CORROSION PREVENTION AND CONTROL PLANNING GUIDEBOOK

Spiral Number 2—July 2004

Issued by: PDUSD (AT&L)

Director, Corrosion Policy and Oversight

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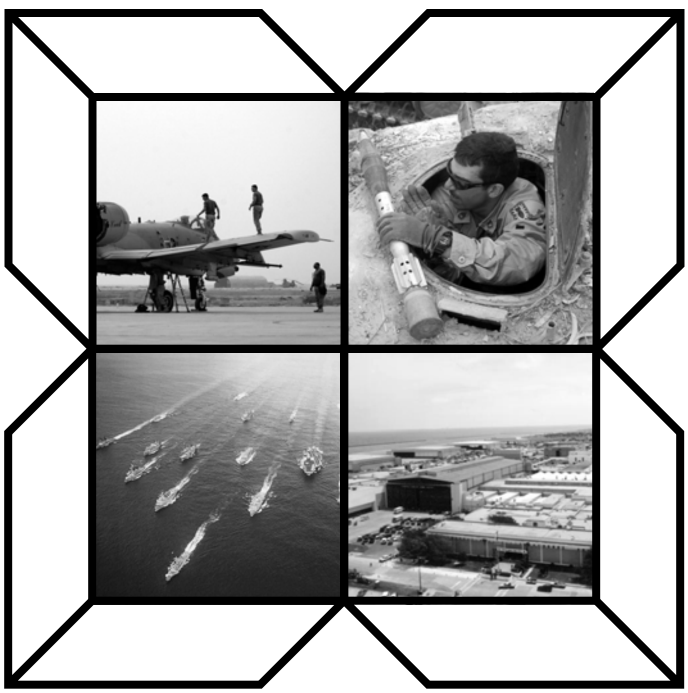

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Contents

Figures

Foreword

This document provides acquisition program managers with guidance for developing and implementing a Corrosion Prevention and Control Program for DoD weapon systems and infrastructure and with corrosion-related technical aspects that should be addressed for a viable design. This guidance is in accordance with 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 Appendix A).

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 effectively combat the effect 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. 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 design 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 can initiate and execute plans and actions to employ satisfactory materials and processes.

1. Background, Introduction, and General 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]
>
> *Honorable Michael W. Wynne*
> *DoD Corrosion Executive*

1.1 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 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 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.
- Financial—The cost of corrosion to the DoD is estimated to be between $10 billion and $20 billion annually.[2]

DoD has a long history of corrosion prevention and control (CPC). 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.

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

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

- In order to perform its mission, the Department must train and fight 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 primarily formulated to perform a special function, such as resistance to chemical agents or maintaining low signature. Corrosion is, at best, a secondary consideration.

1.2 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, facilities, and infrastructure or during the sustainment of existing systems, facilities, and infrastructure. That is why this *Corrosion Prevention and Control Guidebook* is targeted to them. It identifies the requirements for 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. 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. Guidebook Organization

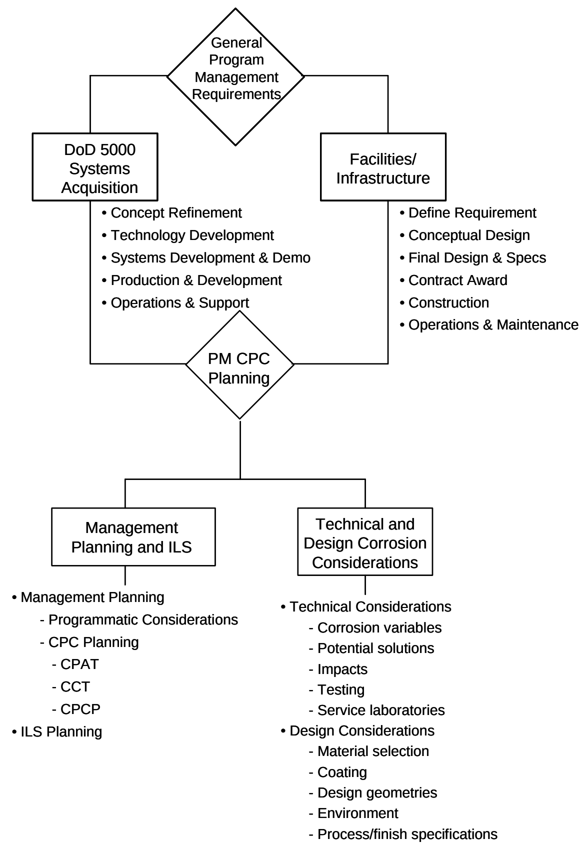


Figure 1-1 outlines the structure of this guidebook. The remainder of this chapter further explores the corrosion requirements as they relate to program managers (PMs). It also identifies general program manager requirements. Chapter 2 outlines specific corrosion-related planning requirements. Chapter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

1.2.1 Intended Use

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

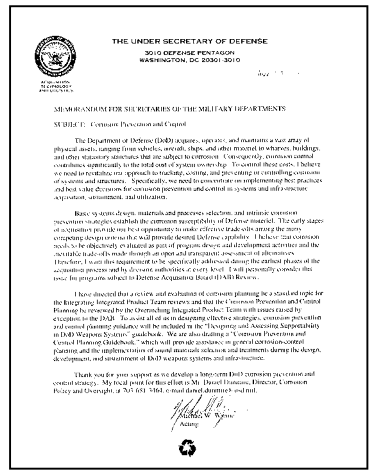
- provides tools and techniques for implementing sound material/process selection practices and finish treatments during all phases of DoD weapon system and infrastructure development;

- 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 advisory 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.

1.2.2 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 infrastructure as well as 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.

1.2.3 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

Among recent policy accomplishments, the most important may have been the publication of DoD corrosion prevention and control policy guidance (Appendix A).[3] 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.
- 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.*[4]
- 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.*[5]

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[3] USD(AT&L) memorandum, *Corrosion Prevention and Control*, 12 November 2003, Appendix A.

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

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

1.2.4 Applicable Documents

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

- DoD's corrosion 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*)[6]
- DoD's corrosion points of contact (POCs) (included as Appendix J)
- The military services' corrosion policies
- Links to corrosion-related laws and regulations
- Links to corrosion-related specifications and standards
- Copies of minutes from pertinent conferences and symposia
- Advanced Materials and Processes Technology Information Analysis Center (AMPTIAC) publications.

1.2.5 Definitions

The term "corrosion" means the deterioration of a material or its properties due to a reaction of that material with its chemical environment.[7] Other key definitions are as follows:[8]

- 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 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.

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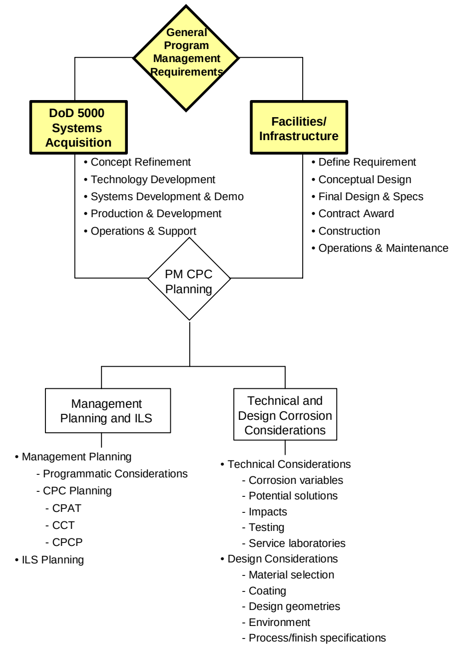
[6] DoD Report to Congress, *Long-Term Strategy to Reduce Corrosion and the Effects of Corrosion on the Military Equipment and Infrastructure of the Department of Defense*, December 2003.

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

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

1.3 General Program Management Requirements



DoD policy requires program and project managers to accomplish corrosion-related planning during acquisition proceedings. Management for acquisition and facilities corrosion prevention and control planning specifically applies to

- systems covered by the DoDD 5000-series publications, and
- facilities and infrastructure programs or projects.

The need for viable CPC planning in both communities is critical to program and project success.

Effective and viable CPC planning should be smoothly and seamlessly integrated. The initial phases of the acquisition cycle should consider the effects of corrosion on the system and should be reflected in the appropriate documentation. The Corrosion Prevention and Control Plan describes how a particular program or project will implement CPC planning. Both communities—systems and facilities/infrastructure—are detailed below.

