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INCH-POUND

MIL-HDBK-1250A
18 August 1995
SUPERSEDING
MIL-STD-1250A
29 June 1992

DEPARTMENT OF DEFENSE

HANDBOOK FOR CORROSION PREVENTION AND DETERIORATION CONTROL IN ELECTRONIC COMPONENTS AND ASSEMBLIES

This handbook is for guidance only. Do not cite this document as a requirement.

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FOREWORD

1. This military standard is approved for use by all Departments and Agencies of the Department of Defense

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, US Army Missile Command, ATTN: AMSMI-RD-SE-TD-ST, Redstone Arsenal, AL 35898-5270 by using the Standardization Document Improvement Proposal (DD For 1426) appearing at the end of this document or by letter.

3. The purposes of this standard are to draw attention to the importance of corrosion as a major factor in the degradation of performance of electronic items; to establish minimum requirements for the control of corrosion and deterioration in DoD systems and applications; and to provide a guide to the selection of protective measures. The choice of materials and processes for electronic applications is, naturally, based on electrical properties not included in this document. It is the aim of this standard to aid in selecting from among suitable materials and processes, those which will withstand the attack of adverse environments during storage, shipment and service.

4. This standard supplements the more general requirements of MIL-STD-454, titled "Standard General Requirements for Electronic Equipment," with detailed information on the maintenance of desired characteristics during and after exposure to anticipated environments. The circuitry or design is not pertinent to this standard except insofar as design affects susceptibility to corrosion.

5. Contractors (and subcontractors) are encouraged to present new designs, materials, and technology which will improve the items or products, but should obtain procuring activity approval prior to such use.

6. Compliance with this standard will promote reliability of electronic components and assemblies, by preventing or minimizing deterioration from environmental causes.

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CONTENTS

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1. SCOPE

1.1 Scope. This standard establishes minimum requirements for procedures, materials and systems for protecting electronic components in DoD systems and assemblies from adverse environments. Protective measures shall be sufficient to maintain performance characteristics within specified limits both during and after exposure to moisture, high and low temperatures, corrosive gases, chemicals and microbial (fungal) attack. This standard does not deal with protection against damage from stress, shock, vibration or nuclear, biological and chemical (NBC) contamination. It is not concerned with electrical or mechanical design except insofar as design details affect susceptibility to corrosion. Provisions for prevention of deterioration shall apply to housings, chassis, hardware and similar parts which are assembled into electronic equipment, as well as to electronic and electro-mechanical components. Unless specifically mentioned in the item specification or drawing, this standard does not apply to standard commercial equipment.

1.2 Application. Unless otherwise specified, the responsibility for selecting any procedure, material or system shall rest with the activity procuring the end item. Where possible, protective measures shall be chosen from those specified herein. This does not preclude the use of proven commercial materials or processes selected by the manufacturer, supplier, or contractor, and concurred in by the procuring activity.

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2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

FEDERAL

L-P-516	-	Plastic Sheet and Plastic Rod, Thermosetting, Cast
QQ-C-320	-	Chromium Plating (Electrodeposited)
QQ-N-290	-	Nickel Plating (Electrodeposited)
QQ-P-35	-	Passivation Treatments for Corrosion-Resistant Steel
QQ-P-416	-	Plating, Cadmium (Electrodeposited)
QQ-S-365	-	Silver Plating, Electrodeposited: General Requirements for
VV-L-800	-	Lubricating Oil, General Purpose, Preservative (Water-Displacing, Low Temperature)
VV-P-236	-	Petrolatum, Technical
ZZ-R-765	-	Rubber, Silicone

MILITARY

MIL-I-10	-	Insulating Compound, Electrical, Ceramic
MIL-M-14	-	Molding Compounds, Thermosetting
MIL-P-79	-	Plastic Rods and Tubes, Thermosetting, Laminated
MIL-P-116	-	Preservation, Methods of
MIL-T-152	-	Treatment, Moisture and Fungus Resistant, of Communications, Electronic, and Associated Electrical Equipment
MIL-V-173	-	Varnish, Moisture and Fungus Resistant (for Treatment of Communications, Electronic, and Associated Equipment)
MIL-F-495	-	Finish, Chemical, Black, for Copper Alloys
MIL-P-997	-	Plastic Material, Laminated, Thermosetting, Electrical Insulation: Sheets, Glass Cloth, Silicone Resin
MIL-L-2105	-	Lubricating Oil, Gear, Multipurpose (Metric)

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MIL-R-3065	-	Rubber, Fabricated Products
MIL-L-3150	-	Lubricating Oil, Preservative, Medium
MIL-D-3464	-	Desiccants, Activated, Bagged, Packaging Use and Static Dehumidification
MIL-L-3918	-	Lubricating Oil, Instrument, Jewel Bearing
MIL-S-5002	-	Surfaces Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems
MIL-C-5541	-	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-L-6085	-	Lubricating Oil: Instrument, Aircraft, Low Volatility
MIL-L-6086	-	Lubricating Oil, Gear, Petroleum Base
MIL-R-6855	-	Rubber, Synthetic Sheets, Strips, Molded or Extruded Shapes, General Specification for
MIL-W-6858	-	Welding, Resistance: Spot and Seam
MIL-S-7124	-	Sealing Compound, Polysulfide, Accelerator Required for Aircraft Structures
MIL-F-7179	-	Finishes, Coatings, and Sealants for the Protection of Aerospace Weapons Systems
MIL-B-7883	-	Brazing of Steels, Copper, Copper Alloys, Nickel Alloys, Aluminum and Aluminum Alloys
MIL-S-8516	-	Sealing Compound, Polysulfide Rubber, Electric Connectors and Electric Systems, Chemically Cured
MIL-I-8574	-	Inhibitors, Corrosion, Volatile, Utilization of
MIL-A-8625	-	Anodic Coatings, for Aluminum and Aluminum Alloys
MIL-C-8837	-	Coating, Cadmium (Vacuum Deposited)
MIL-W-8939	-	Welding, Resistance, Electronic Circuit Modules
MIL-T-10727	-	Tin Plating: Electrodeposited or Hot-Dipped, for Ferrous and Nonferrous Metals
MIL-C-11796	-	Corrosion Preventive Compound, Petrolatum, Hot Application
MIL-T-12664	-	Treatment, Fungus Resistant, Paranitrophenol, for Cork Products
MIL-T-12879	-	Treatments, Chemical, Prepaint and Corrosion Inhibitive, for Zinc Surfaces
MIL-S-13165	-	Shot Peening of Metal Parts
MIL-C-14550	-	Copper Plating (Electrodeposited)
MIL-P-15037	-	Plastic Sheet, Laminated, Thermosetting, Glass Cloth, Melamine-Resin
MIL-L-15719	-	Lubricating Grease (High-Temperature, Electric Motor, Ball and Roller Bearings)
MIL-C-16173	-	Corrosion Preventive Compound, Solvent Cutback, Cold-Application

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MIL-I-16923	-	Insulating Compound, Electrical, Embedding
MIL-L-17331	-	Lubricating Oil, Stream Turbine and Gear, Moderate Service
MIL-I-17563	-	Impregnants for Aluminum, Copper, Iron, Magnesium and Zinc Alloy Castings
MIL-H-17672	-	Hydraulic Fluid, Petroleum, Inhibited
MIL-W-18142	-	Wood Preservative Solutions, Oil-Soluble, Ship and Boat Use
MIL-P-19161	-	Plastic Sheet, Laminated, Glass Cloth, Polytetrafluoroethylene Resin
MIL-T-22361	-	Thread Compound; Antiseize, Zinc Dust-Petrolatum
MIL-S-22473	-	Sealing, Locking, and Retaining Compounds (Single Component)
MIL-T-23142	-	Tape, Pressure Sensitive Adhesive, for Dissimilar Metal Separation
MIL-P-23377	-	Primer Coatings: Epoxy, Chemical and Solvent Resistant
MIL-L-23398	-	Lubricant, Solid Film, Air-Cured, Corrosion Inhibiting, NATO Code Number S-749
MIL-P-23408	-	Plating: Tin-Cadmium (Electrodeposited)
MIL-S-23586	-	Sealing Compound, Electrical, Silicone Rubber, Accelerator Required
MIL-G-23827	-	Grease, Aircraft and Instrument, Gear and Actuator Screw, NATO Code Number G-354, Metric
MIL-M-24041	-	Molding and Potting Compound, Chemically Cured, Polyurethane
MIL-G-24139	-	Grease, Multipurpose, Water Resistant
MIL-M-24325	-	Molding Material, Plastic, Epoxy Compounds, Thermosetting
MIL-P-25518	-	Plastic Materials, Silicone Resin, Glass Fiber Base, Low Pressure Laminated
MIL-C-26074	-	Coatings, Electroless Nickel, Requirements for
MIL-P-28809	-	Circuit Card Assemblies, Rigid, Flexible, and Rigid-Flex
MIL-G-45204	-	Gold Plating, Electrodeposited
MIL-P-45209	-	Palladium Plating, Electrodeposited
MIL-P-46002	-	Preservative Oil, Contact and Volatile Corrosion-Inhibited
MIL-L-46010	-	Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting
MIL-I-46058	-	Insulating Compound, Electrical (for Coating Printed Circuit Assemblies)

