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MIL-STD-1250(MI
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MILITARY STANDARD

CORROSION PREVENTION AND DETERIORATION CONTROL

IN

ELECTRONIC COMPONENTS AND ASSEMBLIES

FSC 1400

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DEPARTMENT OF ARMY

WASHINGTON, D. C.

Corrosion Prevention and Deterioration Control in Electronic Components and Assemblies

MIL-STD-1250(MI)

1. This Standard has been approved by the Missile Command, Department of Army, and is mandatory for use by that activity. All other Military activities are required to employ this Standard where suitable.
2. Recommended corrections, additions or deletions should be addressed to U. S. Army Missile Command, AMSMI-IDD, Redstone Arsenal, Alabama, 35809.

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FOREWORD

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; 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 among suitable materials and processes, those which will withstand the attack of adverse environments during storage, shipment, and service.

This standard supplements the more general requirements of MIL-STD-454, 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.

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

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1. SCOPE

1.1 SCOPE. This standard serves as a guide and establishes minimum requirements for procedures, materials and systems for protecting electronic components 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 temperature, corrosive gases, chemicals, and microbial attack. This standard does not deal with protection against damage from stress, shock, or vibration. 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.

1.3 CONFLICTS. In the event of conflict between the requirements of this standard and those of specifications or drawings, the following order of precedence shall apply:

1. Contract
2. Drawing
3. Item Specification
4. Military Standard

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2. REFERENCED DOCUMENTS

2.1 The issues of the following documents in effect on the date of invitation for bids form a part of this standard to the extent specified herein.

SPECIFICATIONS

FEDERAL

QQ-A-250	Aluminum Alloy Plate and Sheet, General Specification for
QQ-C-320	Chromium Plating (Electrodeposited)
QQ-N-290	Nickel Plating (Electrodeposited)
QQ-P-35	Passivation Treatments for Austenitic, Ferritic, and Martensitic Corrosion-Resisting Steel (Fastening Devices)
QQ-P-416	Plating, Cadmium (Electrodeposited)
QQ-S-365	Silver Plating, Electrodeposited, General Requirements for
QQ-S-571	Solder, Tin Alloy, Lead-Tin Alloy and Lead Alloy

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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 the Treatment of Communications, Electronic, and Associated Electrical Equipment)

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MIL-F-495	Finish, Chemical, Black, for Copper Alloys
MIL-R-3065	Rubber, Fabricated Parts
MIL-M-3171	Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion on
MIL-D-3464	Desiccants, Activated, Bagged, Packaging Use and Static Dehumidification
MIL-S-3927	Sealing Compound, Thread, Polymerizing, Room Temperature
MIL-S-5002	Surface Treatments and Metallic Coatings for Metal Surfaces of Weapon Systems
MIL-C-5541	Chemical Films and Chemical Film Materials for Aluminum and Aluminum Alloys
MIL-S-6855	Synthetic Rubber Sheets, Strips, Molded or Extruded Shapes
MIL-W-6858	Welding, Resistance, Aluminum, Magnesium, Non-Hardening Steels or Alloys, Nickel, Alloys, Heat-Resisting Alloys, And Titanium Alloys, Spot and Seam
MIL-I-6869	Impregnants for Aluminum Alloy and Magnesium Alloy Castings
MIL-S-6872	Soldering Process, General Specifications for
MIL-S-7124	Sealing Compound, Elastomeric, Accelerator Required, Aircraft Structure
MIL-B-7883	Brazing of Steels, Copper, Copper Alloys, and Nickel Alloys
MIL-P-8116	Putty, Zinc Chromate, General Purpose
MIL-S-8516	Sealing Compound, Synthetic Rubber, Electric Connectors and Electric Systems, Accelerator Required