1.3.1 DoD Systems Acquisition Process

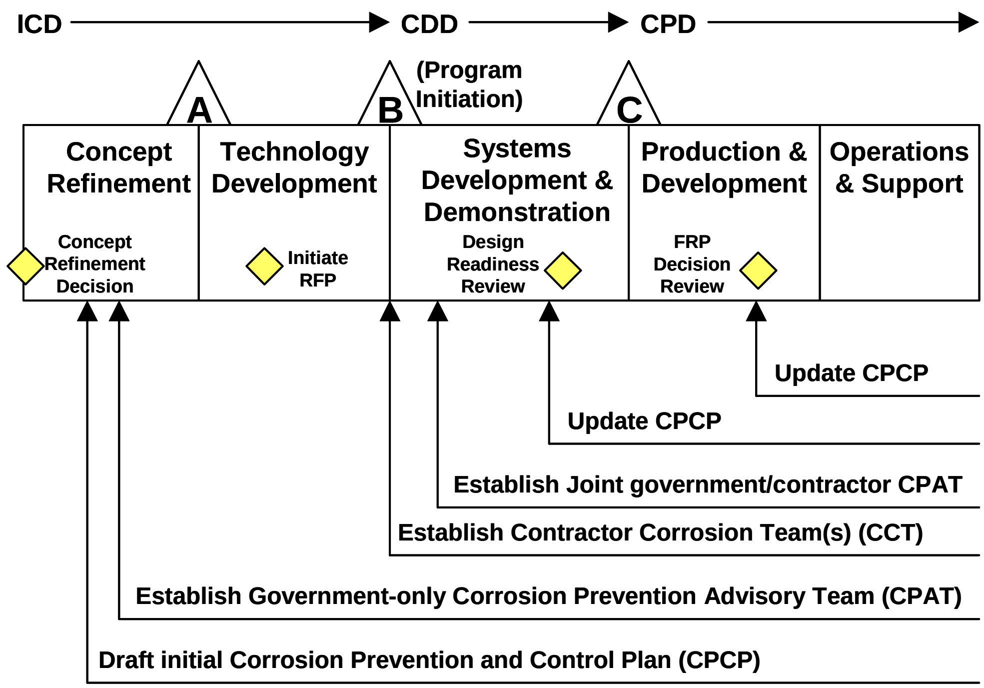
1.3.1.1 Systems Acquisition Community

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.[9] Figure 1-2 depicts the acquisition process with the corrosion-related requirements added.[10]

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

[10] 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 Chapter 2.

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 Advisory Team;
- development of a process or finish specification;
- environmental testing and verification plans;
- regimen 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 C 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.

1.3.1.2 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 methodology 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.

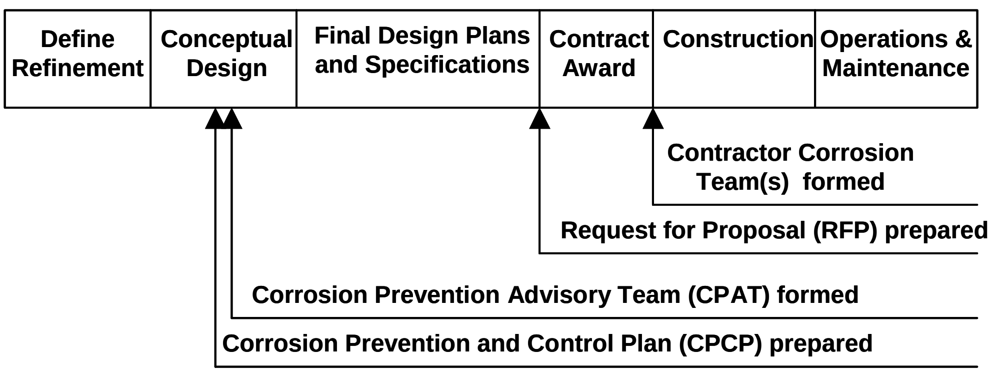
Success criteria should include both retention of functionality and freedom from required corrosion repair per specified performance requirements. Qualification should be based upon environmental exposure testing to the system requirements. Qualification by analysis or similarity should be on an exception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

1.3.2 Facilities and Infrastructure

1.3.2.1 Facilities Community

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 1-3 reflects the process to implement corrosion control during a construction project. An expanded discussion of the process is at Appendix D.

Figure 1-3. Process to Implement Corrosion Control During a Construction Project



The facilities/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.

1.3.2.2 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 that should be incorporated in the environmental test and verification plan. Standard government or industry test methods should be used where possible. The component/subsystem testing should reflect both the severity and duration of exposures. Success criteria should be both retention of functionality and freedom from required corrosion repair per specified performance requirements.

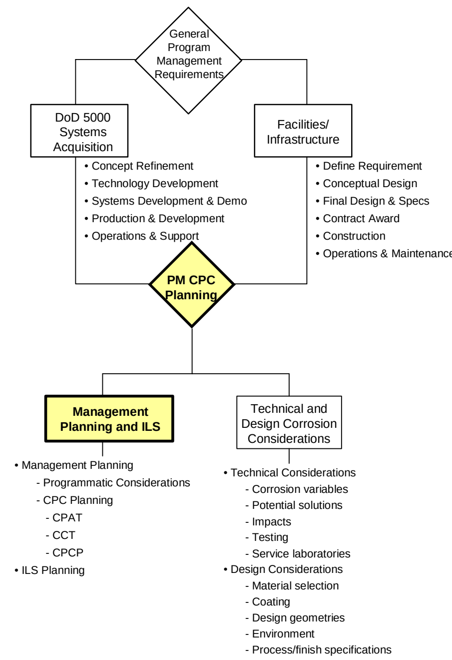
The next chapter covers program management corrosion prevention and control planning.

2. Program Management Corrosion Prevention and Control Planning

2.1 Program Management Requirements

Program managers and procuring agencies should consider corrosion prevention and control a key issue in designing, procuring, and maintaining a DoD system or facility. 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 (weapon system or facilities/ infrastructure) 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 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 and construction programs or projects. These are detailed in the Management Planning and Integrated Logistics Support (ILS) sections (this chapter) and Technical and Design sections (Chapter 3).

2.1.2 Management Planning

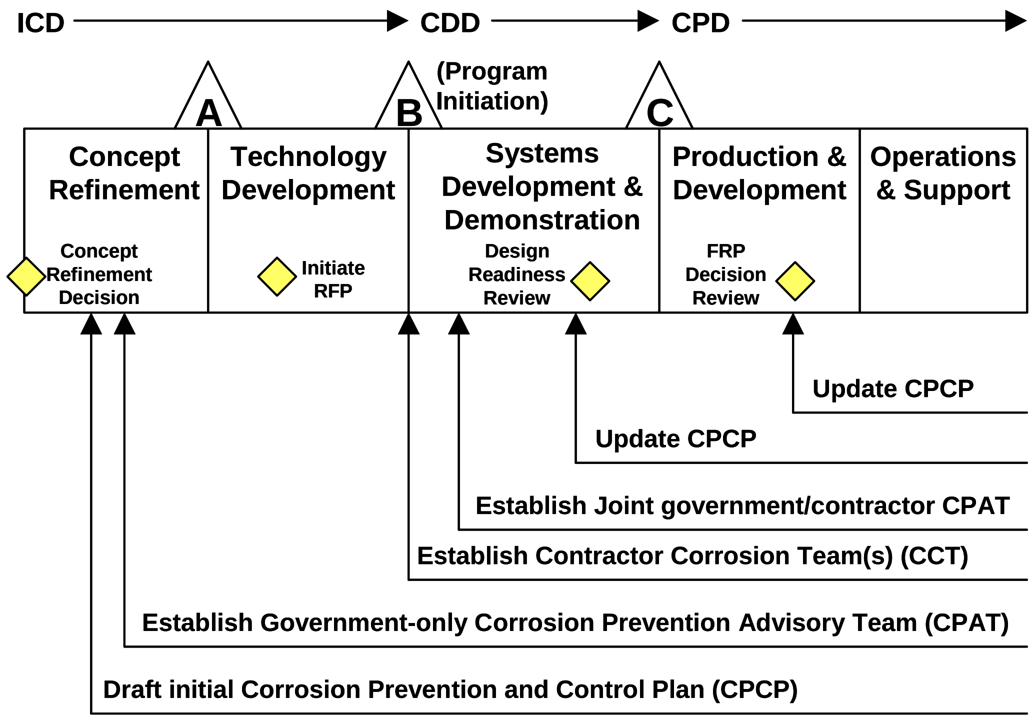
2.1.2.1 CPC Planning

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

- Prepare the 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 Advisory 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.