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MIL-P-46067	-	Plastic Embedding Compound, Epoxy Resin System
MIL-R-46085	-	Rhodium Plating, Electrodeposited
MIL-P-46105	-	Primer Coating; Weld-Through, Zinc-Rich
MIL-P-46112	-	Plastic Sheet and Strip, Polyimide
MIL-S-46163	-	Sealing, Lubricating and Wicking Compounds: Thread-Locking, Anaerobic, Single-Component
MIL-C-46168	-	Coating, Aliphatic Polyurethane, Chemical Agent Resistant
MIL-P-46847	-	Plastic Material, Foamed Polyurethane for Encapsulating Electronic Components
MIL-C-81309	-	Corrosion Preventive Compounds, Water Displacing, Ultra-Thin Film
MIL-G-81322	-	Grease., Aircraft, General Purpose, Wide Temperature Range, NATO Code Number G-395
MIL-C-81562	-	Coatings, Cadmium, Tin-Cadmium and Zinc (Mechanically Deposited)
MIL-P-81728	-	Plating, Tin-Lead (Electrodeposited)
MIL-S-81733	-	Sealing and Coating Compound, Corrosion Inhibitive
MIL-C-83488	-	Coating, Aluminum, Ion Vapor Deposited
MIL-C-85054	-	Corrosion Preventive Compound, Water Displacing, Clear (Amlguard)
MIL-L-87177	-	Lubricants, Water Displacing, Synthetic

STANDARDS

MILITARY

MIL-STD-186	-	Protective Finishing for Army Missile Weapon Systems
MIL-STD-276	-	Impregnation of Porous Nonferrous Metal Castings
MIL-STD-454	-	Standard General Requirements for Electronic Equipment
MIL-STD-810	-	Environmental Test Methods and Engineering Guidelines
MIL-STD-838	-	Lubrication of Military Equipment
MIL-STD-1276	-	Leads for Electronic Component Parts
DOD-STD-1866	-	Soldering Process, General (Non-Electrical)
MIL-STD-2000	-	Standard Requirements for Soldered Electrical and Electronic Assemblies
MIL-STD-2219	-	Fusion Welding for Aerospace Applications

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(Unless otherwise indicated, copies of the federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Ave., Philadelphia, PA 19111-5094.)

2.2 Non-Government publication. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM G 15	-	Standard Terminology Relating to Corrosion and Corrosion Testing
ASTM G 21	-	Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi
ASTM B 117	-	Standard Test Method of Salt Spray (Fog) Testing
ASTM D 495	-	Standard Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation
ASTM D 4300	-	Standard Test Methods for Ability of Adhesive Films to Support or Resist the Growth of Fungi

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

SOCIETY OF AUTOMOTIVE ENGINEERS, INC. (AEROSPACE MATERIAL SPECIFICATIONS)

SAE AMS 2401	-	Cadmium Plating, Low Hydrogen Content Deposit
SAE AMS 2404	-	Electroless Nickel Plating
SAE AMS 2416	-	Nickel-Cadmium Plating, Diffused

(Application for copies should be made to the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.)

(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 other informational services.)

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

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3. DEFINITIONS

3.1 Standard definitions. Standard definitions relating to corrosion and corrosion testing are found in ASTM G 15. The definitions that follow supplement or expand those found in ASTM G 15.

3.2 Corrosion. A specific type of deterioration resulting in damage or impairment of metals or metallic parts as the result of attack by moisture, air, acid, alkali, chemicals, or electrochemical action. Although mechanical stress is a factor in certain types of corrosion, damage or breakage as the result of purely mechanical load or shock is not included in this document.

3.3 Corrosion-resistant steels. Steel with sufficient alloy content (usually chromium and nickel) to resist atmospheric corrosion; sometimes called "stainless" steels, although they are neither stainless nor rustless. A wide variety of analyses and properties are included in the term "corrosion-resistant steels."

3.4 Deterioration. A general term describing the impairment of desired physical, chemical, mechanical or electrical properties resulting from aging, environmental exposure, chemical or biological attack, or changes in temperature or pressure.

3.5 Dissimilar metals. Any combination of bare metals which is not indicated as a permissible couple in table III, Galvanic Couples. The greater the difference in the electromotive force (EMF) the more dissimilar are the two metals and the greater is the galvanic attack on the anodic metal (see 3.9).

3.6 Electromagnetic interference (EMI). Any spurious external disturbance causing unwanted response in electronic equipment, or any unwanted signal emanating from the equipment; sometimes called radio frequency interference (RFI).

3.7 Encapsulation. The embedment and complete envelopment of an item or assembly in a solid mass of a plastic, elastomeric, or ceramic insulating material.

3.8 Fungi. Any of a large group of thallophytic organisms described as molds, mildews, mushrooms, yeasts, or any organism absorbing nutrition from living or dead organic materials.

3.8.1 Fungicidal. Capable of killing fungi.

3.8.2 Funginert. Neither destroying nor supporting the growth of fungi.

3.8.3 Funginutrient. Providing sustenance for fungi.

3.8.4 Fungus resistant. Unaffected by fungi, as established through testing in accordance with MIL-STD-810.

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3.9 Galvanic series. A ranking of metals in accordance with their relative anodic and cathodic position determined in some specific electrolyte as defined in table III.

3.10 Hermetic seal. An impervious seal made by the fusion of metals or ceramic materials (as by brazing, soldering, welding, fusing glass or ceramic) which prevents the passage of gas or moisture.

3.11 Purple plague. A brittle, gold-aluminum compound formed in the presence of silicon.

3.12 Red plague. A copper oxide corrosion product formed on silver plate-over-copper at pinholes or breaks in the silver plate.

3.13 Stress corrosion. A specific type of accelerated corrosion resulting from the combined effects of mechanical tensile stress and corrosive environments.

3.14 Vapor (or Volatile) corrosion inhibitor. A chemical which vaporizes and condenses on nearby surfaces, retarding corrosion from moisture.

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4. GENERAL REQUIREMENTS

4.1 Unacceptable designs. Equipment design shall be considered unacceptable from a corrosion/deterioration prevention standpoint if any of the following conditions are included:

a. Traps or crevices susceptible to moisture collection
b. Unsealed permanent fasteners (install with wet primer of polysulfide sealant)
c. Ineffective gasket and lid design and insufficient fasteners in moisture-tight housing design
d. Untested adhesively bonded designs (qualify with stress and humidity testing)
e. Metallic construction if nonmetallic is acceptable
f. Printed circuit boards (PCBs) without conformal coating (use MIL-I-46058)
g. Unprotected galvanic couples as defined in table III
h. Equipment requiring preventive maintenance for corrosion control
i. Non-hermetic design for sealing integrated circuits
j. Graphite composite construction not insulated from structural metals
k. Conductive material or EMI gaskets without an environmental seal on both sides of the contact area.
l. Improper drain holes (size and location)
m. Unsealed heat-shrinkable electrical connector boots
n. Surface metal coating susceptible to whisker growth
o. Wooden containers or components housed in corrosive woods such as oak, chestnut, beech, douglas fir, cedar, birch or teak
p. Desiccant design without visual indicators for periodic inspection
q. Design that allows static potential build-up which could result in spark discharge
r. Design that emits electromagnetic energy which could affect the operation of other equipment
s. Copper alloys coupled to aluminum
t. High residual stresses in formed metallic parts
u. Electronic design located near and vented to vehicle exhaust gases
v. Printed wiring assemblies (PWAs) mounted horizontally (mount PWAs vertically with the card edge connector on the vertical edges, not the bottom edge)
w. Electrical connectors mounted vertically (mount connectors horizontally with the wires leading up to the connector back shells)
x. Coaxial connectors with no sealant around the point where cable enters a connector (use a non-acid cure RTV-type sealant)
y. Corrosion susceptible hinge mechanisms
z. Wire rope and chain-type lanyard assemblies that are not corrosion resistant

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aa. Equipment and components mounted directly to compartment floors where standing water is possible.