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MIL-I-8574	Inhibitors, Corrosion, Volatile, Utilization of
MIL-P-8585	Primer Coating, Zinc Chromate, Low-Moisture-Sensitivity
MIL-W-8604	Welding of Aluminum Alloys, Process for
MIL-W-8611	Welding, Metal Arc and Gas, Steels, and Corrosion and Heat Resistant Alloys, Process for
MIL-A-8625	Anodic Coatings, for Aluminum and Aluminum Alloys
MIL-C-8837	Coating, Cadmium (Vacuum Deposited) (ASG)
MIL-W-8939	Welding, Resistance, Electronic Circuit Modules (ASG)
MIL-T-10727	Tin Plating, Electrodeposited or Hot-Dipped, for Ferrous and Nonferrous Metals
MIL-S-11030	Sealing Compound, Noncuring, Polysulfide Base
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 Ferrous Metal Parts
MIL-P-13380	Primer, Weld-Through
MIL-L-13762	Lead Alloy Coating, Hot Dip (for Iron and Steel Parts)
MIL-L-13808	Lead Plating (Electrodeposited)
MIL-F-14256	Flux, Soldering, Liquid (Rosin Base)
MIL-C-14550	Copper Plating (Electrodeposited)

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MIL-P-15930	Primer Coating, Shipboard, Vinyl-Zinc Chromate (Formula No. 120 – for Hot Spray)
MIL-C-16173	Corrosion Preventive Compound, Solvent Cutback, Cold Application
MIL-C-16555	Coating Compound, Strippable, Sprayable
MIL-I-16923	Insulating Compound, Electrical, Embedding
MIL-W-18142	Wood Preservative Solutions, Oil-Soluble, Ship and Boat Use
MIL-W-18326	Welding of Magnesium Alloys, Gas and Arc, Manual and Machine Processes for
MIL-S-22473	Sealing, Locking and Retaining Compounds, Single-Component
MIL-C-22750	Coating, Epoxy-Polyamide
MIL-C-22751	Coating System, Epoxy-Polyamide, Chemical and Solvent Resistant; Process for Application Of
MIL-P-22808	Paint, Epoxy, Hydraulic Fluid Resistant
MIL-T-23142	Tape, Pressure-Sensitive Adhesive, for Dissimilar Metal Separation
MIL-C-23217	Coating, Aluminum, Vacuum Deposited (ASG)
MIL-P-23377	Primer Coating, Epoxy-Polyamide, Chemical and Solvent Resistant
MIL-L-23398	Lubricant, Solid Film, Air Drying
MIL-P-23408	Plating, Tin-Cadmium (Electrodeposited)
MIL-C-23411	Corrosion Preventive Compound Clear
MIL-S-23586	Silicone Rubber Compound, Room Temperature Vulcanizing

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MIL-C-26074	Coating, Nickel-Phosphorus, Electroless Nickel, Requirements for
MIL-M-45202	Magnesium Alloy, Anodic Treatment of
MIL-G-45204	Gold Plating (Electrodeposited)
MIL-P-45209	Palladium Plating (Electrodeposited)
MIL-S-45743	Soldering, High Reliability, Electrical Connections, for Guided and Ballistic Missile Systems, With Electrically Heated Soldering Irons, and Resistance Soldering Apparatus, Procedures for
MIL-L-46002	Lubricating Oil, Contact and Volatile Corrosion Inhibited
MIL-L-46010	Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting
MIL-C-46057	Coating, Polyurethane
MIL-I-46058	Insulating Compound, Electrical (for Coating Printed Circuit Assemblies)
MIL-P-46067	Plastic Embedding Compound, Epoxy, Rigid
MIL-P-46076	Plastic, Polyurethane, Flexible, Potting and Holding Compound
MIL-R-46085	Rhodium Plating, Electrodeposited
MIL-R-46092	Rubber, Silicone, Encapsulating Compound
MIL-S-46844	Solder Bath Soldering of Printed Wiring Assemblies, Automatic Machine Type
MIL-P-46847	Plastic Material, Foamed Polyurethane for Encapsulating Electronic Components
MIL-P-52192	Primer Coating, Epoxy
MIL-C-52210	Coating, Epoxy, Spray Type, for Printed Circuitry

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STANDARDS

MILITARY

MIL-STD-186	Protective Finishing Systems for Rockets, Guided Missiles, Support Equipment and Related Materials
MIL-STD-276	Impregnation of Porous Nonferrous Metal Castings
MIL-STD-446	Environments for Electronic Parts, Tubes and Solid State Devices
MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-810	Environmental Test Methods
MIL-STD-1276	Lead, Weldable, for Electronic Component Parts

2.2 OTHER PUBLICATIONS. The following documents form a part of this standard to the extent specified herein.

ARMY REGULATIONS

AR-705-15	Operation of Material Under Extreme Conditions of Environment

MICOM REGULATIONS

MICOM Regulation 705-8	Prevention of Weapon System Deterioration

SOCIETY OF AUTOMOTIVE ENGINEERS

AMS 2401	Plating – Cadmium, Low Hydrogen Content Deposit
AMS 2416	Plating – Nickel-Cadmium, Diffused

(Copies of AMS specifications may be obtained from the Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York, New York 10017.)