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

2.1.2.2 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.

2.1.2.2.1 Acquisition Cost

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

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

2.1.2.2.2 Warranties

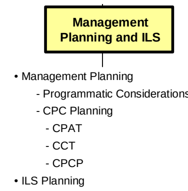
With a warranty, the seller essentially assures the buyer that the product will perform as represented over a period of time. If the product fails to perform as represented, the seller may be required to provide a new product or satisfactorily repair the existing product. With respect to corrosion in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

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 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 (outlined above) that implements and reflects the CPC planning
- Actual design, manufacture or construction, test, and support of the system.

2.1.2.3.1 Corrosion Prevention Advisory 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 program or project:

- 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 E.
- For a construction project, the project manager should establish the CPAT during the conceptual design phase of the project.

In either case, 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 or project manager on corrosion-related issues, 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 Integrating IPT (IIPT). Appendix J contains corrosion points of contact for DoD, the Coast Guard, NASA, and selected private sector organizations.

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 program or project manager and includes all involved military services. Membership from the services should include but not be limited to
  - program or 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 AMPTIAC), and
    - operational test personnel.

2.1.2.3.1.3 CPAT Duties

DoD team members have several responsibilities:

- Interface with the Contractor Corrosion Team (CCT) 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 or project manager 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.

In order 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 contractor and subcontractor facilities where critical parts and assemblies are being fabricated, processed, assembled, and readied for shipment.

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

The CPAT should provide 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 adequacy of maintenance documentation and guidance.

2.1.2.3.2 Contractor Corrosion Team

2.1.2.3.2.1 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 selected chairman 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 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 2.1.2.4.1 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 which 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 materials selection, treatments, and finishes;
- 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 documents 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 program's Milestone B or as early as possible in the program or project. The plan should describe the specific anticipated CPC measures to be implemented. Examples of a CPCP for systems or equipment and a CPCP for facilities or infrastructure are provided at Appendices F and G, respectively.

For facilities acquisition or construction, the program 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 system or facility being procured or constructed; and
- outline how the contractor will ensure vendor and subcontractor compliance with the corrosion plan approved by the program or project manager, including installation of government furnished equipment.

After contract award, the CPCP—for both equipment/systems programs and facilities/infrastructure programs—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
- 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

2.1.3 ILS As It Applies to the CPC Program

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 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.

2.1.3.2 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 Appendix H) should be integrated with each other and into the CPCP:

- Maintenance plan
- Support and test equipment

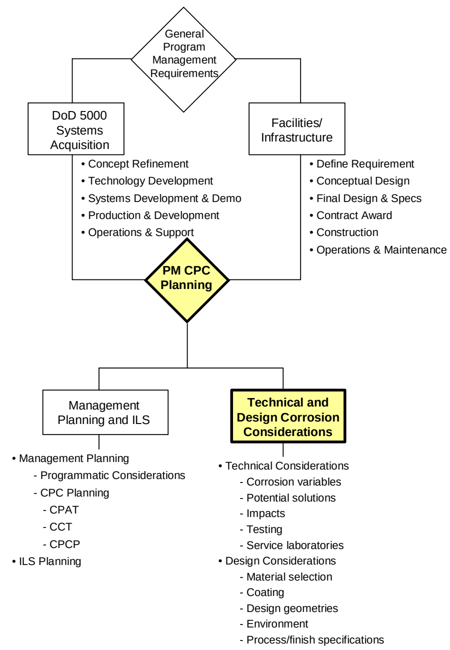
[2] DoDD 5000.1, *The Defense Acquisition System*, Enclosure 1, paragraph E1.17, 12 May 2003.

- 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 program manager.

3. Technical and Design Considerations



The design and construction of DoD weapon systems or facilities requires the proper blend of safety, affordability, and environmental needs with mission and operational requirements. DoD systems or facilities 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 manufacturing methods that will satisfy system requirements. The following are among the deterioration modes that contribute to failures:

- Pitting corrosion
- Stress corrosion
- Fretting fatigue
- Weathering
- Galvanic corrosion
- Corrosion fatigue
- Oxidation
- Fungus growth
- Exfoliation corrosion
- Thermal embrittlement
- Hydrogen embrittlement.

The CPCP and program or project specifications should detail specific requirements. To assist program managers and others participating in the acquisition of aerospace-related systems, a set of aerospace systems guidelines has been develop and included at Appendix K.

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 system or facility 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.)
- 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 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 acquisitions 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.

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 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 Exchange website (http://www.dodcorrosionexchange.org).

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, and avoid design features that make it difficult for protective coatings to function (sharp corners, for instance), and geometries that unnecessarily trap moisture. Appendix I outlines specific design guidance for facilities and infrastructure.

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
Corrosion Prevention and Control Memorandum

THE UNDER SECRETARY OF DEFENSE

3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION,
TECHNOLOGY
AND LOGISTICS

NOV 1 2 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

Appendix B
Acronyms

AFCESA	Air Force Civil Engineering Support Agency
AFI	Air Force instruction
AFP	Air Force pamphlet
AFPD	Air Force policy directive
AFRL	Air Force Research Laboratory
AMPTIAC	Advanced Materials and Processes Technology Information Analysis Center (scheduled to change name to Advanced Materials, Manufacturing, and Testing Information Analysis Center [AMMTIAC] in late 2004)
AS	allowable standard
CCT	Contractor Corrosion Team
CDD	capabilities development document
CFR	Code of Federal Regulations
CPAT	Corrosion Prevention Advisory 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
IIPT	integrating IPT
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
ORD	operational requirements document
OT&E	operational test and evaluation

PM	program 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
SSPC	Society for Protective Coatings
T.O.	technical order
TM	technical manual
TPC	Technical Practices Committee
TR	technical report
U.S.C.	United States Code
USAF	United States Air Force
UST	underground storage tanks

Appendix C
DoD Acquisition Process

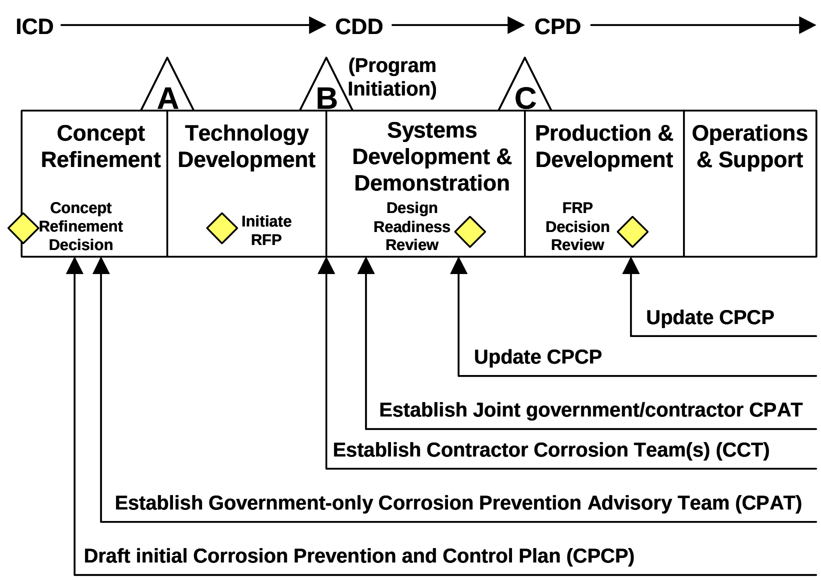
This appendix provides additional background information on DoD's acquisition process that is too detailed to include in Chapters 1, 2, or 3. Readers who require specific acquisition information for decision-making are encouraged to consult the Department's acquisition website for current and detailed 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 (MDAP) 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 (MNS) and operational requirements documents (ORD) 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 C-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 (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.); 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)."

- "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 expected participation 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-961D, 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-RRF), 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 your specification unless it is called out in Section 3 or 4 of your 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, 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 the section describing the CPCP.