4.2 Unacceptable materials. The following materials shall be considered unacceptable in equipment design:

a. Magnesium
b. Aluminum alloy 2024-T3 or 2024-T4 (use 2024-T8 or 5000/6000 series aluminum alloys)
c. Aluminum alloy 7075-T6 (use 7075-T73 or 7050-T76)
d. Precipitation hardening steels in H900, H950, or H1000 tempers
e. Graphite lubricants
f. Polyvinyl chloride (PVC) and chlorinated polyvinyl chloride (CPVC)
g. Corrosive-type RTV silicone rubber sealant (yields acetic acid during cure)
h. Rubber that is susceptible to ozone damage
i. Teflon-insulated silver plated hookup wire shall only be used with prior approval of the procuring activity
j. MIL-C-5541 (Class 3) conversion coating on aluminum (use anodized or class 1A treatment)
k. Cadmium plating in accordance with QQ-P-416, Type I (use Type II)
l. Gold plated electrical contacts with a nickel undercoating
m. Silver plated electrical contacts
n. Nickel plated aluminum construction
o. Potting materials and/or foam materials that are reversion-prone
p. Materials not inherently moisture and fungus-resistant
q. RA solder flux
r. Gold over silver or copper without a barrier coat of nickel
s. Organic materials that outgas corrosive vapors
t. Polymide insulation.

4.3 Cleaning. All surfaces shall be thoroughly cleaned before joining, coating, potting, impregnating, or encapsulating. Surfaces shall be cleaned after brazing, soldering or welding to remove contaminants. General cleaning shall meet the requirements of MIL-S-5002 and the cleaning of high reliability electronic parts shall be in accordance with MIL-STD-2000. High strength steels (over 180 ksi or HRC 40) shall not be cathodically cleaned in either acid or alkaline baths and shall not be acid cleaned except anodically. Organic solvents for use on plastics shall be selected with care to avoid crazing or other damage to the plastic. For vapor degreasing, solvent cleaning and drying, only those materials and procedures listed in MIL-STD-186 shall be used. Care shall be taken that cleaning materials are compatible with all materials in the part or assembly. Dust, dirt and fingerprints shall be removed prior to assembly or storage.

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4.3.1 Wiring assemblies. Printed wiring assemblies (PWAs) shall be cleaned and tested prior to conformal coating. Removal of residual solder flux and other ionic/non-ionic contaminants is critical. The PWA cleanliness should be checked by rinse solution resistivity measurement. Refer to MIL-P-28809 for cleaning and testing requirements. Printed circuit board laminates shall not be roughened by over-zealous cleaning to remove solder flux.

4.4 Workmanship. Workmanship shall be in accordance with MIL-STD-454. Workmanship for electrical soldered assemblies shall be in accordance with MIL-STD-2000 and for non-electrical soldered assemblies shall be in accordance with DOD-STD-1866. Workmanship for soldered assemblies shall be in accordance with DOD-STD-1866. Attention shall be given to protection of items from dust and contaminants during manufacture. Handling shall be restricted to a minimum, fingerprints shall be removed before assembly, and protective bags shall be used during in-process storage where needed.

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5. DETAILED REQUIREMENTS

5.1 Atmosphere in equipment. The design and construction shall minimize the corrosive effect of oxygen, moisture and airborne corrosives in the atmosphere within electronic equipment. Techniques to be used, as applicable, for prevention of deterioration include protective coating or encapsulation of components, evacuation and hermetic seals, filtering air and removal of moisture.

5.1.1 Evacuation. Materials which break down or outgas shall not be incorporated in components or devices which are evacuated and sealed. Partially cured or undercured organic materials shall be avoided.

5.1.2 Hermetic seal. For maximum protection against environments, components shall be evacuated and hermetically sealed by fusion of metals, glass or ceramics. Consideration shall be given to possible corrosion from condensation of moisture unless hermetically sealed units are evacuated before sealing, and to contamination of contact surfaces by outgassing materials.

5.1.3 Clean air. Precautions shall be taken to remove moisture, dust and contaminants from air which is inside, or which enters, compartments of electronic devices.

5.1.3.1 Cooling. When forced air cooling is necessary to maintain equipment at temperatures below the maximum permissible operating temperature, moisture and contaminants shall be removed, preferably externally, before cooling air passes over electronic components.

5.2 Moisture. Unless otherwise specified, the moisture level inside electronic equipment shall be maintained below 45 percent relative humidity at 20° Celsius (C). Moisture shall be excluded from electronic devices by adequate housings, seals, gaskets and closures. The following measures shall be taken:

a. Avoid pockets, wells, traps and sump areas where water and condensed moisture can collect, or provide drainage paths
b. Avoid hygroscopic materials
c. Desiccants shall not be used unless necessary for moisture level control, and then only where adequate surveillance schedules have been established for each specific application. In no case shall desiccant material be in contact with unprotected metallic parts. Unless otherwise specified, desiccants shall be in accordance with MIL-D-3464
d. Preclude condensation by keeping components at temperature above the dewpoint.

5.3 Selection of metals. Metals shall be selected which are suitable for the purpose and which are inherently resistant to corrosion or made corrosion resistant by coating or plating. Dissimilar metals shall not be used in contact or close proximity unless suitably

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protected against electrolytic corrosion. Special attention shall be given to the following problem areas, which can result in lower conductivity, "noise," short circuits or broken leads.

5.3.1 Surface contamination. Where maximum conductivity is required on items exposed to the atmosphere (as on contacts), metals which are inherently resistant to oxidation and tarnish shall be selected, such as gold, rhodium and platinum. When other metals are used, the surface shall be protected from oxidation by plating with the noble metals listed above or by suitable noninsulating coatings.

5.3.2 Intergranular and stress corrosion. Preference shall be given to metals which are resistant to both intergranular and stress corrosion, especially for applications involving residual and induced stresses. The alloys which are normally most resistant to intergranular corrosion are also more resistant to stress corrosion. Preference shall be given these alloys, especially for applications involving residual and induced stresses. In addition, all bending, forming, and shaping shall be performed on metal in the annealed condition. Every effort shall be made to use the lowest stress level practical.

5.3.3 Hydrogen embrittlement. Preference shall be given to metals which are not susceptible to delayed fracture due to hydrogen pickup from acid cleaning or plating, such as the 300-series corrosion resistant steels and oxygen-free copper. Where it is necessary to use metals which are susceptible to hydrogen pickup, coating methods shall be selected in accordance with restrictions in MIL-S-5002. In addition, the following methods shall be used to minimize damage:

a. Organic coating, vapor deposition, mechanical plating, metal spraying and other non-hydrogen-producing processes shall be used in preference to electroplating or chemical plating
b. If plating is necessary, low-hydrogen-embrittlement baths shall be used
c. Parts shall be embrittlement- relieved immediately after plating in accordance with the appropriate specification
d. Where practical, parts shall be thermally stress relieved prior to plating, for a minimum of three hours at 190° ± 14°C
e. Where practical, parts shall be mechanically stress relieved prior to plating, by shot peening in accordance with MIL-S-13165
f. Neither acid nor alkaline cathodic cleaning shall be used on metals susceptible to hydrogen embrittlement.

5.3.4 Whisker growth. The growth of metal whiskers on tin, cadmium, silver, or iron shall be minimized by the following techniques:

a. Use of heavy, rather than thin, metal coatings
b. Use of hot dip tin rather than electrodeposited tin
c. Reheating tin plating to relive stresses
d. Maintaining a low level of humidity in the equipment
e. Use of tin plating with 2 to 5 percent co-deposited lead

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f. Avoiding organic brighteners

5.3.5 Electrolysis and silver migration. The movement of metal from one conductor in a circuit to another which is at a different voltage potential under humid conditions, across ceramic or plastic insulation, is especially liable to occur when one of the metals is silver. This phenomenon of electrolysis or silver migration shall be minimized by use of the following methods, as applicable:

a. The spacing between conductors at different voltage potentials shall be as wide as possible;
b. Conductors shall be protected by an organic moisture barrier coating such as MIL-I-46058
c. Contaminants shall be removed from conductor surface by careful cleaning followed by rinsing with deionized water, and thorough drying prior to conformal coating;
d. Where practicable, gold, platinum, or tin-lead coatings shall be used in lieu of silver;
e. Humidity shall be maintained at a level which precludes condensation under anticipated environments;
f. Nonhygroscopic insulation shall be used.

5.3.6 Metallic coatings. Metallic coatings shall be selected for their suitability for the application involved. Attention shall be given to problems of aging, cracking, diffusion and corrosion. When metallic coatings are applied by electroplating, special care shall be taken to avoid hydrogen embrittlement. In selecting metallic coatings, the recommendations shown in table I for preventing corrosion shall be given consideration.

5.3.6.1 Cadmium plating. Cadmium plating shall be in accordance with type II, class 2 of QQ-P-416; AMS 2401-4; type II of MIL-C-81562; or vapor deposited in accordance with type 2, class II of MIL-C-8837. Parts-plated in accordance with AMS 2401-4 shall be given supplementary chromate treatment in accordance with MIL-T-12879. Cadmium and cadmium-plated parts are susceptible to attack by corrosive vapors. Cadmium shall not be used in enclosed assemblies with materials such as acid, ammonia, adhesives, coatings, plastics, varnishes or other organic materials which give off corrosive vapors. Cadmium plating shall not be used in space applications.

