduce Corrosion and the Effects of Corrosion on the Military Equipment and Infrastructure of the Department of Defense *(February 2005)*

This report is submitted per guidance in Government Accountability Office (GAO) audit, GAO-04-640 that requires the department to submit to Congress, as part of the fiscal year 2006 budget submission, a report identifying the

- long-term funding and personnel resources needed to implement the corrosion strategy,
- status of the corrosion reduction projects funded in FY2005, and
- status of the cost of corrosion baseline study.

In addition, this report updates other key corrosion activities, including the

- transition of corrosion control and oversight activities from task force status to embedding the responsibilities within the Office of the Secretary of Defense (OSD),
- identification and characterization of corrosion-related specifications and standards,
- enhancements in corrosion training for appropriate DoD personnel, and
- activity highlights of the seven working integrated product teams (WIPTs): Communication and Outreach; Facilities/Infrastructure; Impact, Metrics and Sustainment; Policy and Requirements; Science and Technology; Specifications/Standards and Product Qualification; and Training and Doctrine.

DoD Corrosion Report, Efforts to Reduce Corrosion on the Military Equipment and Infrastructure of the Department of Defense *(June 2007)*

The report provides the status of key corrosion activities, including the

- results of the 28 corrosion mitigation projects funded in FY2005,
- status of the 54 corrosion mitigation projects funded in FY2006 and FY2007,
- results of the DoD cost of corrosion effort,
- launching of a user-friendly web tool to guide suppliers through the product introduction process,
- status of the DoD instruction on prevention and mitigation of corrosion on DoD’s military equipment and infrastructure,
- development of a Corrosion Prevention and Control Overview course for the department’s acquisition workforce,

- planning for a corrosion study by the National Materials Advisory Board of The National Academies, and
- activity highlights of the seven WIPTs.

OSD Memorandum, Facility Corrosion Prevention and Control *(10 March 2005)*

This memorandum establishes policy to apply the proper corrosion prevention practices in the management of facilities. It initiates a review of the sustainment program to ensure corrosion prevention is fully incorporated into the management of facilities requirements.

Army Policies and Directives

AR 70-1, Army Acquisition Policy *(31 December 2003)*

This regulation implements DoD Directive 5000.1, DoD Regulation 5000.2-R, DoD Directive 5000.52, DoD 5000.52-M, and DoD Instruction 5000.58. It governs research, development, acquisition, and life-cycle management (LCM) of Army materiel to satisfy approved Army requirements, and it applies to major systems, non-major systems, highly sensitive classified acquisition programs, automated information systems, and clothing and individual equipment (CIE).

This regulation contains no reference to corrosion.

AR 750-1, Army Material Maintenance Policy *(18 August 2003)*

This regulation establishes policies and assigns responsibilities for the maintenance of Army materiel. It provides and defines requirements for performance and management of the materiel maintenance function.

The corrosion prevention and control program is a critical consideration in assuring the sustained performance, readiness, economical operation, and service life of Army systems and equipment. It requires active consideration in the materiel development, acquisition, fielding, operation, and storage processes. CPC requires life-cycle management planning and action in design, development, testing, fielding, training, and maintenance.

AR 750-59, Army Corrosion Prevention and Control Program *(18 March 2003)*

This regulation establishes Army policy and procedures for implementing and managing an effective corrosion prevention and control program for all Army systems, equipment, and components.

This regulation identifies the Army Corrosion Program Manager and prescribes the policies, responsibilities, and procedures for implementing the Army Corrosion Prevention and Control (CPC) Program.

DA Pam 70-3, Army Acquisition Procedures *(15 July 1999)*

This pamphlet provides discretionary guidance on materiel acquisition management. It contains information relevant to research, development, and acquisition, and life-cycle management of Army materiel to satisfy approved Army requirements. The pamphlet applies to major systems, non-major systems, highly sensitive classified acquisition programs, automated information systems, and CIE.