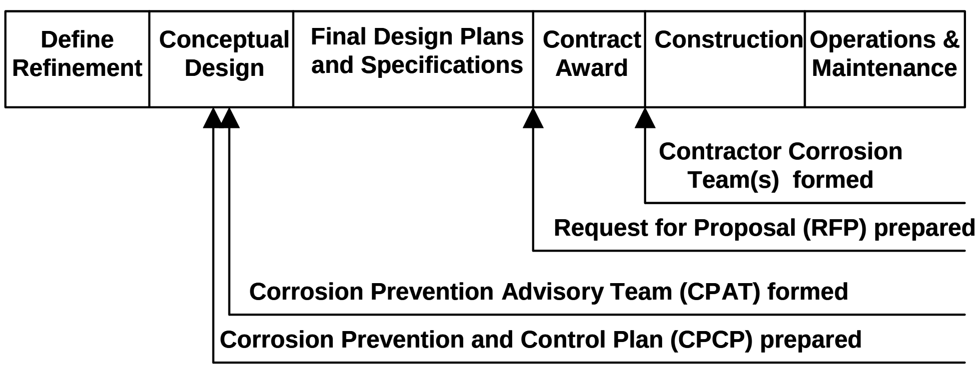
Appendix D
DoD Construction Process

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 Exchange website (http://www.DoDcorrosionexchange.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 D-1 depicts the implementation process for corrosion control during a DoD construction project. The individual steps of the process are explained below.

Figure D-1. Construction Process and CPC 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).

Conceptual Design

Once the requirements are defined, the 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 the National Association of Corrosion Engineers (NACE) and the Society for Protective Coatings (SSPC).

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 E
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:

4.2.1 Co-Chair the CPAT and assist the PM and user in tracking/resolving action items.

4.2.2 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.

4.2.3 Evaluate the CPCP to confirm it covers the proper steps for preventing corrosion and ensuring material compatibility.

4.2.4 Identify and help solve corrosion and material compatibility problems in the design, maintenance, and use of the system.

4.2.5 Periodically review and update technical data; send pertinent information to appropriate training organizations for use in training courses.

4.2.6 Review modification proposals to ensure proper requirements for corrosion prevention and control are included.

4.2.7 Review and validate Corrosion maintenance facility requirements documents.

4.3 User members will:

4.3.1 Serve on the CPAT.

4.3.2 Take part in contractor reviews and other actions to identify potential corrosion and material compatibility problems.

4.3.3. Assist in the review of the contractor's effectiveness in preventing corrosion through the design, production, and sustainment phases of acquisition.

4.3.4 Ensure recommendations for corrective actions or CPAT action items are submitted as early as possible and followed up.

4.3.5 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:

5.5.1 Definition or description

5.5.2 Alternatives

5.5.3 Team recommendation

5.5.4 Responsible action individual or agency

5.5.5 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 F
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 or project's actual CPCP will vary and should reflect the needs of the particular program/project.

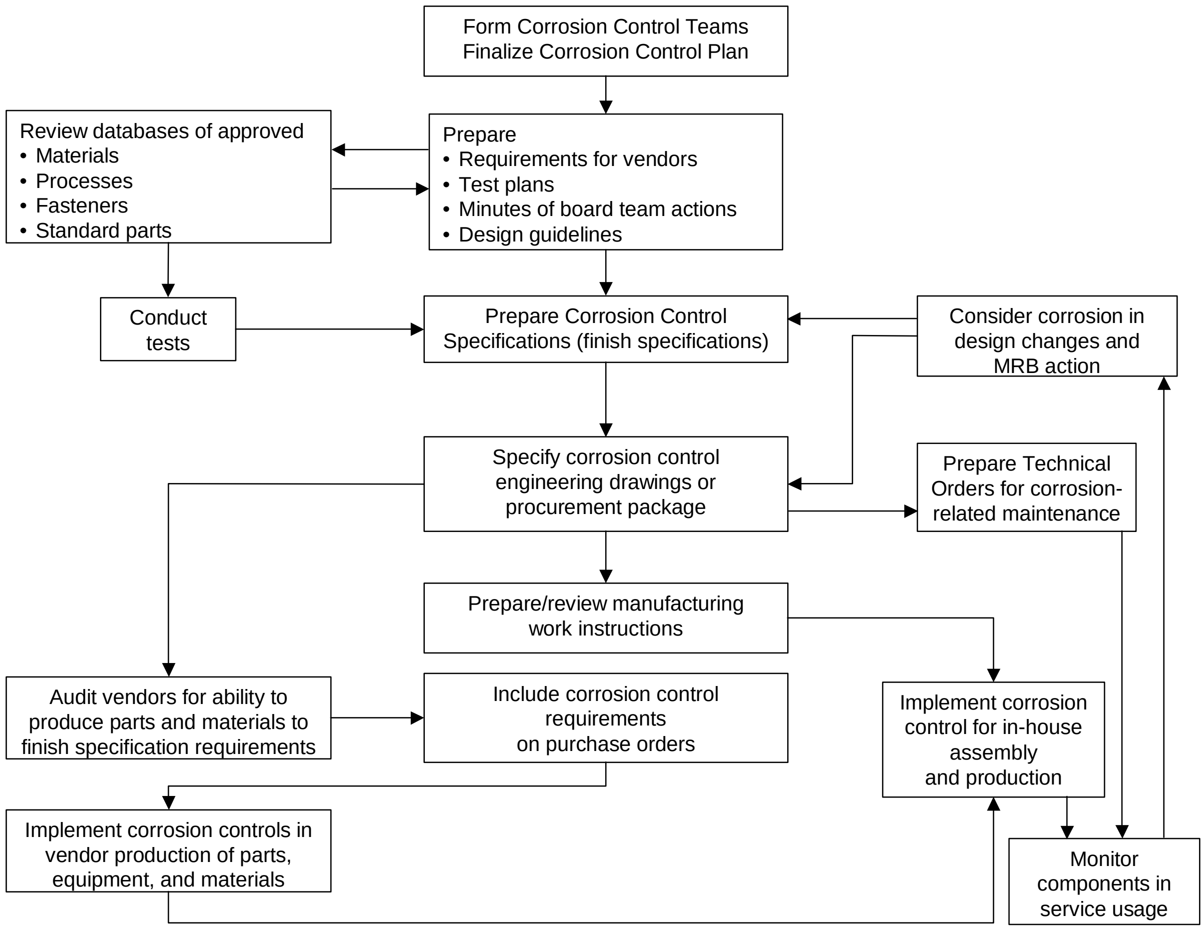
SECTION 1.0 INTRODUCTION

The purpose of the Corrosion Prevention and Control Plan 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/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 by participating in CCT meetings on an as-required basis. A corrosion control group that consists of 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 1-1. 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 1-1: 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 consisting of at least one Program representative from each of the team companies, chaired by the company IPT Corrosion Control Specialist. This team will provide and coordinate a consistent corrosion prevention and control (CPC) 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/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 Advisory 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, to establish engineering, manufacturing, and quality requirements that will be implemented by the responsible organizations at that company consistent with CCT direction. 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 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 that 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 that 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 at 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 that 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 assuring that 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 to ensure compliance with the JMS.

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 disposition of parts whose surface finish is damaged or defective.

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, 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 by the CCT with actions taken by the CCT 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. Recognize CCT decisions and incorporate these decisions into the product designs.

2. Coordinate corrosion-related design problems with the CCT.

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 to 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 as required during this process.

2. Request changes to engineering documentation to correct finishing procedures or 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 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 upon request for such assistance.

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

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

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

4. Reject any material or part that has been damaged or has not been finished as required by applicable specification/standards.

2.2.2.6 Manufacturing (Planning)

1. Translate processing and finishing requirements of engineering data on 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 changes to engineering design or specification requirements occur.

2.2.2.7 Hazardous Materials

1. Ensure that materials and processes comply with all federal and state regulations attempting to do so without compromising corrosion resistance.

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 Design into engineering datasets and drawings. Materials and Processes 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 Manufacturing (Planning) 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 may provide, through the CCT, alternate finish materials for approval by the CCT and cognizant 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 0.250 inches.

3.1.2.2 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, for fasteners that may be used in the 950 condition, and for 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 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, 304L and 316L may be used without heat treatment.

3.1.2.3 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 thin film sulfuric acid anodize per MIL-A-8625, Type I C.

   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-C-5541 Class 1A using materials conforming to MIL-C-81706. Where a low resistivity contact is necessary for electrical bonding purposes, MIL-C-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 Class 1A using materials conforming to MIL-C-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 each surface in the joint to protect against galling. Prior to application of primer to titanium, the 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 Alloy Steels

Non-corrosion resistant alloy steels should be protected from corrosion as follows:

- Non-corrosion resistant steel alloys with a maximum ultimate tensile strength is 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 plated 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 Materials & Processes approval.