5.3.6.2 Chromium plating. Chromium plating shall be in accordance with QQ-C-320. It shall be used for applications involving wear or requiring hardness, and not for corrosion prevention.

5.3.6.3 Copper plating. Copper plating shall be in accordance with MIL-C-14550.

5.3.6.3.1 Plating over copper. Copper oxide corrosion products (Red Plague) which occur at pinholes or porosity in other metallic plating over copper, may be precluded by the interposition of a layer of nickel between the copper and the top metallic coating.

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TABLE I. Selection of metallic coatings for minimum corrosion.

Purpose	Recommended	Not Recommended
Contact with aluminum	Cadmium or tin	Chromium, copper, silver, gold, nickel
Prepaint coating	Cadmium or tin	Chromium, copper, nickel, gold, silver
Tarnish prevention	Rhodium over silver	
	Gold over silver, copper or nickel	
	Nickel between copper and silver (See 4.2.r)	
Marine exposure	Heavy gold 0.00030 inch minimum	
Solderability	Tin, gold or tin-lead	Nickel, chromium, rhodium
Storage	Gold, rhodium, or reflowed heavy tin	Cadmium, silver, copper
Wear	Chromium, nickel, rhodium or hard gold	Cadmium, tin

5.3.6.4 Gold plating. Gold plating shall be in accordance with MIL-G-45204. Special care shall be taken to prevent or retard diffusion of substrate metals, especially copper into the gold electro-deposits. A suitable barrier to prevent diffusion is a thin nickel or palladium coating under the gold. Thickness of gold shall be sufficient to minimize porosity and provide corrosion protection. The recommended minimum thickness of gold plating is 0.000050 inches over 0.000100 inches minimum of the barrier coating. Attention is directed to problems of brittle gold solder compound formation (see 5.7.5) and of Purple Plague when bonding gold to aluminum (see 5.7.7).

5.3.6.5 Nickel coating. Nickel coatings shall be electrodeposited in accordance with QQ-N-290, or electrolessly deposited in accordance with MIL-C-26074 or AMS 2404. Corrosion resistance shall meet the requirement of AMS 2404. Where desired for electrical bonding, nickel-cadmium coating shall be in accordance with AMS 2416. Nickel shall be

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used under gold or rhodium on contacts and for applications requiring high mechanical strength and hardness. Electrical connectors with finishes of nickel plating shall not be used.

5.3.6.6 Palladium plating. Palladium plating shall be in accordance with MIL-P-45209. The use of palladium plating in enclosed assemblies containing organic materials shall be avoided, to prevent polymerization of organic compounds.

5.3.6.7 Silver plating. Silver plating shall be in accordance with QQ-S-365. Silver plating may be passivated for temporary protection, or may be over-coated with rhodium in accordance with MIL-R-46085 to prevent tarnish. Silver plating shall be protected from sulfurous fumes during storage, and shall be cleaned immediately prior to soldering. Attention shall be given to prevention of silver migration (see 5.3.5). Silver plating shall not be used for contacts without prior approval from the procuring activity.

5.3.6.8 Tin coating. Tin coating shall be applied by hot dip or electrodeposition in accordance with MIL-T-10727. For maximum protection, tin shall be reflowed (diffused) after coating. Where desired for electrical bonding, tin-cadmium plating shall be in accordance with MIL-P-23408. Care shall be taken to prevent formation of metal whiskers on tin surfaces during storage (see 5.3.4).

5.3.6.9 Tin-lead coating. Tin-lead (solder) coating shall be applied by hot dip or electrodeposited for solderability or purposes of electromagnetic compatibility, in accordance with MIL-STD-2000 or MIL-P-81728.

5.3.6.10 Zinc plating. Zinc plating may be used as an alternate coating for cadmium where it meets the requirements for the component or system. However, cadmium plating is the preferred choice for avionics and systems used in marine environments. Zinc plating shall not be used without prior approval from the procuring activity.

5.3.6.11 Metallic coatings on nonmetals. Metallic coatings may be applied to nonmetallics to provide a conductive surface. Although problems of dissimilar metal corrosion are thereby minimized or eliminated, other corrosion reactions of the metal coating shall be considered in the same manner as for plated or solid metals.

5.3.6.12 Vapor deposited coatings. Metallic coatings may be applied by vapor deposition to either metallic or nonmetallic surfaces for electrical conductivity. Vapor deposited coatings shall not be used for any mechanical application because of their extreme thinness, fragility and susceptibility to damage. Aluminum coatings shall be applied in accordance with MIL-C-83488.

5.3.7 Castings. Surface porosity in castings shall be impregnated in accordance with MIL-STD-276 before receiving appropriate surface finish. Impregnants for aluminum castings shall be in accordance with MIL-I-17563.

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5.4 Ferrous Metals.

5.4.1 Corrosion resistant steels. Corrosion resistant steels shall be passivated in accordance with QQ-P-35. No further finish is required to provide corrosion resistance to steels of the 300 series. Where tarnish, rust or surface stain is objectionable, the 400 series and precipitation hardening steels shall be given additional protection by a suitable plating or paint finish after passivation.

5.4.2 Carbon and low alloy steels. Ordinary iron and steel shall be coated with cadmium, nickel or tin except as follows:

a. Precision parts which are totally and continuously immersed in oil, grease, encapsulant or moisture-proof coating, or which are contained in hermetically sealed units, need not be given any further protection. Local application of oil or grease shall not automatically be considered corrosion protection.
b. Laminations used in magnetic circuits need not be plated if they are otherwise protected from corrosion
c. Springs shall preferably be given organic coatings, or be coated by ion deposition or other non-hydrogen-producing processes, rather than electroplated
d. Structural parts may be cleaned, primed, and painted in accordance with MIL-STD-186 or applicable specifications
e. Close tolerance parts, not exposed to outdoor atmosphere, may be protected with approval of the procuring activity by corrosion preventive compounds such as MIL-C-81309, MIL-C-16173, MIL-C-11796, MIL-L-87177, or MIL-C-85054.

5.5 Nonferrous metals. The noble metals (gold, palladium, platinum and rhodium) and the corrosion-resistant metals (chromium, nickel, and titanium) require no finish other than cleaning. Surface finish for electrical bonding or grounding is listed in 5.8 and table II. Applications of aluminum and copper shall receive the protection specified in 5.5.1 and 5.5.2 unless in hermetically sealed units.

5.5.1 Aluminum. All aluminum and aluminum alloys shall be anodized in accordance with MIL-A-8625, then primed with MIL-P-23377 or equivalent and given a suitable top coat and painted with MIL-C-46168, except as follows:

a. In areas of electrical bonding (see 5.8.1)
b. For applications where anodizing is not required, chemical film treatment in accordance with MIL-C-5541 may be used, although it is not to be considered to afford corrosion protection equivalent to anodize. Whenever possible, chemical films shall be given the additional protection of organic coatings.
c. For applications involving continued exposure to elevated temperatures, where the resultant oxide buildup is objectionable (such as heat sinks) consideration shall be given to metallic coatings with suitable thermal characteristics in lieu of anodize.

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The anodic or chemical film, or the metallic coating, shall be applied after all punching, drilling, machining, forming and fabrication have been completed.

5.5.2 Copper. Copper and copper alloys may be given a black oxide treatment in accordance with MIL-F-495 or may be plated or painted as required. Where bare copper is required by the design, a tarnish-preventive thin silicone cured resin film may be used. Do not use silicone oils or greases.

TABLE II. Surface finish for electrical bonding.

Metal	Surface Finish
Aluminum 1100, 3003, and clad alloys.....	Bare, or low electrical resistance chromate type film treatment, MIL-C-5541, class 1A
Aluminum, all other alloys.....	Tin-lead (solder) plate or tin plate, MIL-T-10727, preferred Cadmium plate, QQ-P-416 Nickel-cadmium plate Low electrical resistance chromate type chemical film treatment, MIL-C-5541, class 1A
Copper, copper alloys.....	Bare Tin plate, MIL-T-10727, or tin-lead (solder) plate, preferred Cadmium plate, QQ-P-416 Gold plate, MIL-G-45204
Cadmium.....	Bare or chromate treated
Iron and steel.....	Tin coat, MIL-T-10727 or tin-lead (solder) plate, preferred Cadmium plate, QQ-P-416
Nickel and corrosion resistant steel.....	Bare; difficult to bond because of adherent oxide film
Silver.....	Bare
Solder.....	Bare
Tin.....	Bare

5.5.3 Magnesium. Because of magnesium's poor resistance to corrosion, magnesium and magnesium alloys shall not be used.

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5.6 Galvanic corrosion. Dissimilar metals as defined in table III shall not be used in intimate contact unless suitably protected against electrolytic corrosion. Because of the seriousness of galvanic corrosion, every effort shall be made to avoid the use of dissimilar metals, to exclude moisture or other electrolyte from the system, and to protect metal surfaces in the contact area. Where it is necessary that metals not shown as "compatible" in table III be assembled, applicable measures such as those given in table IV or MIL-F-7179 shall be used to prevent corrosion. Special attention is called to the following:

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Table III. Galvanic couples.