This corrosion prevention and control section contains guidelines for establishing and managing the Army CPC program throughout the life cycle of Army materiel systems. It applies to all active Army elements that have responsibility for the development, acquisition, and support of military materiel. The ultimate goal of the CPC Program is to reduce corrosion in Army products. This goal must translate into specific, achievable objectives so that manpower and cost savings can be realized.

AR 700-127, Integrated Logistics Support *(10 November 1999)*

This regulation prescribes Department of the Army (DA) policies and assigns responsibilities for the management of acquisition logistics (ACQ LOG) as authorized by Department of Defense Directive (DOD) 5000.1 and DOD Regulation 5000.2. Integrated logistics support (ILS) is the process used by the Army to implement these mandatory ACQ LOG procedures and includes all elements of planning, developing, acquiring, and sustaining Army materiel throughout its life cycle.

This regulation contains no reference to corrosion.

DA Pam 750-40, Guide to Reliability Centered Maintenance for Fielded Equipment *(15 May 1982)*

This pamphlet is intended for use by all Army commands that have responsibility for materiel development and management. The guidance presented in this pamphlet illustrated how the elements of reliability-centered maintenance (RCM) are planned, developed, and incorporated into maintenance plans/programs for materiel systems.

This pamphlet contains no reference to corrosion.

USMC Policies and Directives

MCO 4790.18B, Corrosion Prevention and Control Program *(16 July 2004)*

This order establishes an effective CPC program to extend the useful life of all Marine Corps tactical ground and ground support equipment, and to reduce maintenance requirements and associated costs through the identification, implementation, and, if necessary, development of corrosion prevention and control products, materials, technologies, and processes. The use of these technologies and processes will repair existing corrosion damage and prevent, or at least significantly retard, future corrosion damage on all Marine Corps tactical ground and ground support equipment.

The overall program includes two primary elements:

- *Preventive corrosion control*. Preventive corrosion control employs approved techniques, materials, and technologies. Preventing corrosion starts during the acquisition process. The acquisition community shall consider state-of-the-art technologies and processes that directly address corrosion.
- *Corrective corrosion control*. Corrective corrosion control focuses on identifying, developing, and implementing technologies and processes that will correct current equipment deficiencies that result from corrosion and environmental damage. Corrective corrosion control includes all Marine Corps programs designed to correct corrosion damage (such as general maintenance and corrosion control and coating [C3]).

MCO4790.19, Depot Maintenance Policy *(7 October 2003)*

This document publishes Marine Corps policy for depot maintenance. It contains no reference to corrosion.

USN Policies and Directives

OPNAVINST 3750.6R, Naval Aviation Safety Program, August 11, 2003

This document issues policies and provisions of the Aviation Safety Program. It contains 9 references to corrosion as it relates to unsafe working conditions, material factors that deal with component failures due to corrosion, and damage incurred as a result of corrosion.

OPNAVINST 4700.7K, Maintenance Policy for US Navy Ships *(11 July 2003)*

This instruction sets policy and establishes responsibility for the maintenance of U.S. Navy ships. It applies to all ships and patrol craft of the U.S. Navy (active and reserve).

This instruction contains no reference to corrosion.

OPNAVINST 4790.2J, The Naval Aviation Maintenance Program *(1 February 2005)*

This instruction issues the maintenance policies, procedures, and responsibilities for the conduct of the Naval Aviation Maintenance Program (NAMP) at all levels of maintenance throughout naval aviation.

The NAMP provides for the maintenance, manufacture, and calibration of aeronautical equipment and material at the level of maintenance that will ensure optimum use of resources. It further provides for the protection of weapon systems from corrosive elements through an active corrosion control program, and the application of a systematic planned maintenance program.

OPNAVINST 4790.13, Maintenance of Surface Ship Electronic Equipment *(11 September 1987)*

This instruction establishes the maintenance policy for surface ship electronic equipment.

This instruction applies to all surface ships of the U.S. Navy with electronic equipment and the system commands that acquire and support equipment. This includes electronic equipment in combat systems as well as electronic components in hull, mechanical, and electrical systems.

This instruction contains no reference to corrosion.