- 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 whose ultimate tensile strength range is 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 <u>if and only if</u> no suitable alternate is acceptable and each use of cadmium plating will require Materials & Processes approval.
- When a wear-resistant coating is required on non-corrosion resistant alloy steels the surface should be nickel plated in accordance with QQ-N-290, Class 2, minimum thickness 0.002 inches or electroless nickel plated in accordance with MIL-C-26074 Class 1 or 2, Grade C, minimum thickness 0.0015 inch. This treatment is limited to steel alloy 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 QQ-P-35 (or by methods approved by materials and processes engineering) except as noted in the following.

- 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 and/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 QQ-P-35 or methods approved by Materials & 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 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 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 MIL-C-27725.

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 3-1 (when completed) and Table 3-2 for guidance on these coatings. Dissimilar metals as defined in Table 3-2 are protected from galvanic corrosion in accordance with the requirements of the Process/Finish Specification.

Table 3-1. Coating Thickness (Mils)

Spec#	Description	1-coat	2-coats

3.3 Sealing

Faying surfaces composed of dissimilar metals as defined in Table 3-2, 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 3-2. Grouping of Metals and Alloys

Group I	Magnesium and its alloys (use requires approval), Aluminum alloy 5052, 5056, A356 (and other casting alloys), 6061 6013, and 6063 (and other 6000 series alloys)
Group II	Cadmium, zinc (use requires approval) 2000,7000 aluminum alloys
Group III	Iron, lead, and tin and their alloys (except corrosion-resistant steel)
Group IV	Copper, chromium, nickel, silver, gold, platinum, titanium, cobalt, and rhodium and their alloys; brass, corrosion-resistant steel, 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 been shown that, frequently, during paint stripping the sealant is also removed. 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 ten 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 type 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 which 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 where 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 contaminate electrical and avionic equipment. When damp, a poultice is formed against the structure, resulting in corrosion. Furthermore, even though the climate may other wise 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

The 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 cause erosion of 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 four (4) or below is an indication that cleaning is required.

4.10 Solar Radiation

Although solar radiation (sunlight) is not corrosive, it will cause chalking of paint; it will cause hydrolysis of chlorinated organics; and it will degrade exposed plastics and elastomers. Degradation of these materials will allow 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.

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 G
Example of Corrosion Prevention and Control Plan for Facilities

This appendix provides an example of an Air Force Corrosion Planning 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 the 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:

2.1 Establishment of a Corrosion Prevention Advisory Team (CPAT)

2.2 Establishment of a Contractor Corrosion Team (CCT)

2.3 Corrosion control by design and materials selection

2.4 Use of cathodic protection to eliminate electrochemical reactions (corrosion)

2.5 Use of industrial water treatment to reduce corrosion, scale-forming deposits, and biological growths in heating and cooling systems

2.6 Use of protective coatings to reduce atmospheric corrosion or cathodic protection current requirements

2.7 Analysis of logs and records for failure prediction and selection of corrective actions

2.8 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 *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).

3.1.1 AFCESA assists HQ USAF (HQ USAF/ILE) in formulating corrosion control policy.

3.1.2 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.

3.1.3 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.

3.1.4 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)

3.1.5 AFCESA approves corrosion control methods and equipment not specified in Air Force publications.

3.1.6 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.

3.1.7 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 *Major Commands*. Major command civil engineers assist bases in developing and executing corrosion control planning (including aqueous, atmospheric, and underground corrosion) to ensure compliance with Department of Defense and Air Force policy; Environmental Protection Agency, Department of Transportation, and Occupational Safety and Health Administration regulations; and local (including host country) requirements.

3.2.1 Major command civil engineers, 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.

3.2.2. Major command civil engineers, 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.

3.2.3 Major command civil engineers, 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.

3.2.4 Major command civil engineers, 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 HQ AFCESA for review support when necessary.

3.3 *Corrosion Prevention Advisory Team* (CPAT)

3.3.1 The CPAT ensures design according to publications referenced in attachment 1 to this appendix.

3.3.1.1 Accomplishes surveys and design before construction contract advertisement or before construction in design-build contracts.

3.3.1.2 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.

3.3.2 CPAT does not delete corrosion control measures from any design without the specific approval of the command corrosion engineer.

3.3.3 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.

3.3.4 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.

3.3.5 CPAT coordinates among design team members to ensure material selections and system designs are compatible with the corrosion control approach selected.

3.3.6 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.

3.3.7 CPAT ensures the contractor notifies the contracting officer a minimum of 24 hours prior to installation, testing, or final acceptance of corrosion control systems.

3.3.8 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.

3.3.9 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.

3.3.10 As-built drawings shall provide the location of corrosion control system equipment, testing points, sampling points, and items requiring periodic maintenance.

3.3.11 CPAT uses field surveys, field tests, and experience of installation personnel in the design.

3.3.12 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.

3.3.13 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.

3.3.14 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.

3.3.15 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.

3.3.16 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.

3.3.17 CPAT publishes a squadron operating instruction for the corrosion control planning. Ensure civil engineer squadron craftspersons receive annual training on the requirements of the squadron operating instruction.

3.3.18 CPAT develops and manages the base corrosion control planning.

3.3.19 CPAT assists programmers in narrative and cost estimates for corrosion control line items on DD Forms 1391.

3.3.20 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.

3.3.21 CPAT provides technical advice to the construction inspector during installation, testing, and final acceptance of corrosion control systems.

3.3.22 CPAT coordinates operations and maintenance of corrosion control systems with the operations flight, including preventive maintenance scheduling. Ensure control charts for industrial water treatment detail the frequency and actions for testing and adjustment of each system.

3.3.23 CPAT reviews corrosion control records and takes action to correct deficiencies.

3.3.24 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.

3.4 *The Contractor Corrosion Team* (CCT)

3.4.1 The CCT ensures adequate corrosion prevention and control requirements are being implemented in accordance with the project contract, plans, and specifications.

3.4.2 The CCT ensures the implementation of corrosion prevention and control is documented and that documents are submitted in accordance with the required schedule.

3.4.3 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.

3.4.4 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.

3.4.5 The chairperson or his designees should sign off on all construction drawings after review of materials selection, treatments, and coatings.

3.4.6 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*, and associated Air Force instructions (AFIs) 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*; 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*. 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 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 organic materials in the air directly relates to the ozone concentration in the air, volatile organic compounds used in the drying and curing of coatings have environmental impact. Volatile organic compound limits vary by region of the country and the end-use surface coating operation.

4.2 *Safety*. Consult AFPD 91-2, *Safety Programs*, and AFPD 91-3, *Occupational Safety and Health*, as well as their associated AFIs, 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*. 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 wing 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*. 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 wing 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 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 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:

- Carries flammable product
- Is mission critical
- Would be expensive to maintain
- Would waste energy or impact the environment if corroded
- 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.

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*.

4.3.13 Installed cathodic protection systems shall provide protective potentials meeting criteria in NACE International Standard RP0169, *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 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 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 attachment 1).

4.4.4 Cathodic protection situations involving stray currents and stray electrical gradients require special analysis. For additional information, see MIL-HDBK 1136, *Maintenance and Operation of Cathodic Protection Systems*, Section 7; and NACE International Standard RP0169, 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 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 MIL-HDBK 1136, 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 ANG, booklets will be maintained at the installation and made available upon request.

5.1.5 Leak investigation using AF Form 1687, *Leak/Failure Data Record*. Use the information captured on AF Forms 1687 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*; MIL-HDBK 1164, *Operation and Maintenance of Water Supply Systems*; and MIL HDBK 1022, *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. A future publication will update treatment, testing and reporting procedures previously contained in rescinded AFP 91-41, *Industrial Water Treatment Procedures* (will be replaced by MIL HDBK 1149). 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*, as a minimum.