Group	Metallurgical Cagetory	EMF (Volt)	permissible Couples*
1	Gold, solid and plated; gold-platinum alloys; wrought platinum	+0.15	
2	Rhodium; graphite	+0.05	
3	Silver, solid or plated; high silver alloys	0	
4	Nickel, solid or plated; monel; high nickel-copper alloys; titanium	-0.15	
5	Copper, solid or plated; low brasses or bronzes; silver solder; German silver; high copper-nickel alloys; nickel-chrome alloys; austenitic stainless steels (301, 302, 304, 309,316, 321, 347)	-0.20	
6	Commercial yellow brasses and bronzes	-0.25	
7	High brasses and bronzes; naval brass; Muntz metal	-0.30	
8	18% Chromium type corrosion-resistant steels 440-430, 431, 446, 17-7PH, 17-4PH	-0.35	
9	Chromium, plated; tin, plated; 12% chromium type corrosion-resistant steel, 410, 416, 420	-0.45	
10	Tin-plate, terneplate; tin-lead solders	-0.50	
11	Lead, solid or plated; high lead alloys	-0.55	
12	Aluminum, wrought alloys of the 2000 series; type 2014, 2024, 2017	-0.60	
13	Iron, wrought, gray, or malleable; plain carbon and low alloy steels; armco iron	-0.70	
14	Aluminum, wrought alloys other than 2000 series; type 6061, 7075, 5052, 5056, 1100, 3003. Cast alloys of the silicon type 355, 356	-0.75	
15	Aluminum, cast alloys other than silicon type; cadmium, plated and chromated	-0.80	
16	Hot-dip-zinc plate; galvanized steel	-1.05	
17	Zinc wrought; zinc-base die cast alloys; zinc, plated	-1.10	
18	Magnesium and magnesium-base alloys cast or wrought	-1.60	

* Members of groups connected by lines are considered as permissible couples; however, this should not be construed as being devoid of galvanic action. Permissible couples represent a low galvanic effect.

O Indicates the most cathodic member of the series. ● An anodic member, and the arrows indicate the anodic direction. Refer to Table XI, MIL-STD-186, for group amplification of galvanic couples.

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Table IV. Prevention of dissimilar metal corrosion.

Preventive measure	Example
Select metals which form a permissible couple in table I.	Use nickel, not naval brass, in contact with silver.
Interpose a metal which reduces the potential difference between the two metals.	Tin plate brass to be used next to aluminum.
Design the metal contact so the relative area of the cathodic (more noble) metal is the smaller.	Stainless steel screws in aluminum chassis.
Apply corrosion inhibitor such as zinc chromate primer TT-P-1757 or zinc chromate paste MIL-P-8116.	Use zinc chromate inhibitor when assembling steel screws in aluminum.
Interpose an insulating barrier or nonhygroscopic gasket between the dissimilar metals.	In structural joints, interpose tape MIL-T-23142. In components, use organic insolvents such as conformal coating MIL-I-46058.
Apply insulating organic coating to surface of each metal.	Coatings such as MIL-P-23377 epoxy primer, MIL-C-46168 polyurethane topcoat, MIL-V-173, or MIL-I-46058.
Seal joint area with moisture-proof coating or organic sealant.	In structural joints, sealant such as MIL-S-7124 or MIL-S-81733. In components, coatings such as MIL-V-173 or MIL-I-46058

a. When reference is made to a metal, it is the metal on the surface, regardless of whether solid, plated, laminated or dipped.
b. Graphite and graphite containing composites act as a metal and shall be so considered for purposes of determining dissimilar metal contact. Solid film lubricants containing graphite shall not be used.
c. Cadmium plated, tin plated or stainless steel hardware may be mounted on aluminum chassis without further protection or insulation, except parts in contact with aluminum in exterior applications.
d. The anodic layer on aluminum is ordinarily insulating, but may lose this quality after exposure to humidity. Anodized coatings cannot be depended upon for prevention of dissimilar metal contact.

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e. Appropriate measures shall be taken to avoid metals widely separated in the galvanic series. This can be accomplished by applying to the cathodic member a sacrificial metal coating having a potential similar to or near that of the anodic member; by sealing to insure that faying surfaces are watertight; by painting or coating all surfaces to increase the resistance of the electrical circuit.
f. A small anodic area relative to the cathodic area should be avoided. The same metal or more noble (cathodic) metals should be used for small fasteners or bolts. The larger the relative anode area, the lower the galvanic current density on the anode, and the lesser the attack. The galvanic corrosion effect may be considered as inverse to the node-cathode area ratio.

5.7 Joining. The joining method, whether primarily for mechanical strength or for electrical applications, shall be scrutinized with regard to possible corrosion problems. Joints shall be continuous and impervious or shall be sealed to prevent moisture intrusion and/or entrapment. Where it becomes necessary that relatively incompatible metals must be assembled, the following precautions and joining methods are provided for alleviation of galvanic corrosion:

a. Select materials which are indicated to be more compatible in accordance with the galvanic series; design metal couples so that the area of the cathode is smaller (appreciably) than the area of the anodic metal. For example, bolts or screws of stainless steel for fastening aluminum sheet, but not the reverse. Interpose a compatible metallic gasket or washer between the dissimilar metals prior to fastening or plate the cathodic member with a metal compatible to the anode. These precautions are applicable to couples which are to serve as an electrical connection.
b. Interpose a non-absorbing, inert gasketing material or washer between the dissimilar materials prior to connecting them. This is applicable to couples which do not serve as electrical conductors.
c. Seal all faying edges to preclude the entrance of liquids.
d. Where practical or where it will not interfere with the proposed use of the assembly, the external joint should be coated externally with an effective paint system.
e. Welded or brazed dissimilar metal assemblies should be coated with a paint system or other suitable protective coatings to at least 0.33 inch beyond the heat affected zone.
f. In protective environments (usually referred to as humidity-controlled), caution should be used in dissimilar metal combination treatments. If the assumption is made that no corrosion will occur because humidity control will be maintained, the stringent requirements would be unnecessary. It must be recognized that Humidity and moisture controlled environments can be assured only by hermetically sealed compartments or containers in which the moisture vapor content has been adequately reduced so as to preclude condensation of water at the lowest temperature expected to be encountered on the actual surface of the item. If humidity and condensate control cannot be maintained or is uncertain,

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then dissimilar metal contacts should be treated as if protection were required against the worst environment.

5.7.1 Adhesive bonding. Adhesives shall be in accordance with MIL-STD-454. They shall not emit volatile products, attack nearby equipment, or deteriorate under exposure to moisture, air, ozone, fungus, heat or cold. Each assembly shall be thoroughly cured before storing or packaging in next assembly, to preclude outgassing of potentially corrosive organic vapors. Adhesive applications shall be verified under stress and humidity conditions. To minimize bonding problems, attention shall be given to items listed in table V.

5.7.2 Mechanical joints, structural. Bolts, nuts, screws and other fastener hardware items shall be made of corrosion-resistant metal or shall be treated to resist corrosion. Suitable plating includes nickel, tin, zinc, and cadmium. Rivets, bolts, and threaded fasteners shall be assembled with wet epoxy primer in accordance with MIL-P-23377 or coated with sealant in accordance with MIL-S-81733 or other sealant approved by the procuring activity. Threads shall be avoided in soft metals such as aluminum. When it is necessary to thread into aluminum, sealant in accordance with MIL-S-81733 shall be used. At any joint involving dissimilar metals, measures as defined in table IV shall be taken to prevent galvanic corrosion. Locking compounds in accordance with MIL-S-46163 and MIL-S-22473 shall not be used in contact with cellulosics, methacrylates, polycarbonates, styrenes, or vinyls.

TABLE V. Checklist for adhesive bonding.

(1)	Surfaces shall be clean and free from contaminants before cement is applied.
(2)	Pot life shall be checked to assure good condition of adhesive.
(3)	Lids and caps shall be kept tightly closed on containers of both resin and hardener even though next use is anticipated within a few minutes, and even when using systems with 100 percent solids.
(4)	Adhesives shall be mixed thoroughly.
(5)	Unless otherwise instructed by the manufacturer, adhesive shall be allowed to dry tack-free before curing at elevated temperature.
(6)	Assembly shall be cured thoroughly before storing or packaging in next assembly.
(7)	Absolute cleanliness shall be maintained; adhesive joints shall not be handled prior to curing.
(8)	Dissimilar metal contacts shall be overcoated with insulating organic coatings to prevent corrosion.