OPNAVINST 4790.15D, The Aircraft Launch and Recovery Equipment Maintenance Program *(1 March 2001)*

The Aircraft Launch and Recovery Equipment Maintenance Program (ALREMP) provides an integrated system for performing maintenance and related support functions on ship-installed aircraft launching and recovery systems and associated peripheral support systems and equipment. This instruction outlines command, administrative and management relationships and establishes policies and procedures for the assignment of maintenance tasks and responsibilities for the ALREMP.

One of the special programs of ALREMP is Corrosion Prevention and Control, which prevents mishaps, excessive out-of-service time, serious damage to aircraft and equipment, and a resultant reduction in readiness with increased costs. Corrosion must be prevented or corrected at all levels of maintenance. Responsibilities for corrosion prevention and control and documentation procedures are outlined in NAVAIRSYSCOM, NAVSEASYSCOM, and other supporting directives. Under Organizational Maintenance Management Systems (PMMS NG), corrosion control documentation is mandatory. For additional information, see Appendix C for corrosion codes that must be entered on the ALRE MAF, OPNAV 4790/160.

OPNAVINST 4790.16, Condition Based Maintenance Policy *(6 May 1998)*

This instruction establishes policy and responsibility for the implementation and integration of condition-based maintenance (CBM) for naval ships, submarines, aircraft systems, equipment, and infrastructure.

This instruction contains no reference to corrosion.

OPNAVINST 5100.19D, Navy Occupational Safety and Health Program Manual for Forces Afloat *(30 August 2001)*

This document updates and clarifies occupational safety and health guidance for afloat forces.

The basic document and three attached volumes contain 19 references to corrosion. They generally discuss standards, causes, and recommended actions concerning safety related corrosion discrepancies, lead removal due to corrosion, CPC-incompatible materials, and incorrect procedures, general precautions, and observed defects where corrosion is a factor.

OPNAVINST 5100.23F, Navy Occupational Safety and Health Program Manual *(15 July 2002)*

This manual affirms the Navy Occupational Safety and Health (NAVOSH) program for all Navy personnel and implements applicable DoD instructions.

One reference to corrosion (Chapter 21) deals with the removal of any lead-containing materials as a result of corrosion.

OPNAVINST 8000.16, Naval Ordnance Maintenance Program *(26 June 2001)*

This document issues maintenance policies, procedures, and responsibilities for conduct of the Naval Ordnance Maintenance Program (NOMMP) at all levels of naval ordnance maintenance.

It contains 202 references to corrosion, dealing with the organizational, intermediate, and depot maintenance and repair of

- airborne armament equipment and armament handling equipment,
- air-launched missiles,
- aircraft guns, gun pods and associated equipment,
- hazardous materials, and
- other naval ordnance.

This document also references corrosion prevention and cleaning and minor corrosion treatment, corrosion control treatment and repainting, specific procedures to be followed for each type of metal and substrate to be cleaned, and the organization responsibilities to carry out an effective corrosion prevention and control program.

NAVFAC Business Management Standard, B-15.14, Cathodic Protection Program Objectives and Methodology

This standard defines the NAVFAC Cathodic Protection Program and details the requirements, processes, and resources for the successful planning, design, construction, operation, and maintenance of cathodic protection systems (CPS).

It provides guidance on requirements, processes, and resources for the successful planning, design, construction, operation, and maintenance of cathodic protection systems. Cathodic protection along with protective coatings is the effective method for mitigating corrosion of buried or submerged metallic structures.

NAVAIRINST 4200.25D, Management of Critical Application Items Including Critical Safety Items *(20 June 2002)*

This document establishes policy and procedures and assigns responsibilities for life-cycle management of replenishment items critical to naval aviation safety, and implements the DoD Flight Safety Critical Aircraft Part (FSCAP) Program.

It contains one reference to corrosion, which defines the failure of components due to fatigue or stress related to corrosion.

USAF Policies and Directives

AF Instruction 21-105, Maintenance-Air and Space Equipment Structural Maintenance *(9 April 2003)*

This instruction provides procedural guidance to establish and support the Corrosion Prevention and Control, Non Destructive Inspection (NDI), and Advanced Composites maintenance programs.