5.2.3 Use AF Form 1459, *Water Treatment Operating Log for Steam and Hot Water Boilers*, 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

AF Form 491, *Cathodic Protection Operating Log for Impressed Current Systems*

AF Form 1457, *Water Treatment Operating Log for Cooling Tower Systems*

AF Form 1686, *Cathodic Protection Operating Log for Sacrificial Anode System*

AF Form 1687, *Leak/Failure Data Record*

AF Form 1688, *Annual Cathodic Protection Performance Survey*

AF Form 1689, *Water Calibration*

AF Form 3221, *Absorption Operating Log*

AF Form 3222, *Centrifugal/Reciprocating Operating Log*

Attachment 1 to Appendix G: Glossary of References and Supporting Information

References

Public Laws

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

Air Force

AFPD 32-70, Environmental Quality

AFPD 91-2, Safety Programs

AFPD 91-3, Occupational Safety and Health

AFI 21-105, Aerospace Equipment Structural Maintenance

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

AFP 91-41, Industrial Water Treatment Procedures

AFH 32-1290(I), Cathodic Protection Field Testing

Military Handbooks

MIL-HDBK 1022, Petroleum Fuel Facilities

MIL-HDBK 1110/1, Paints and Protective Coatings

MIL-HDBK 1136, Maintenance of Operation of Cathodic Protection Systems

MIL-HDBK 1164, Operations and Maintenance of Water Supply 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

Protective Coatings Best Practices and Standards and Specifications

SSPC Good Painting Practices Volume 1

SSPC Systems and Specifications, 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

Air Force Publications

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 Reports

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

Technical Manual

TM 5-811-7, *Electrical Design, Cathodic Protection*, April 1985

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

Corps of Engineers Guide Specifications for Construction

UFGS 09900, *Painting, General*, July 1992

CEGS 16640, *Cathodic Protection System* (Sacrificial Anode), December 1988 (Rev Jun 97)

CEAGS 16640A, *Cathodic Protection System* (Sacrificial Anode), June 1990 (Rev Jun 97)

CEGS 16641, *Cathodic Protection System* (Steel Water Tanks), February 1989 (Rev Jun 97)

CEGS 16642, *Cathodic Protection System* (Impressed Current), October 1994 (Rev Jun 97)

Navy Publications

Maintenance and Operation Manuals

MO-225, *Industrial Water Treatment*, August 1990

MO-307, *Corrosion Control*, September 1992

Naval Facilities Guide Specifications

NFGS-09900J, *Paints and Coatings*, March 1997

NFGS-13110A, *Cathodic Protection by Galvanic Anodes*, June 1996

NFGS-13111A, *Cathodic Protection by Impressed Current*, June 1996

NFGS-13112, *Cathodic Protection System (Steel Water Tanks)*, December 1995

Military Handbooks, Tri-Service

MIL-HDBK-1004/10, *Electrical Engineering*, Cathodic Protection, January 1990

NACE International Recommended Practices and Technical Reports

SSPC Standards and Specifications, Volume 2, *Protective Coatings for Facilities*

Cathodic Protection

RP0177-83, *Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems*

RP0186-86, *Application of Cathodic Protection for Well Casings*

RP0285-85, *Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Metallic Liquid Storage Systems*

RP0286-86, *The Electrical Isolation of Cathodically Protected Pipel*ines

RP0387-90, *Metallurgical and Inspection Requirements for Cast Sacrificial Anodes for Offshore Applications*

RP0388-90, *Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Tanks*

RP0572-85, *Design, Installation, Operation, and Maintenance of Impressed Current Deep Anode Beds*

RP0675-88, *Control of External Corrosion on Offshore Steel Pipelines*

TPC (Technical Practices Committee) 11, *A Guide to the Organization of Underground Corrosion Control Coordinating Committees*

NACE International Item No. 54276, *Cathodic Protection Monitoring on Buried Pipelines*

NACE International Item No. 54277, *Specialized Surveys for Buried Pipelines*

Industrial Water Treatment

RP0189-89, *Online Monitoring of Cooling Waters*

RP0281-86, I*nitial 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*

SSPC Systems and Specifications, *SSPC Painting Manual*, Volume 2

Abbreviations and Acronyms

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
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
MIL-HDBK	Military Handbook
NACE	National Association of Corrosion Engineers
RCS	Report Control Symbol

Appendix H
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 is normally one of the subordinate plans 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

Real property, including all buildings and land, and permanent improvements to real property, including access roads and railroad spurs, security fencing, utility lines, dedicated spaces, piers required for operation and support of a system or equipment. Wash racks and other permanent corrosion control facilities need to be identified early on 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).

Appendix I
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

    - carries flammable product,
    - is mission critical,
    - would be expensive to maintain,
    - would waste energy or affect the environment if corroded, or
    - 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.

11. Based upon qualified analysis, provide both cathodic protection and protective coatings for the following aboveground tanks:

    - All ferrous tanks in contact with the earth, unless built on an oil-filled sand pad with plastic liner underneath
    - Interiors of steel water distribution storage tanks.

12. 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.

13. Ensure installed cathodic protection systems provide protective potentials meeting criteria in NACE International Standard RP0169, *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).

14. 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.

15. 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.

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 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.

17. 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.

18. 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.

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.

20. 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 J
Corrosion Points of Contact

OSD

Director, Corrosion Policy and Oversight
2001 North Beauregard Street
Suite 210
Alexandria, VA 22311
(703) 681-3464
(703) 681-3537 (fax)

Deputy Director
Corrosion Policy and Oversight
PDUSD(AT&L)/DS/SE
Crystal Mall #3, Suite 104
Arlington, VA 22202
(703) 602-0851, ext. 128

Associate Director, Materials and Structures
Office of the Deputy Under Secretary of Defense (Science & Technology)
1777 North Kent Street
Suite 9030
Arlington, VA 22209-2110
(703) 588-7418, DSN: 425
(703) 588-7560

Joint Staff

JCS/J4
Pentagon, Room 2C828
Washington, DC 20301-2500
DSN 227-6849
Comm. (703) 697-6849
Fax (703) 693-2584

Army

HQ Army Materiel Command
5001Eisenhower Ave.
Alexandria, VA 22333
ATTN: AMCOPS-IEI
(703) 617-9840
DSN 767-9840

U.S. Army Research Laboratory
AMSRL-WM-MC
Building 4600
APG, MD 21005
(410) 306-0869
(410) 306-0829 (fax)

U.S. Army TACOM
Building 172 AMSTA-AR-WET
Picatinny Arsenal, NJ 07806-5000
(973) 724-5795
DSN 880-5795

CEERDC-CFM (Facilities)
2902 Newmark Drive
Champaign, IL 61822-1076
(217) 373-6753

Army (continued)

U.S. Army, Aviation and Missile Command
AMSAM-RD-PS-AM
Redstone Arsenal, AL 35898
(256) 876-7472
DSN 746-7472

Navy

Office of Naval Research
ONR 332 Materials Division
800 N Quincy Street
Arlington, VA 22217
(703) 696-4309
(703) 696-0934 (fax)

NAVAIR (AIR-4.3.4)
BLDG 2188
Patuxent River, MD 20670
(301) 342-8000

(Ships/Submarines)
Head, Corrosion Control Division
NAVSEA 05M1
1333 Isaac Hull Ave. SE
Washington Navy Yard, DC 20376-5131
(202) 781-3671
(202) 781-3659

Code 613 Carderock Division
Marine Corrosion Branch
Naval Surface Warfare Center
9500 MacArthur Boulevard
West Bethesda, MD 20817-5700
DSN 287-5128
(301) 227-5128
(301) 227-5548 (fax)

NFESC (Facilities)
1100 23rd Avenue
Code ESC 63
Port Hueneme, CA 93043-4370
DSN 551-1057
(805) 982-1057

NAVFAC CP Technical Expert (Facilities)
NFESC
258 Makalapa Drive
Suite 100
Pearl Harbor, HI 96860-3134
DSN 472-1254
(808) 472-1254

Associate for Engineering Technology
Office of the Chief Engineer
Naval Facilities Engineering Command
(202) 685 9172
(202) 685-1577 (fax)

(Aviation)
NAVAIRSYSCOM/Head, Materials Protection/Corrosion
JCAA/Corrosion Steering Group Lead
Building 2188; Unit 5
48066 Shaw Road
Patuxent River, MD 20670
(301) 342-8007
(301) 342-8062 (fax)

Air Force

(Weapon Systems)
USAF Corrosion Prevention and Control Office
AFRL/MLS-OLR
325 Richard Ray Blvd (Building 165)
Robins AFB, GA 31098-1639
DSN 468-3284
(478) 926-3284
(478) 926-6619 (fax)

(Infrastructure/Facilities)
HQ AFCESA/CESM
139 Barnes Drive, Suite 1
Tyndall AFB, FL 32403
(850) 283-6215
DSN 523-6215
523-6219 (fax)

Marine Corps

Marine Corrosion Branch, Code 613
Naval Surface Warfare Center, Carderock Division
9500 MacArthur Blvd.
West Bethesda, MD 20817-5700
(301) 227-5135

Marine Corps Systems Command (MCSC)
2200 Lester Street (ACENG/ES&P)
Quantico, VA 22134-6050
DSN 378-3800
(703) 432-3800