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3. DEFINITIONS

3.1 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.

3.2 CORROSION RESISTANT STEELS. Steel with sufficient alloy content (usually chromium and nickel) to withstand 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."

3.3 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.

3.4 DISSIMILAR METALS. Any combination of bare metals which is not indicated as a permissible couple in table III. The greater the difference in the EMF listed in table III, the more dissimilar are the two metals and the greater is the galvanic attack on the anodic metal.

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

3.6 ENCAPSULATION. The embedment and complete envelopment of an item or assembly in a plastic, elastomeric, or ceramic insulating material.

3.7 FUNGUS. Mold, yeast, mildew, and other micro-organisms.

3.7.1 Fungicidal. Able to kill fungi.

3.7.2 Funginert. Neither destroying nor supporting fungi.

3.7.3 Funginutrient. Providing sustenance for fungi.

3.7.4 Fungus resistant. Unaffected by fungi, as established by test in accordance with method 508, MIL-STD-810.

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3.8 GALVANIC SERIES. A ranking of metals in accordance with their relative anodic and cathodic position determined in some specific electrolyte; similar to table I.

3.9 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.

3.10 PURPLE PLAGUE. A brittle gold-aluminum compound formed in the presence of silicon.

3.11 RED PLAGUE. A copper oxide corrosion product formed on silver-plate-over-copper at pinholes or breaks in the silver plate.

3.12 STRESS CORROSION. A specific type of accelerated corrosion resulting from the combined effects of mechanical stress and corrosive environment.

3.13 VAPOR CORROSION INHIBITOR 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 DESIGN. Corrosion or deterioration of military electronic devices shall be prevented or minimized by attention to the following:

(a) Definition of anticipated environments, in accordance with AR-705-15, MIL-STD-446, or applicable specification;
(b) Avoidance of moisture traps;
(c) Selection of suitable materials;
(d) Protection against action of condensate produced by changes in temperature or pressure;
(e) Sealing joints;
(f) Providing for inspection and maintenance;
(g) Minimizing high stress concentration;
(h) Compliance with MICOM Regulation 705-8.

4.1.1 Degree of Protection Required. In establishing the degree of protection required to prevent degradation, attention shall be given to the following factors which affect the need for sealing, insulation, and preservation:

(a) Importance of function;
(b) Density of packaging;
(c) Impedance of circuit;
(d) Amplification factor;
(e) Susceptibility to electrolysis, silver migration or whisker growth;
(f) Proximity of conductor paths;
(g) Fragility of leads and interconnections.

4.2 MATERIALS. Materials shall be selected which are suitable for the purpose and are inherently resistant to deterioration, or are adequately protected against deterioration by compatible coatings. Unless otherwise specified, surfaces shall be smooth, providing no crevices for collection of moisture or contaminants. Care shall be taken that all materials in an assembly are compatible with each other, and that none outgas or liberate corrosive fumes.

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. Care shall be taken in the selection of proper cleaning methods and materials.

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(a) High strength steels shall not be cathodically cleaned in either acid or alkaline baths. High strength steels shall not be acid cleaned except anodically.
(b) Organic solvents for use on plastics shall be selected with care to avoid crazing or other damage to the plastic.
(c) Printed circuit board laminates shall not be roughened by over-zealous cleaning to remove soldering flux.
(d) For vapor degreasing, solvent cleaning and drying, only those materials and procedures listed in paragraph 4.2 of MIL-STD-186 shall be used.
(e) Care shall be taken that cleaning materials are compatible with all materials in the part or assembly.
(f) Dust, dirt and fingerprints shall be removed prior to assembly or storage.

4.4 WORKMANSHIP. Workmanship shall be in accordance with requirement 9 of MIL-STD-454. In addition, 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 corrodents in the atmosphere within electronic equipment. Techniques to be employed, 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 surface 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 30 percent relative humidity at 20°C (68°F). 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 temperatures above the dewpoint.