The Corrosion Prevention and Control Program ensures structural integrity of air and space systems and supporting equipment by preventing, assessing, detecting and controlling the damage and effects of corrosion.

AF Technical Order 36-1-191, Technical and Managerial Reference for Motor Vehicle Maintenance *(15 December 2004)*

The purpose of this manual is to provide Air Force vehicle fleet managers, supervisors, and technicians a single publication that encompasses technical and managerial guidance related to the maintenance and upkeep of their respective vehicle and vehicular equipment fleets.

Chapter 6, "Corrosion Prevention and Control for USAF Vehicles," establishes policies and procedures for controlling materials, processes, and levels of protection to be incorporated in, or performed upon, Air Force vehicles or vehicular equipment for corrosion prevention and control. It also contains general information pertaining to the scope of this publication, reference publications, definitions, Air Force policy, responsibilities, and levels of corrosion prevention. It includes a list of installations and the corrosive susceptibility of vehicles at or within close proximity to those installations, and the minimum effective wash cycle for the specified corrosion severity zone the equipment is assigned to or operating from. In addition, it provides the local installation commanders and vehicle fleet managers with the knowledge-based tools to establish an effective corrosion prevention and control program.

MIL-HDBK-1568 (USAF), Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems *(12 October 1994)*

This standard establishes the requirements for materials, processes, and techniques and identifies the tasks required to implement an effective corrosion prevention and control program during the conceptual, validation, development, and production phases of aerospace weapon systems. The intent is to minimize life-cycle corrosion-related costs and to improve reliability.

This standard provides a mechanism for implementation of sound materials selection practices and finish treatments during the design, development, production, and operational cycles of aerospace weapon systems. This standard defines requirements to ensure establishment and implementation of a corrosion prevention advisory board (where applicable), a corrosion prevention and control plan, and its accompanying finish specification as directed in Section 4. The corrosion prevention and control plan will dictate the organization of the boards, their basic duties, operating procedures, and the finish philosophies used in the systems. The finish specification will therefore be required to specify the detailed finish and coating systems to philosophies as approved in the corrosion prevention and control plan.

AETCI 21-106, Maintenance-Corrosion Control *(31 March 2005)*

This instruction establishes Air Education and Training Command (AETC) corrosion control guidance and procedures and assigns responsibilities for implementing and maintaining an effective corrosion control program for aircraft, aerospace ground equipment (AGE), electronic equipment, support vehicles, communications, electronics, meteorological (CEM) equipment, and all other end items relative to the functions of AETC.

The purpose is to orient command, base, and unit corrosion control programs toward preventing corrosion through the timely inspection and proper treatment of aerospace vehicles and support equipment to include proper maintenance of protective finishes and ensuring equipment cleanliness.

ACCI 21-105, Maintenance–Fabrication Program *(13 May 2003)*

This instruction provides guidance and direction necessary to develop an effective aircraft metals technology program, nondestructive inspection program, aircraft structural maintenance-corrosion control program and survival equipment program.

This instruction assigns responsibilities and establishes policies and procedures for implementing and maintaining the aircraft structural maintenance and corrosion control program for aircraft, aerospace ground equipment (AGE), communications, electronics and meteorological (CEM) equipment, and other end items relative to the functions of Air Combat Command.

Aircraft structural maintenance (ASM) incorporates design, repair, and fabrication of metal, fiberglass, plastic, and composite structures for aircraft. Corrosion identification, prevention and treatment procedures as well as removal and application of radar absorbing material (RAM) are also integral components of ASM. All aspects of ASM are geared toward maintaining the structural integrity and low observable systems at the organizational and intermediate levels.

Corrosion control programs will be oriented toward the prevention and control of corrosion through frequent cleaning, corrosion inspection and early detection, application of proper treatment materials/procedures, and maintenance painting. Frequent cleaning has proven to be the most effective means of preventing corrosion. Maintenance painting is defined for field purposes as spot painting, sectionalized painting, and complete scuff sand and overcoat.