Coast Guard

USCG Technical Support Manager (ARINC)
USAF Corrosion Prevention and Control Office
325 Richard Ray Blvd., Building 165
Robins AFB, GA 31098-1639
(478) 926-3284
(478) 926-6619 (fax)

NASA

Corrosion Studies
ASRC Aerospace/NASA
mail stop: ASRC-15
Kennedy Space Center, FL 32899
(321) 867-7558

NACE-International

Executive Director
NACE International
1440 South Creek Drive
Houston, TX 77084
281-228-6205
281-228-6305
www.nace.org

Director, Public Affairs
NACE International - The Corrosion Society
1440 South Creek Drive
Houston, Texas 77084
281-228-6213
281-228-6313 (f)

Advanced Materials and Processes Technology (AMPTIAC)

201 Mill Street
Rome, NY 13440
315-339-7023 or 315-339-7009

ManTech Enterprise Integration Center (DoD Corrosion Website)

318 Second Avenue
Hinton, WV 25951
Voice: 304-466-0513 or 304-466-1065
Fax: 304-466-6821

Society for Protective Coatings (SSPC)

Director, Product Development/Director of Marketing
40 24th Street, 6th Floor
Pittsburgh, PA 15222
Phone: 412-281-2331
Toll-free: 1-877-281-7772
www.sspc.org

Appendix K
Aerospace Systems Guidelines

1 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 provides for 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 Advisory Team (CPAT) is established, strong technical guidance is available to assure 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 as 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

AMSDL	Acquisition Management Systems and Data Requirements Control List
AMT	accelerated mission test
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
DoD	Department of Defense
EMI	electromagnetic interference
IAW	in accordance with
IVD	ion vapor deposited
KSI	kilo pounds per square inch
MPa	MegaPascaals
NATO	North Atlantic Treaty Organization
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 Applicable Documents

Listed below are a number of the aerospace documents, some of which have been cancelled or inactivated for new design. Even if cancelled or inactivated, the contents of these documents should be considered in development of the CPCP and the Process/Finish Specification.

Helpful websites include

- http://assist.daps.dla.mil/quicksearch/
- http://www.dscc.dla.mil/Programs/MilSpec/DocSearch.asp
- www.ihs.com.

2.1 Government Documents

2.1.1 Specifications and Standards

2.1.1.1 Specifications

2.1.1.1.1 Federal

A-A-371, *Linseed Oil, Boiled* (for use in organic coating)

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

QQ-C-390, *Copper Alloy Castings* (including cast bar)

TT-P-1757, *Primer Coating, Alkyd, One Compound*

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

TT-P-2760, *Primer Coating: Polyurethane, Elastomeric, High Solids*

2.1.1.1.2 Military

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, publish-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/research database (website above).

MIL-PRF-3043, *Resin-Coating, Unpigmented, For Engine Components and Metal Parts*

MIL-C-5056, *Coating, Permanent Resin, Process for Application on Aircraft Parts*

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

MIL-C-8514, *Coating Compound, Metal Pretreatment, Resin-Acid*

MIL-C-8779, Aircraft Requirements for Colors, Interior

MIL-S-8784, *Sealing Compound Aluminum Integral Fuel Tanks and Fuel Cells, Cavities, Low Adhesion, Accelerator Required*

MIL-C-11796, *Corrosion Prevention Compound, Petrolatum, Hot Application*

MIL-PRF-16173, *Corrosion Preventive Compound, Solvent Cutback, Cold-Application*

MIL-F-18264, *Finishes: Organic, Aircraft: Application and Control of—Inactive*

MIL-O-19838, *Oil Systems, Aircraft, Installation and test of*

MIL-PRF-22750, *Coating, Epoxy, High Solids*

MIL-PRF-23377, *Primer Coatings: Epoxy, High Solids*

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

MIL-M-24041, *Molding and Potting Compound, Chemically Cured, Polyurethane*

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

MIL-M-38510, *General Specification* for *Microcircuit*

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

MIL-PRF-46010, *Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting*

MIL-I-46058, *Insulating Compound, Electrical* (for coating printed wiring boards)

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

MIL-C-46168, *Coating, Aliphatic Polyurethane, Chemical Agent Resistant*

MIL-P-53022, *Primer, Epoxy Coating, Corrosion Inhibiting, Lead and Chromate Free*

MIL-P-53030, *Primer Coating, Epoxy, Water Reducible, Lead and Chromate Free*

MIL-C-53039, *Coating, Aliphatic Polyurethane, Single Component, Chemical Agent Resistant*

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

MIL-P-53084, *Primer, Cathodic Electrodeposition, Chemical Agent Resistant*

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

MIL-DTL-64159, *Coating, Water Dispersible Aliphatic Polyurethane, Chemical Agent Resistant*

MIL-C-81309, *Corrosion Preventive Compounds, Water Displacing, Ultra-Thin Film*

MIL-I-81550, *Insulating Compound, Electrical, Embedding, Reversion Resistant Silicone*

MIL-G-81322, *Grease, Aircraft, General Purpose, Wide Temperature Range*

MIL-DTL-81706, *Chemical Conversion Materials for Coating Aluminum and Aluminum Alloys*

MIL-PRF-81733, *Sealing and Coating Compound, Corrosion Inhibitive*

MIL-H-83282, *Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Metric,* NATO Code Number H-537

MIL-PRF-83483, *Thread Compound, Antiseize, Molybdenum Disulfide-Petrolatum*

MIL-DTL-83488, *Coating, Aluminum, Ion Vapor Deposited*

MIL-P-83953, *Pencil, Aircraft Marking*

MIL-DTL-85054, *Corrosion Preventive Compound, Water Displacing, Clear* (Amlguard)

MIL-PRF-85285, *Coating: Polyurethane, Aircraft and Support Equipment*

MIL-C-85322, *Coating, Elastomeric, Polyurethane, Rain-Erosion*

MIL-PRF-85582, *Primer Coatings: Epoxy, Waterborne*

MIL-HNBK-729 *Corrosion Prevention of Metals*

NAVMATP-4855-2, *Design Guidelines for Prevention and Control of Avionic Corrosion*

2.1.1.2 Standards

2.1.1.2.1 Federal

FED-STD-595, *Colors Used in Government Procurement*

2.1.1.2.2 Military

MIL-STD-171, *Finishing of Metal and Wood Surfaces*

MIL-STD-464, *Electromagnetic Environmental Effects, Requirements for Systems*

MIL-STD-883, *Test Methods and Procedures for Microelectronics*

MIL-STD-889, *Dissimilar Metals*

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

MIL-STD-1500, *Cadmium-Titanium Plating, Low Embrittlement, Electrodeposition*

MIL-STD-1530, *Aircraft Structural Integrity Program, Airplane Requirement*

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

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

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

2.1.2 Handbooks

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

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

MIL-HDBK-838, *Lubrication of Military Equipment*

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

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

2.1.3 Other Government Documents, Drawings, and Publications

2.1.3.1 Federal Aviation Administration (FAA)

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

2.2 Non-Government Publication

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 (ASTM)

Refer to 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, *Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems*

ASTM B117, *Standard Test Method of Salt Spray* (Fog)

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

ASTM B196, *Standard Specification for Copper-Beryllium Alloy Rod and Bar*

ASTM B197, *Standard Specification for Copper-Beryllium Alloy Wire*

ASTM D1732, *Standard Practices for Preparation of Magnesium Alloy Surfaces for Painting*

ASTM D2247, *Standard Practice for Testing Water Resistance of Coatings in 100 Percent Relative Humidity*

ASTM D2803, *Standard Guide for Testing Filiform Corrosion Resistance of Organic Coatings on Metal*

ASTM G47, *Standard Test Method for Determining Susceptibility to Stress-Corrosion Cracking of 2XXX and 7XXX Aluminum Alloy Products*

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

ASTM G85, *Standard Practice for Modified Salt Spray* (Fog)

2.2.2 Society of Automotive Engineers (SAE) Publications

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

AMS-QQ-P-35, *Passivation Treatments for Corrosion-Resisting Steel*

AMS-QQ-N-290, *Nickel Plating* (Electrodeposited)

AMS-QQ-C-320, *Chromium Plating* (Electrodeposited)

AMS-QQ-P-416, *Plating, Cadmium* (Electrodeposited)

AMS-2175, *Classification and Inspection of Castings*

AMS-2424, *Nickel, Plating, Low Stressed Deposit*

AMS-M-3171, *Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion*

AMS-3265, *Sealing Compound, Polysulfide (T) Rubber, Fuel Resistant, Nonchromated Corrosion Inhibiting for Intermittent Use to 360Mdf* (182Mdc)