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5.7.2.1 Crevice corrosion. The mechanisms of crevice corrosion and pitting corrosion are very similar. A metal susceptible to pitting will also be susceptible to crevice corrosion, although the reverse is not true.

Crevice corrosion is usually characterized by intense localized attack in crevices of other shielded areas in contact with an electrolyte which, because of the shielding effect, is stagnant. Holes, gaskets, lap joints, crevices under bolt heads, rivet heads, and washers, as well as surface deposits are potential corrosion sites. Crevice corrosion is generally only a problem in stagnant crevices less than 0.125 inches wide. To prevent corrosion in crevices:

a. Eliminate sharp corners, re-entrant angles, pockets, or other conditions where solid or liquids could collect. Design equipment boxes and bays for complete drainage.
b. Insulating materials or other substances which can absorb or retain water should not be in contact with metallic surfaces. Use nonabsorbent, solid gasket materials.
c. Use butt-welded joints in place of riveted or spot welded lap joints. Seal all lap joints with solder weld metal, or caulking compound to prevent any trapping of corrosive agents.
d. When possible lower the relative humidity of the operating environment to reduce the occurrence of under-film corrosion.
e. Mechanical assembly components such as washers, threaded fasteners, and rivets shall be sealed with polysulfide, polyurethane, epoxy, silicone (non-acid emitting) or a similar sealant during assembly.

5.7.3 Crimped and wrapped leads. When leads are crimped or wrapped, care shall be taken to prevent cracking the protective plating. Metals selected for crimped joints should be inherently resistant to corrosion and not dissimilar to each other.

5.7.4 Brazing. Brazing of steel, copper, copper alloys and nickel alloys shall be in accordance with MIL-B-7883. Flux residues shall be removed by cleaning after brazing.

5.7.5 Soldering. Soldering for non-electrical applications shall be in accordance with DOD-STD-1866. Soldering for all electrical and electronic applications shall be in accordance with MIL-STD-2000 unless otherwise approved by the procuring activity. Soldered joints shall be protected with moisture-proof coating such as MIL-V-173 and MIL-I-46058.

5.7.6 Welding, structural. Fusion and resistance welding shall be in accordance with MIL-STD-2219 and MIL-W-6858. All welded joints shall be cleaned of scale, oxidation, and rough areas which may hold moisture or contaminants. Resistance welded joints shall be sealed with sealant such as MIL-S-7124, except when the assembly is made through primer MIL-P-46105.

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5.7.7 Welding, electrical purposes. Resistance welding of electrical interconnections shall be in accordance with MIL-W-8939, using component leads in accordance with MIL-STD-1276. Other welding processes such as electronbeam welding, laser welding, pressure welding, and thermocompression bonding shall be in accordance with high quality industry practice, and subject to the approval of the procuring activity. Care shall be taken to prevent formation of a gold-aluminum intermetallic (Purple Plague) by one of the following techniques: use silver or copper instead of gold; deposit aluminum upon the gold before bonding; or remove the gold plate from the post or other item before bonding.

5.8 Electrical bonding and grounds. Consideration shall be given to obtaining an electrical ground through use of a bus-strap or a shear-splice joint, adequately insulated on the exterior. Surface finishes for metals which are to be electrically bonded to provide electromagnetic compatibility are listed in table II. The surfaces to be bonded shall be free from all oxides and contaminants. Protective finish (organic coating, sealant, paint system) shall be applied to the joint area after making the electrical bond or ground. Attention is directed to table IV.

TABLE IV. Checklist for electrical bonding.

(1)	Provision shall be made to assure electromagnetic compatibility in the original design.
(2)	Insofar as possible, materials shall be selected which are compatible, such as cadmium or tin plate on steel with aluminum.
(3)	If bonding dissimilar metals is unavoidable, the joint area shall be coated after bonding with organic sealant such as silicone, epoxy or polyurethane.
(4)	Metal surfaces shall be clean before bonding and shall be free from oil, dirt, moisture, or other contaminants.
(5)	Bond shall be made by means of a bus-strap or shear-splice joint when practical.
(6)	Bonds made by conductive gaskets or adhesives, and involving dissimilar metal contact, shall be sealed with organic sealant.
(7)	A combination environmental and electromagnetic seal, such as wire or other metal form in an elastomer, shall be preferred.
(8)	When strippable coating is used to preserve a clean surface for later bonding, compatibility of coating and surface shall be established prior to use.

5.8.1 Aluminum surfaces to be bonded. When aluminum is to be electrically bonded, preference shall be given to the use of clad alloys or the 6000 series alloys. If the part is anodized, the bond areas should be masked before the anodic process or spot-faced after anodizing to remove the insulating anodic layer. Chemical film treatment for electrically

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bonded areas shall be chromate type in accordance with MIL-C-5541, Class 1A. It is thin, fragile and easily damaged by abrasion, so bond should be made immediately after application of the chemical film.

5.8.2 Bonding dissimilar metals. Where electrical bond is made between dissimilar metals the surface of one or both shall be coated with a metal compatible to both, where possible. Special care shall be taken to assure complete sealing of any joint between dissimilar metals.

NOTE: If a bond is made by use of a conductive gasket in which the conductive metal is protected from the atmosphere by resin or elastomer, this precludes contact of the dissimilar metal bond with moisture, and galvanic corrosion is not likely to occur. However, it should be sealed where possible.

5.8.3 Bonding at a later time. If it is necessary to make an electrical bond at some later time than at original fabrication, the metal surface to be bonded shall be treated in accordance with table V and then coated with strippable plastic coating in accordance with MIL-C-16173. At the time bond is made, this coating shall be removed and the joint area shall be protected after bonding.

5.8.4 Conductive adhesives. When conductive adhesives are used to make an electrical bond, all resultant fumes shall be thoroughly dissipated before incorporation into the next assembly. Special care shall be taken that the conductive metal (usually silver) does not constitute a dissimilar metal contact, or that adequate moisture-proofing protects the joint. When conductive adhesives are used, their location shall be identified to the procuring activity.

5.8.5 Conductive gaskets. When conductive gaskets are used, provision shall be made in design for both environmental and electromagnetic seal. Where practical, a combination gasket with conductive metal encased in resin or elastomer shall be preferred. Attention is drawn to possible moisture retention when sponge elastomers are used. Because of the serious loss in conductivity caused by corrosion, special precautions such as environmental seals or external sealant bead shall be taken when wire mesh caskets of monel or silver are used in conjunction with aluminum. When conductive gaskets are used, their locations shall be identified to the procuring activity.

5.9 Selection of nonmetallics. To assure reliability of electronic devices, nonmetallic materials shall be selected for their ability to maintain desired electrical and mechanical properties within specified limits during and after exposure to anticipated environments. In addition to suitability for the intended application, nonmetallic materials shall be selected which have the following characteristics:

a. Low moisture absorption
b. Resistance to fungi and microbial attack
c. Stability throughout the temperature range

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d. Freedom from outgassing
e. Compatibility with other materials in the assembly
f. Resistance to flame and arc
g. For outdoor applications, ability to withstand weathering.

5.10 Moisture resistance. The deleterious effects of moisture on nonmetallic materials, shown in table VII, shall be avoided or minimized by the following techniques:

a. Materials shall have minimum moisture absorption, no greater than 1.00 percent
b. Materials which "wick" or are hygroscopic shall not be used
c. Cut or machined edges of laminated, molded or filled plastics shall be sealed with impervious material
d. Parts shall have a sound, unbroken surface, free from cracks, holes, or other discontinuities which allow moisture to enter
e. Materials which undergo hydrolysis reaction shall not be used.

TABLE VII. Effect of moisture on nonmetallic materials.

Electrical Properties:
- Increases surface conductivity - Increases loss angle - Increases capacitance - Increase dissipation factor - Reduces volume resistivity - Reduces dielectric strength
Physical and Mechanical Properties:
- Swelling - Distortion - Decomposition - Change in strength - Wicking and moisture retention - Reversion
Fungal Resistance:
- Encourages fungal growth

5.11 Fungus resistant. Materials shall be selected which are funginert, in order to avoid the degradation (loss of insulation, short circuits, etched optics, corrosion and deteriorated seals) caused by fungal attack. Funginert materials are listed in table VIII and MIL-STD-454. If the design requires the use of nutrient material, prior approval shall be obtained from the procuring activity. The nutrient material shall be treated in accordance with MIL-T-152, using varnish in accordance with MIL-V-173 or other suitable coating approved

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by the procuring activity. Resistance to fungus shall be established in accordance with ASTM G 21, ASTM D 4300, or by MIL-STD-810. Fungal growth shall be further discouraged by removal of dust, dirt, fingerprints and other contaminants from the surface before assembly, and by maintenance of low humidity.