AMCI 21-119, Maintenance–Corrosion Control Program *(3 November 2003)*

This instruction establishes Air Mobility Command (AMC) standards, procedures, and policies for aircraft and aerospace ground equipment corrosion abatement programs. It provides guidance and direction to develop an effective corrosion prevention, treatment, and management program. This instruction applies to all AMC and Air Force Reserve Command (AFRC) Reserve Associate units that maintain aircraft, munitions, support equipment, AGE, avionics and training equipment.

The AMC corrosion management program is oriented towards prevention. This is accomplished through equipment cleaning, maintenance of protective coatings, and early detection and treatment of corrosion. Strict adherence to corrosion prevention policies and technical orders is essential.

AFMCI 21-117, Maintenance–Corrosion Control and Prevention Program and Marking of Aerospace Equipment *(21 January 2003)*

This instruction provides policy and objectives and assigns responsibilities for implementing and maintaining an effective Corrosion Prevention and Control Program for aerospace systems, equipment, and components in AFMC. It specifies responsibilities performed at each level of command and implements guidance presented in AFI 21-105, *Air Force Occupational*, *Safety, and Health*, 48 and 91 series instructions, Technical Order's (T.O.) 1-1-691, *Aircraft Weapons Systems Cleaning and Corrosion Control*, 36-1-191, *Technical and Managerial Reference For Motor Vehicle Maintenance*, and 1-1-689, *Avionics Cleaning and Corrosion Prevention/Controls*, command instructions, and the specific aircraft-23 T.O.s.

The Air Logistics Centers (ALC), Aerospace Maintenance and Regeneration Center (AMARC), and other AFMC depot maintenance activities will implement this instruction as written.

AFI 21-101, AFRCSUP 1, Maintenance–Aerospace Equipment Maintenance Management *(31 March 2003)*

This supplement implements AFPD 21-1, *Air Force Maintenance Management*, and extends the guidance of Air Force Instruction 21-101, *Aerospace Maintenance Management*, dated 1 October 2002. This supplement describes Air Force Reserve Command procedures to be used in conjunction with the basic instruction.

This supports the Air Force Corrosion Program Office (AFCPO) by participating in equipment evaluations, corrosion program managers meetings, advisory boards, executive counsel meetings, and field surveys. It coordinates with Air Force Materiel Command (AFMC) on the development and testing of corrosion control techniques and material. It also organizes, directs, and manages the wing/group corrosion prevention program according to AFIs 21-101.

ANGI 21-105, Corrosion Control and Non-Destructive Test Programs

This instruction establishes objectives and assigns responsibilities for implementing and maintaining an effective corrosion prevention and control program. Paragraph 3, "Unit Corrosion Control Program," ensures the unit has an effective corrosion prevention and control program.

It publishes operating instruction (OI) that outline local policy and procedures for the following:

- Designate a senior NCO with appropriate technical background and corrosion control experience to serve as the unit corrosion prevention and control manager.
- Ensure a corrosion-training program is established.
- Ensure all personnel involved in aircraft maintenance receive corrosion control (initial and refresher) training, and meet safety and health requirements, as set forth under the Occupational Safety and Health Administration (OSHA).
- Ensure local procedures are established for periodic cleaning of aircraft and support equipment, in accordance with applicable publications.

PACAFI 21-105, Maintenance-Aerospace Fabrication Maintenance *(26 November 2003)*

This instruction provides guidance and direction necessary to develop an effective Aircraft Metals technology Program, Nondestructive Inspection Program, Aircraft Structural Maintenance and Corrosion Control Program, and Survival Equipment Program. PACAF tenant units shall comply with areas of this instruction that apply to their operation.

Aircraft Structural Maintenance incorporates design, repair and fabrication of metal, fiberglass, plastic and composite structures for aircraft. Corrosion identification, prevention and treatment procedures as well as removal and application of Radar Absorbing Material (RAM) are also integral components of ASM. All aspects of ASM are geared towards maintaining the structural integrity and Low Observable systems at the organizational and intermediate levels.