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5.3 SELECTION OF METALS. Metals shall be selected which are suitable for the purpose and are inherently resistant to corrosion. Unless otherwise specified in item specification or drawing, resistance shall be established by ability to pass 48 hours of salt fog in accordance with method 509 of MIL-STD-810. Dissimilar metals shall not be used in contact or close proximity unless suitably 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 to 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 practicable.

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 for high strength steels shall be selected in accordance with restrictions in MIL-S-5002. In addition, the following methods shall be employed to minimize damage:

(a) Organic coating, vacuum 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 for a minimum of three (3) hours at 190° ± 14°C.
(d) Where practicable, parts shall be thermally stress relieved prior to plating, for a minimum of three (3) hours at 190° ± 14°C.
(e) Where practicable, 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.

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5.3.4 Whisker Growth. The growth of metal whiskers on tin, cadmium 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 relieve stresses;
(d) Maintaining a low level of humidity in the equipment.

5.3.5 Electrolysis and Silver Migration. The progress 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 miminized 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 or MIL-C-52210.
(c) Contaminants shall be removed from conductor surfaces by careful cleaning followed by rinsing with deionized water, and thorough drying.
(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 in table I for preventing corrosion shall be given consideration. Coatings shall be in accordance with specifications listed in table II.

5.3.6.1 Cadmium Plating. Cadmium plating shall be in accordance with type II, class 2 of QQ-P416, AMS 2401-4, or vacuum deposited in accordance with type 2, class II of MIL-C-8837. Parts plated in accordance with AMS 2401-4 shall be given a supplementary chromate treatment in accordance with MIL-T-12879. Because of high susceptibility to attack by corrosive vapors, cadmium or cadmium plated parts shall not be used in an enclosed assembly containing acid, ammonia, adhesives, coatings, plastics, varnishes or other organic materials, or vapors therefrom.

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TABLE I. SELECTION OF METALLIC COATINGS FOR MINIMUM CORROSION

Purpose	Recommended	Not Recommended
Contact with aluminum or magnesium	Cadmium or tin	Chromium, copper, silver, gold
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	
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
Easy etching (for printed circuit board manufacture)	Cadmium, nickel (in ferric chloride only), indium, tin.	Rhodium, silver, tin-lead, gold.

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

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TABLE II. SPECIFICATIONS FOR METALLIC COATINGS

Metal	Specification
Aluminum, vacuum deposited	MIL-C-23217
Cadmium, electroplated	QQ-P-416
Cadmium, electroplated, low hydrogen content	AMS 2401
Cadmium, vacuum deposited	MIL-C-8837
Chromium, electroplated	QQ-C-320
Copper, electrodeposited	MIL-C-14550
Gold, electrodeposited	MIL-G-45204
Lead, electrodeposited	MIL-L-13808
Lead, hot dip	MIL-L-13762
Nickel, electrodeposited	QQ-N-290
Nickel-cadmium, diffused	AMS-2416
Nickel-phosphorus, electroless	MIL-C-26074
Palladium, electrodeposited	MIL-P-45209
Rhodium, electrodeposited	MIL-R-46085
Silver, electrodeposited	QQ-S-365
Tin, electrodeposited or hot dip	MIL-T-10727
Tin-cadmium, electrodeposited	MIL-P-23408

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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 silver, copper, or chromium, into gold electrodeposits under high temperature conditions. 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. Recommended thickness of gold plating is 0.000050 inch for tarnish prevention over silver, 0.00010 inch for waveguides or contacts where a nonmigrating material is required, 0.00020 inch for general engineering use and 0.00030 inch for resistance to extreme corrosion and wear. 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. Where desired for electrical bonding, nickel-cadmium coating shall be in accordance with AMS 2416. Electroless nickel may be applied directly to aluminum or magnesium alloys without preliminary zincate treatment, for use as a base for additional plating. Nickel shall be used under gold or rhodium for applications requiring high mechanical strength and hardness.

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 overcoated 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).

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. Electroless tin may be applied directly to aluminum or magnesium alloys without preliminary zincate treatment, for use as a base for additional plating. Care shall be taken to prevent formation of metal whiskers on tin surfaces during storage (see 5.3.4).

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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.