AMS-3276, *Sealing Compound, Integral Fuel Tanks and General Purpose, Intermittent Use to 360Mdf* (182Mdc)

AMS-3277, *Sealing Compound, Polythioether Rubber, Fast Curing for Integral Fuel Tanks and General Purpose, Intermittent Use to 400℉* (204°C)

AMS-3281, *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)

AMS-3374, *Sealing Compound Aircraft Firewall*

AMS-4890, *Copper-Beryllium Alloy Castings 97Cu-2.1Be-0.52Co-0.28Si Solution Heat Treated* (TB00) (UNS C82500)

AMS-S-8802, *Sealing Compound, Temperature Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High Adhesion*

AMS-C-8837, *Coating, Cadmium* (Vacuum Deposited)

AMS-C-27725, *Coating, Corrosion Preventive, Polyurethane for Aircraft Integral Fuel Tanks for Use to 250 Mdf* (121 Mdc)

AMS-C-83231, *Coatings, Polyurethane Rain Erosion Resistant for Exterior Aircraft and Missile Plastic Parts*

ASTM G85, *Standard Practice for Modified Salt Spray* (Fog)

2.2.3 American Welding Society (AWS)

Refer to 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 Definitions

3.1 Aerospace System

All types of aircraft (including unmanned aerial vehicles (UAV)), 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 material applied onto or impregnated into a substrate for protective, decorative, or functional purposes. Such materials include, but are not limited to, paints, varnishes, sealers, metals, ceramics, phosphates, oxides, films, appliqués, adhesives, and inks.

3.1.1.2 Platings

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. 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

Two or more surfaces joined with overlap of adjacent surface or fitted closely or tightly together.

3.5 Hull Bottom

The surface area of a seaplane fuselage below the line 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 General Requirements

4.1 General Requirements

The program manager should prepare a Corrosion Prevention and Control Plan that complies with this guidebook. 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. One part of the requirements for the aerospace system should be the materials, processes, finishes, coatings and sealants to be used, 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 (IAW) this appendix and the basic guidebook, and good engineering practices which identifies the specific organic and inorganic surface pretreatments and 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. After the document has been approved by the responsible DoD procuring activity, these requirements should be included in all applicable production drawings and maintenance documents.

4.2.1 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 current issue of the AMSDL must be researched to ensure that only current and approved DIDs are cited on the DD Form 1423.

5 Detail Requirements

5.1 Materials and Process Considerations in Design

Corrosion design should be in IAW design concepts defined in MIL-STD-1530B. 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-1530B. MIL-STD-1530B 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 affordability of these systems is maintained 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.; which, when developed and applied in accordance with the guidance of this handbook; will ensure reliable, affordable, and supportable flight vehicle primary and secondary 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 those materials, processing methods and protective treatments which reduce failures due to deterioration. Deterioration modes which contribute to failures include but are not limited to 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 into, 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 that can enter by various methods. A "dams and drains" drawing/plan should be developed to assure adequate drainage is provided. This is critical because separate groups or contractors are often responsible for the design of modules or structure and 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 assure 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 MIL-STD-889, 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. 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 MIL-STD-889. 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/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 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, which 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 K-1. Although the ratings are based primarily on the results of standard corrosion tests, an experience factor can be substituted for those materials, which 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.

Table K-1. 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	
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 K-2. 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

In the event 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. The use of 7XXX-T6 aluminum alloys should be limited to thicknesses not to exceed 2.032 mm (0.080 inch). 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 pounds per square inch (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, and/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. In addition, 400 series martensitic steel require coatings for protection against corrosion. Table K-3 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 K-3. 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
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	
	AM355	Moderate	Very High
	AM350	Moderate	Very High
	9Ni 4Co-0.20C	Moderate	Low
	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 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 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 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-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 will not be used without the specific approval of the procuring activity.

5.1.3.8.1 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 MIL-STD-2175, and acquired per QQ-C-390. The use of bronze alloys other than those discussed above is discouraged.

5.1.3.8.2 Composites

Composites are defined as materials, which 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/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/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.

5.1.3.8.3 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 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 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.

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.

5.1.4 Non-metallic Materials

5.1.4.1 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 that cleaning fluids and other chemicals are not used on titanium assemblies where entrapment can occur. Substances that are known to be contaminants and can produce stress corrosion cracking include the following:

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 MIL-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 Class 1 MIL-C-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-C-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 should be Class 1 thickness (0.0005 inch). High strength steels having an ultimate tensile strength of 1241 MPa (180 Ksi) and above, should be plated with MIL-STD-1500, the vacuum deposition process in accordance with AMS-C-8837, or AMS-QQ-P-416, Type II, Class 2.

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-QQ-N-290, 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 1,000^{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-QQ-N-290 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-QQ-C-320, Class 2 (engineering), 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-QQ-N-290 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.

5.3.3.1 Detail Requirements

All finishes and coatings should be consistent with the requirements of MIL-STD-7179.

5.3.3.1.1 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.

5.3.3.1.2 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.

5.3.3.1.3 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 with a corrosion inhibiting sealant conforming to MIL-PRF-81733 or AMS-3265, and all fasteners should be wet installed with MIL-PRF-81733 or AMS-3265 sealants, or MIL-PRF-23377 primer.

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 K-4 should be as specified in Table K-6. The minimum applied dry-film thickness of the coatings in Table K-4 should be as specified in Table K-5. 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 K-5.

5.4 Environmental Sealing

5.4.1 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 K-4. 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 K-5. 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 K-4, 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 K-4, 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 K-6. 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, as defined in MIL-STD-889, should be protected, at a minimum, by the application of primer coating to each surface, in accordance with 5.2.1 and Table K-4 and Table K-5. The dry film thickness of the primer coating should be as prescribed for interior surfaces (see 5.3, and Table K-4 and Table K-5). Exceptions to the above are as follows:

a. Where 5.3 and Table K-4 and Table K-5 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(s) 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 5.3 and Tables 3 and 4) 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, as defined in MIL-STD-889, 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 K-4 and Table K-5. 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 in. (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 ± 0.03 in. (2.3 ±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 metal as defined by MIL-STD-889, 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, 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 to 1.8 mil (30 to 46 µm) to each of the interior surfaces. The surfaces of joints should be fayed, 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, 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.

5.5.3 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 K-4) 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 K-5. 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, 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.

5.5.4 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 surfaces that are fayed, whether sealed or not, should be coated with 0.0009 to 0.0015 inch (23 to 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 K-7 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 K-5.

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 K-7. Tubing Categories and Required Coatings

Category	Category Description	Primer 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 5.2.5, Tables 3 and 4, 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 5.2.11.2.1a.

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. 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

All permanently installed fasteners except as noted in 5.9.3 (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 which does not contain water. In high temperature areas, exceeding 107ºC (225ºF), Type I, Class 1 or 2 epoxy primer, or a sealant which 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.

5.5.11.1.2 Fasteners in Titanium

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 A286. Fastener materials for joining graphite composite structure to aluminum structure should be titanium. Cadmium plated 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 should not be used in contact with titanium. Fastener holes for interference fit fasteners should be primed with MIL-PRF-23377, Type I, Class 1 or 2, or MIL-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, 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.

5.5.11.3 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, 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.

5.5.11.4 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 5.1.5 and Tables 3 and 4 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 3.5) 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 5.1.5 and Tables 3 and 4.

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 5.1.5 and Table K-4 and Table K-5 in 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, should 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 3 and 4 that provides protection from the erosive effects of high speeds in water and should 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 finish should be approved in each instance by the procuring activity.

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 3 and 4). 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, seaspray, 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.

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.

5.5.24.1.4 PWB 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 K-4 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.

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 5.1.5 and Tables 3 and 4. 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, specific corrosion criteria should be formally included in these environmental test plan 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 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 336 hrs. of ASTM G-85 testing for Naval systems only). Avionics components should be exposed to cyclic sodium chloride-sulfur dioxide test of ASTM G85 for a minimum of 336 hours (Navy only systems). 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. Finish and corrosion protection verification should include the cyclic sodium chloride-sulfur dioxide test of ASTM G85 for a minimum of 336 hours (Navy-only systems).

Verification of corrosion protective coatings should comply with Table K-8:

Table K-8. 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 336 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 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 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 may convert to products which are more corrosive to aluminum. These products may be hygroscopic and may 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 should 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. The system must 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 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.

Erosion prevention practices should be applied to 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. All erosion prevention measures should be included 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.