Corrosion control Programs shall be oriented towards the prevention and control of corrosion through frequent cleaning, corrosion inspection and early detection, application of proper treatment materials/procedures, and maintenance painting. Frequent cleaning has proven to be the most effective means of preventing corrosion. Maintenance painting is defined for field purposes as spot painting, sectionalized painting, and complete scuff sand and overcoat.

USAFEI 21-107, Maintenance-Fabrication Program *(11 April 2005)*

This instruction provides guidance and direction necessary to develop an effective Aircraft Metals Technology Program, Nondestructive Inspection Program, Aircraft Structural Maintenance and Corrosion Control Program, and Survival Equipment Program.

This instruction assigns responsibilities and establishes policies/procedures for implementing and maintaining the aircraft structural maintenance and corrosion control program for aircraft and aerospace ground equipment.

Aircraft Structural Maintenance (ASM) incorporates design, repair and fabrication of metal, fiberglass, plastic and composite structures for aircraft. Corrosion identification, prevention and treatment procedures are also integral components of ASM. All aspects of ASM are geared towards maintaining the structural integrity at the organizational and intermediate levels.

Corrosion control programs must be oriented toward the prevention and control of corrosion through frequent cleaning, corrosion inspection and early detection, application of proper treatment materials/procedures, and maintenance painting. Frequent cleaning has proven to be the most effective means of preventing corrosion. Maintenance painting is defined for field purposes as spot painting, sectionalized painting and complete scuff sand and overcoat.

All aircraft, ground and support equipment users and maintainers must attend periodic corrosion prevention and identification training as defined in Section 3.14, structural personnel are exempt from this requirement. Awareness is the key to an effective corrosion management program.

USCG Policies and Directives

The Coast Guard does not promulgate CPC policy directives; however, the Coast Guard does use the other services' policies as guidance. Specifically the USCG complies with Air Force and Navy technical orders and directives.

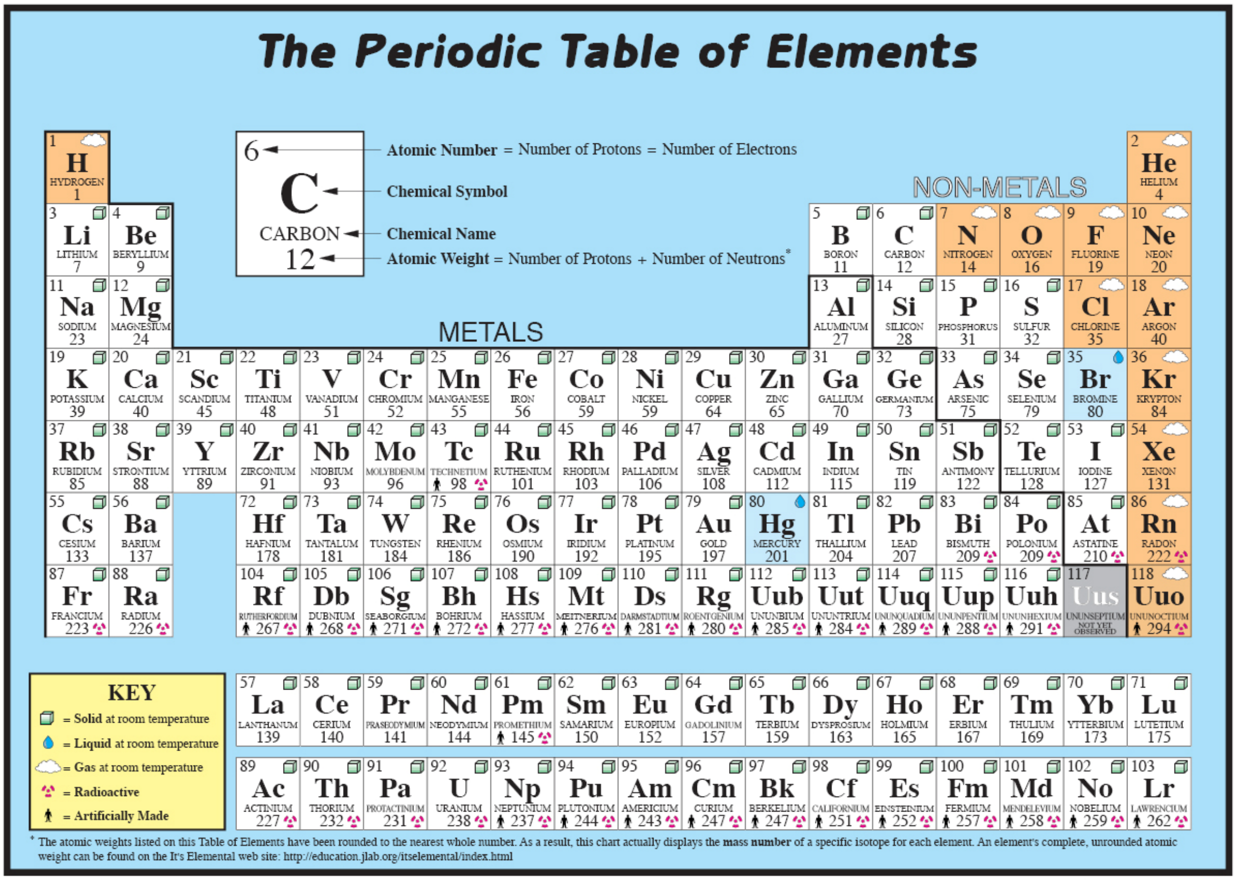
For aviation, the Coast Guard typically follows either the OEM or complies with Air Force and Navy technical orders. Specific application of corrosion protection components are contained within the Coast Guard's Aircraft Computerized Maintenance System (ACMS) procedure cards, which are peculiar for each weapon system. Procedure cards are similar to, but much more condensed than, the Air Force job guides and are used on the job site by the technician to accomplish a maintenance task.