5.11.1 Metals. Although not nutrients for fungus, metals are attacked by acid liberated by microbial growth. Care shall be taken to avoid use of protective finishes which support fungi, to keep parts clean and to keep humidity low.

5.11.2 Glass and ceramics. While glass and ceramics are not in themselves funginutrient, the coatings used on optics often support fungal growth. To prevent or minimize microbial attack, glass, ceramics and optics should be smooth and clean, with an unbroken surface and glazed. Where practicable, fungicide should be incorporated into the coating for optics.

TABLE VIII. Funginert materials.

Funginert in all grades and conditions	Some grades funginert; establish by testing in accordance with ASTM G 21 or MIL-STD-810
Asbestos	Acetal resins
Ceramics	Acrylonitrile-vinylchloride copolymer (variable)
Chlorinated polyether	Cellulose acetate (variable)
Glass	Cellulose acetate butyrate
Metals	Epoxy glass fiber laminates
Mica	Epoxy resin
Silicone glass fiber	Melamine-formaldehyde
Phenolic nylon fiber	Natural rubbers (susceptible)
Diallylphthalate	Phenol-formaldehyde
Polyacrylonitrile	Polymethyl methacrylate
Polyamide	Polyvinylchloride
Polycarbonate	Polyvinylchloride acetate (susceptible)
Polyetheylene (High Density)	Polyvinylfluoride
Polymonochlorotrifluoroethylene	Polyvinylidene chloride (variable)
Polypropylene	Plastic laminates using:
Polystyrene	Cotton filler (susceptible)
Polytetrafluoroethylene	Linen filler (susceptible)
Polyethylene terephthalate	Paper filler (susceptible)
Silicone resin	Wood-flour filler (susceptible)
	Synthetic rubbers
	Urea-formaldehyde

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5.12 Temperature resistance. Materials shall be selected which maintain their desired properties throughout the temperature range anticipated to be experienced by the equipment. Attention is directed to the possible adverse effects of cycling temperatures or pressures, with consequent condensation of water vapor, expansion and contraction of parts, creeping of lubricants and breathing of seals.

5.13 Compatibility with other materials. Care shall be taken to select materials which are compatible with other materials in the equipment. Special attention shall be given to corrosion prevention and control, avoidance of outgassing and the effect of coatings on electrical properties. Certain combinations of materials shall be avoided; examples are listed in table IX.

5.13.1 Outgassing. Materials, as installed in the equipment, shall not liberate corrosive or reactive fumes under any conditions encountered during storage, shipment or service. Special consideration shall be given to materials, such as insulation on wire, which may be exposed to overheating and resultant outgassing or breakdown. Extra attention shall also be paid to combinations of materials in closed compartments, where even a small amount of outgassing may reach dangerous concentration in time. Damage from outgassing shall be minimized by the following techniques:

a. Organic materials shall be thoroughly cured before assembly, especially acid-activated plastics
b. Polyvinylchloride shall not be used
c. Where practical, the use of neoprene, phenolic, and polysulfide shall be avoided in closed areas
d. Cadmium shall not be used in closed compartments
e. Acid emitting, liquid or vapor, room temperature vulcanizing (RTV) silicones shall not be used.

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TABLE IX. Examples of incompatible materials.

Material:	Attacks, or is otherwise incompatible with:
Acid	Acrylic, alkyd, acrylate, cadmium, cellulosic, polyamide, polyester, polyethylene, urethane, zinc
Alcohol	Acrylate, urethanes
Alkali	Acrylic, alkyd, cellulosic, polyester, acrylate, isoprene, nitrile, polyester urethane, polysulfide, styrene-butadiene
Ammonia	Cadmium, copper, zinc, cobaltous chloride humidity indicators
Copper, iron manganese	Rubber
Cyanoacrylate sealant	ABS, cellulosic, methylmethacrylate, polycarbonate, vinyl
Diester oil	Polychloroprene (neoprene), butadiene, butyl, chlorosulfonated polyethylene, ethylene propylene, nitrile, silicone, styrene-butadiene, urethane
Glycol antifreeze	Acrylate, polysulfide, urethane
Ketones	Acrylate, chloroprene, chlorosulfonated polyethylene, epichlorohydrin, fluoroelastomer, fluorosilicone, isoprene, nitrile, styrene-butadiene, urethane
Hydrocarbon solvents	Acrylic, cellulosic, polycarbonate, polystyrene, silicone, butadiene, butyl, ethylene, propylene, styrene-butadiene
Organic vapors	Cadmium, zinc
Paper, cardboard	Brass, copper, silver
Polyvinylchloride	Zinc, aluminum, brass, copper, lead, tin, tin-lead, gold plate over brass
Silicone oil or grease	Most organic coatings, silicone
Steam	Chlorosulfonated polyethylene, isoprene, nitrile, polymides, silicone, styrene-butadiene, urethane
Wagner brake fluid	Fluoroelastomers, nitrile, polysulfide, silicone

5.14 Flame and arc resistance. Materials used in military equipment shall, in the end item configuration, be noncombustible or fire retardant in the most hazardous conditions of atmosphere, pressure, and temperature to be expected in the application. Fire retardant additives may be used provided they do not adversely affect the specified performance requirements of the basic materials. Fire retardance shall not be achieved by use of nonpermanent additives to the basic material. For further guidance, refer to MIL-STD-454. Arc resistant materials shall conform to table X. The materials listed have passed the minimum requirements of 115 seconds when subjected to the arc-resistant test of ASTM D 495 and are listed in approximate order of arc resistance.

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TABLE X. Arc-resistant materials.

Materials	Specification	Types
Ceramic	MIL-I-10	All
Plastic(s), thermosetting, molding	MIL-M-14	CMI-5, GDI-30, GDI-30F, MAG, MAI-30, MAI-60, MAI-100, MAT-30, MDG, MME, MMI-5, MMI-30, MSG, } MSI-30, SDG, SDG-F, SDI-30
Molding, epoxy compounds	MIL-M-24325	MEE
Laminated rods and tubes	MIL-P-79	GMG
Laminated sheets		
Glass cloth, melamine resin	MIL-P-15037	GME
Glass cloth, polytetra-fluoroethylene resin	MIL-P-19161	GTE
Glass cloth, silicone resin	MIL-P-997	GSG
Low pressure laminate, silicone resin, glass fiber base	MIL-P-25518	All
Sheet and rod, cast	L-P-516	E-2
Sheet and strip, polyimide	MIL-P-46112	All
Silicone rubber	ZZ-R-765	All

5.15 Rubbers and elastomers. Rubbers and elastomers for such applications as gaskets, seals and O-rings shall be resistant to ozone and weathering, moisture-proof, funginert, and noncorrosive. Blended or reused elastomers shall not be used. Rubber shall be in accordance with MIL-R-3065 or MIL-R-6855 where applicable. Where the mechanical properties are adequate, silicone rubber shall be preferred. Heat shrinkable elastomers may be used where applicable.

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5.16 Oils, greases, and lubricants. Oils and greases intended for use in electronic equipment shall be selected in accordance with MIL-STD-838 and MIL-STD-454, and shall have suitable viscosity to prevent spreading or creeping at service or storage temperatures. If other oils are required, a migration control agent shall be used to prevent spreading. Oils and greases shall not be depended upon as the sole corrosion preventive measure, unless protection has been established by test in accordance with MIL-STD-810 (humidity) and ASTM B 117 (salt fog). Lubricants containing graphite shall not be used. Attention is directed to table XI for a description of the uses and limitations of a variety of oils, greases and lubricants.

5.16.1 Silicone oils and greases. Because of their incompatibility with organic finishes, silicone oils and greases shall not be used without approval of the procuring activity.

5.16.2 Corrosion inhibiting oil. When oil containing volatile corrosion inhibitor in accordance with MIL-P-46002 is used to provide both lubrication and corrosion protection, suitable notice shall be placed on the equipment to inform personnel of its use and to assure replacement in case of draining.

5.16.3 Water displacing compounds. Where close tolerance precludes other protective finishes, or for field repair, water displacing corrosion preventive compounds in accordance with MIL-C-81309, MIL-C-85054, or MIL-L-87177 shall be used to coat metal surfaces against moisture, fingerprints, and corrosion. For external surfaces exposed to the elements, use MIL-C--85054 or MIL-L-87177. For other external surfaces, use MIL-C-81309, Type II. For the interior of electrical connectors, use MIL-C-81309, Type III only.

5.16.4 Solid film lubricants. When solid lubricating films are used, care shall be taken that no graphite is present in the film. Graphite-free heat cured solid film lubricant shall be in accordance with MIL-L-46010; air cured solid film lubricant shall be in accordance with MIL-L-23398.