For the facilities and ship organizations, the Coast Guard follows guidance as provided by the Navy technical orders.

Attachment 6 Scales, Tables, and Elements

Periodic Table of Elements

Figure 1. Periodic Table



Source: http://education.jlab.org/, accessed 9/17/2007.

Galvanic Corrosion Chart

Galvanic corrosion is the corrosion that results when two dissimilar metals with different potentials are placed in electrical contact in an electrolyte.

A difference in electrical potential exists between the different metals and serves as the driving force for electrical current flow through the corrodant or electrolyte. This electrical current results in corrosion of one of the metals. The larger the potential difference, the greater the probability of galvanic corrosion.

Galvanic corrosion only causes deterioration of one of the metals. The less resistant, active metal becomes the anodic corrosion site. The stronger, more noble metal is cathodic and protected.

Galvanic corrosion potential is a measure of how dissimilar metals will corrode when placed against each other in an assembly. Metals close to one another on the galvanic corrosion chart (Figure 3) generally do not have a strong effect on one another, but the farther apart any two metals are separated, the stronger the corroding effect on the one higher in the table.

The galvanic corrosion chart lists the potential differences for various metals in water. The order of the series can change for different electrolytes (for example, different pH, ions in solution).

Figure 2. Galvanic Corrosion Chart

Electrode Potential at 77 F (25 C)		
Anodic end (this is where the corrosion occurs)		
Element	Standard Electrode Potential (Volts)	
Lithium	-3.045	⇧ Anodic or Active
Potassium	-2.920	
Sodium	-2.712	
Magnesium	-2.340	
Beryllium	-1.700	
Aluminum	-1.670	
Manganese	-1.050	
Zinc	-0.762	
Chromium	-0.744	
Iron; Mild Steel	-0.440	
Cadmium	-0.402	
Yellow Brass	-0.350	
50-50 Tin-Lead Solder	-0.325	
Cobalt	-0.277	
Nickel	-0.250	
Tin	-0.136	
Lead	-0.126	
Hydrogen reference electrode	0.000	
Titanium	+0.055	
Copper	+0.340	
Mercury	+0.789	
Silver	+0.799	
Carbon	+0.810	
Platinum	+1.200	
Gold	+1.420	
Graphite	+2.250	Cathodic or Passive ⇩
Cathodic end, passive - (no corrosion here)		

Source figure and text: http://www.thelenchannel.com/1galv.php, accessed 8/30/2007

Note: Stainless steel alloys have been eliminated from this table as they can significantly change their potential and become much more active if exposed to stagnant or poorly aerated water.

Electromotive Series Chart

The electromotive series chart lists of chemical species (atoms, molecules, and ions) in the order of their tendency to gain or lose electrons (be reduced or oxidized, respectively), expressed in volts and measured with reference to the hydrogen electrode, which is taken as a standard and arbitrarily assigned the voltage of zero. At the hydrogen electrode, an aqueous solution containing hydrogen in its oxidized form (the hydrogen ion, H^+) at a concentration of one mole per liter is maintained at 25°C (77°F) in equilibrium with hydrogen in its reduced form (hydrogen gas, H_2) at a pressure of one atmosphere. The reversible oxidation–reduction half reaction is expressed by the equation $2H^+ + 2e^- \leftrightarrows H_2$, in which e^- represents an electron. The electrode potentials of several elements are shown in Figure 3. Conflicting conventions have been used for the signs of these potentials; those shown in Figure 3 generally agree with the recommendations of an international conference in 1953.

Figure 3. Electrode Potentials of Several Elements

Electromotive series at 25° C

	ion	half reaction	electrode potential (volt)
metals			
lithium	Li^+	$Li = Li^+ + e^-$	−3.05
potassium	K^+	$K = K^+ + e^-$	−2.92
barium	Ba^{2+}	$Ba = Ba^{2+} + 2e^-$	−2.90
calcium	Ca^{2+}	$Ca = Ca^{2+} + 2e^-$	−2.87
sodium	Na^+	$Na = Na^+ + e^-$	−2.71
magnesium	Mg^{2+}	$Mg = Mg^{2+} + 2e^-$	−2.37
aluminum	Al^{3+}	$Al = Al^{3+} + 3e^-$	−1.66
zinc	Zn^{2+}	$Zn = Zn^{2+} + 2e^-$	−0.76
iron	Fe^{2+}	$Fe = Fe^{2+} + 2e^-$	−0.44
cadmium	Cd^{2+}	$Cd = Cd^{2+} + 2e^-$	−0.40
nickel	Ni^{2+}	$Ni = Ni^{2+} + 2e^-$	−0.25
tin	Sn^{2+}	$Sn = Sn^{2+} + 2e^-$	−0.14
lead	Pb^{2+}	$Pb = Pb^{2+} + 2e^-$	−0.13
hydrogen	H^+	$H_2 = 2H^+ + 2e^-$	0.00
copper	Cu^{2+}	$Cu = Cu^{2+} + 2e^-$	+0.34
mercury	Hg^{2+}	$2Hg = Hg_2{}^{2+} + 2e^-$	+0.79
silver	Ag^+	$Ag = Ag^+ + e^-$	+0.80
platinum	Pt^{2+}	$Pt = Pt^{2+} + 2e^-$	+1.20
gold	Au^{3+}	$Au = Au^{3+} + 3e^-$	+1.49
nonmetals			
sulfur	S^{2-}	$S^{2-} = S + 2e^-$	+0.48
iodine	I^-	$2I^- = I_2 + 2e^-$	+0.54
bromine	Br^-	$2Br^- = Br_2 + 2e^-$	+1.07
chlorine	Cl^-	$2Cl^- = Cl_2 + 2e^-$	+1.36
fluorine	F^-	$2F^- = F_2 + 2e^-$	+2.87

Source: Figure and text = http://www.britannica.com/eb/art-61158, accessed 9/17/2007.

By subtracting one half reaction (and its potential) from another, the tendency of the resulting complete chemical reaction to occur may be determined. For example, the half reactions for copper and zinc may be combined to show that the reaction $Cu^{2+} + Zn \leftrightarrows Cu + Zn^{2+}$ has a potential of −1.10 volts. In conformity with the 1953 convention, the negative value of the voltage indicates that this reaction proceeds spontaneously from left to right as written; that is, metallic zinc dissolves in a solution of copper(II) ions to form metallic copper and to set free zinc(II) ions in the solution.