5.17 Cotton and linen. Cotton and linen shall not be used as fabric or tape, except on such parts as inductors, transformers and relays which are completely encapsulated and are treated for moisture and fungus resistance in accordance with MIL-T-152.

5.18 Wood and cork. Wood shall not be used in any application where acidic vapors could damage metallic parts. When specified, wood shall be treated for moisture and fungus resistance in accordance with MIL-W-18142. The use of cork shall be avoided when possible. When used, cork shall be treated with class I mildew inhibiting agent in accordance with MIL-T-12664.

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5.19 Encapsulants. Encapsulants shall be selected for suitability for the application, and in addition, for minimum deleterious effect for encased components. Special care shall be taken to avoid damage to components from excessive heat, either from exothermic encapsulants or from heat concentration due to low thermal conductivity. Encapsulated parts shall be designed to prevent breakage of components due to high molding pressure or to extreme thermal contraction of encapsulant. Encapsulants shall conform to MIL-S-8516, MIL-I-16923, MIL-S-23586, MIL-P-46067, MIL-M-24041, or MIL-P-46847, or as approved by the procuring activity.

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TABLE XI. Uses and limitations of lubricants.

Material	Specification	Intended Use	Limitations
Lubricating Oil, Gear, Multipurpose	MIL-L-2105	Automotive gear units, heavy duty industrial type enclosed gear units, steering gears, differentials, manual transmissions and fluid lubricated universal joints.	Not for use in automatic transmissions or power steering systems. Maximum operating oil temperature is 135°C. Should not be used for applications involving moisture.
Grease, Aircraft and Instrument Gear and Actuator Screw	MIL-G-23827	Ball, roller, and needle bearings, gears on sliding and rolling surfaces of instruments, cameras, electronic gear and aircraft control systems. General use on aircraft gears, actuator screws and other equipment requiring a lubricant with high load carrying capacity over a range of -73°C to +121°C.	Caution is advised when using this grease in non-specified applications. Low oil viscosity results in higher rates of storage separation or "bleeding."
Grease, Multi-purpose, Water Resistant	MIL-G-24139	In ball and roller bearings, usable over a range from 0°C to 107°C for continuous operation and for moderate periods up to 121°C.	Use of this grease in non-specified applications should be done only after evaluating its compatibility with all involved materials. Should not be used at operating temperatures below 0°C.
Grease, Aircraft, General Purpose, Wide Temperature Range	MIL-G-81322	Lubrication of aircraft accessories operating at high speeds over a wide temperature range. Also used during recoil mechanism assembly and other artillery items.	Caution is advised when using this grease in non-specified applications. Should not be specified in lieu of MIL-G-21164 or MIL-G-23549 without prior testing.
Lubricating Oil General Purpose Preservative, Water Displacing, Low Temperature	VV-L-800	Lubrication and protection against corrosion of certain small arms and automatic weapons and wherever a general purpose, water displacing, low temperature lubricating oil is required.	Oil loses its Newtonian properties at very low temperatures so its use at temperatures below -40°C is limited by machine design factors and should be proved, by test, before adoption.

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TABLE XI. Uses and limitations of lubricants, continued.

Material	Specification	Intended Use	Limitations
Lubricating Oil, Preservative, Medium	MIL-L-3150	Preservation of ferrous and non-ferrous surfaces, particularly where lubrication under light loads is required, such as gun mounts.	Not to be used below 0°C, or under medium or heavy loads.
Lubricating Grease (High-Temperature, Electric Motor, Ball and Roller Bearings)	MIL-L-15719	Lubricating ball and roller bearings in class H insulated (silicone) electric motors with heat-stabilized ball bearings operating above 150°C; also for lubrication of boiler sliding feet.	Should not be applied to bearings in which the main action involves the sliding of metal on metal, as in journal bearings, spiral gears, or gear trains, with the exception of sliding boiler feet.
Lubricating Oil, Steam Turbine and Gear, Moderate Service	MIL-L-17331	Lubrication for main and auxiliary steam turbines and gears, air compressors, and hydraulic equipment, as well as general mechanical lubrication.	Should not be used for non-specified applications without prior performance evaluation.
Hydraulic Fluid, Petroleum Inhibited	MIL-H-17672	Symbols 2110-I-H and 2135-T-H are intended for use in surface ship deck equipment. Symbol 2135-T-H is also used in hydraulic steering gears. Symbol 2075-T-H is used in submarine external hydraulic systems.	This fluid is not fire-resistant and should not be used in accumulator-loaded hydraulic systems at pressures above 600 pounds force per square inch (lbf/in^2).
Thread Compound, Antiseize, Zinc Dust-Petrolatum	MIL-T-22361	To prevent seizing during assembly or disassembly of threaded or unthreaded components made of aluminum or its alloys, engaged with components made of similar or dissimilar metals.	Application of an excessive amount of the compound may prevent proper seating of the components. Under low temperature conditions, the compound hardens and is difficult to apply. Not suitable for use on threaded or unthreaded components of optical equipment.

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TABLE XI. Uses and limitations of lubricants, continued.

Material	Specification	Intended Use	Limitations
Lubricating Oil, Instrument, Jewel Bearing, Non-Spreading, Low Temperature	MIL-L-3918	Lubrication of steel pivot and jewel bearing combinations in timepieces and other fine instruments. Allows operation of most instrument mechanisms at temperatures as low as -40°C.	Should not be used on instrument-type ball bearings because of the non-spreading properties of the material.
Lubricating Oil, Instrument, Aircraft, Low Volatility	MIL-L-6085	This is a low temperature oil, containing a synthetic oil component, inhibited against oxidation and having rust-preventive properties. Primary applications are for aircraft instruments and electronic equipment.	May soften paint, natural rubber, neoprene, and electrical insulating materials.
Lubricating Oil, Gear, Petroleum Base	MIL-L-6086	Lubrication in gear boxes where extreme pressure properties are required.	Contains extreme pressure additives and is not suitable for lubrication of internal combustion engines.
Petrolatum, Technical	VV-P-236	Light grade of lubricating grease. Also used as a constituent in certain types of corrosion or rust preventive compounds.	Should not be used as a lubricant in heavily loaded or hot running bearings.

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5.20 Conformal coatings. Unless otherwise specified, conformal coatings for moisture resistance, debris isolation and protection, and insulation shall be in accordance with MIL-I-46058, or as approved by the procuring activity. Coatings shall be selected for insulating and protective qualities. They shall not affect electrical properties nor physically damage fragile components being coated. Where practical, the desired total coating thickness shall be obtained by applying several thinner coats. Coatings shall be fully cured before next assembly in accordance with the applicable application instructions.

5.21 Insulators, insulating and dielectric materials. Insulators, insulating and dielectric materials shall be in accordance with MIL-STD-454.

5.21.1 Ceramic and glass materials. Unless otherwise specified, ceramic materials shall be glazed. Surfaces shall be smooth, uniform and free from porosity. Glass bonded mica shall not be used except with prior approval of the procuring activity.

5.22 Packaging and preservation. Packaging and preservation of electronic components and assemblies shall be in accordance with MIL-P-116 or as directed by the procuring activity. Desiccants, when used, shall be in accordance with paragraph 5.2(c).

5.22.1 Incompatible packaging materials. In addition to avoiding the incompatible materials listed in table IX, special care shall be taken to avoid enclosing incompatible materials within a package or compartment. Attention is called to the following:

a. Wood (sometimes used for shelves and boxes) emits harmful gases. Oak, cedar, chestnut, and some plywoods are especially bad.
b. Cushioning materials often give off sulfurous or acidic vapors, attacking silver, cadmium and other metals.
c. Acidic and ammonia vapors attack cadmium.
d. Vapors from paper and cardboard not specifically designed for packaging electronic hardware may tarnish silver and copper.
e. Copper, iron and manganese promote cracking of rubber.
f. Uncured or partially cured organic materials outgas, corroding nearby surfaces.

5.22.2 Volatile corrosion inhibitors. Volatile corrosion inhibitors shall be used to protect metals against corrosion in accordance with MIL-I-8574. Volatile corrosion inhibitors may be used as crystals, in oil or grease, or impregnated in paper or other materials.

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6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This document provides requirements for corrosion prevention and deterioration control in electronic components and assemblies, and as a reference for the selection of various protective measures designed to allow such equipment to withstand a variety of adverse environments.

6.2 Issue of DODISS. When this standard is used in acquisitions, the applicable issue of the DODISS must be cited in the solicitation (see 2.1.1, 2.1.2, and 2.2).

6.3 Metrication. Metric equivalents in accordance with FED-STD-376 are acceptable for use in this specification.

6.4 Subject term (keyword) listing.

Coating, protective
Corrosive effects prevention
Degeneration of equipment
Degradation of protective coatings
Moisture contamination

6.5 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

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