5.3.6.10 Zinc Plating. Zinc plating shall not be used.

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 vacuum deposition to either metallic or nonmetallic surfaces for electrical conductivity. Vacuum deposited coatings shall not be used for any mechanical application because of their extreme thinness, fragility and susceptibility to damage.

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 and magnesium castings shall be in accordance with MIL-I-6869.

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 shall, after passivation, receive one coat of zinc chromate primer followed by suitable topcoat.

5.4.2 Carbon and Low Alloy Steels. Ordinary iron and steel shall be coated with cadmium, nickel or tin in accordance with table II 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.

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(c) Springs shall preferably be given organic coatings, or be coated by vacuum 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 compound such as MIL-C-23411, MIL-C-16173, or MIL-C-11796.

5.5 NONFERROUS METALS. The noble metals (gold, palladium, platinum and rhodium) and the corrosion-resistant metals (chromium, nickel, tin, tin-lead solder and titanium) require no finish other than cleaning. Surface finish for electrical bonding or grounding is listed in 5.8 and table VI. Applications of aluminum, copper and magnesium shall receive the protection specified in 5.5.1 through 5.5.3.1 unless in hermetically sealed units.

5.5.1 Aluminum. All aluminum and aluminum alloys shall be anodized in accordance with MIL-A-8625, except as follows:
(a) In areas of electrical bonding (see 5.8.1).
(b) For applications where anodizing is not possible, 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 (such as electroless nickel) in lieu of anodize.

The anodic or chemical film, or the metallic coating, shall be applied after all punching, drilling, machining, forming and fabrication have been completed. Paint finish systems, if required, may be applied over anodic or chemical film treatment. Paint finishes shall be in accordance with MIL-STD-186 or applicable specifications.

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.

5.5.3 Magnesium. Because of magnesium's poor resistance to corrosion, whenever the contractor proposes to use magnesium, he shall furnish sufficient

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justification and obtain approval from the procuring activity for each specific application prior to design incorporation. The contractor shall specify a long duration protective system which must have demonstrated ability to adequately protect magnesium, and which is subject to approval by the procuring activity. The contractor shall make provision for regular corrosion inspection which can be accomplished without extensive disassembly of structure. As the minimum requirement, magnesium parts shall receive the following:

(a) Rigid magnesium parts shall be anodized in accordance with type II, class A, grade 3 of MIL-M-45202. Magnesium parts subject to flexing shall, in lieu of anodize, receive chemical treatment in accordance with MIL-M-3171.

(b) All magnesium parts shall then be given two coats of alkali resistant primer, followed by one or more coats of compatible topcoat. Typical organic finishes for magnesium are MIL-P-23377 primer, applied in accordance with MIL-C-22751, with MIL-C-22750 topcoat; or MIL-P-52192 primer, with MIL-C-22750 topcoat; or MIL-P-23377 primer, with MIL-P-22808 topcoat.

(c) Magnesium parts for electronic applications may be given other moisture proofing coatings such as epoxy or polyurethane, in lieu of above primer and topcoat, at the option of the procuring activity.

5.5.3.1 Magnesium in Dissimilar Metal Contacts. Magnesium requires extreme precautions to prevent destructive corrosion when used with any other metal. In addition to anodize or chemical film treatment on the magnesium, each of the metal surfaces shall receive a minimum of two coats of one of the primers of paragraph 5.5.3 subject to approval of procuring activity. Furthermore, an aluminum alloy 5052 gasket, QQ-A-250, should be interposed between the two metals. If use of a gasket is not practical, the joint shall be sealed with moisture-proofing compound such as MIL-S-7124.

5.6 GALVANIC CORROSION. Dissimilar metals as defined in 3.4, 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 "permissible" in table III be assembled, the applicable measures in table IV shall be used to prevent corrosion. Special attention is called to the following:

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Table III
GALVANIC COUPLES

GROUP	METALLURGICAL CATEGORY	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 DURALUMIN 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 DURALUMIN; 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.
○ INDICATES THE MOST CATHODIC MEMBER OF THE SERIES, ● AN ANODIC MEMBER, AND THE ARROWS INDICATE THE ANODIC DIRECTION.
REFER TO TABLE II, MIL-STD-186, FOR GROUP AMPLIFICATION OF GALVANIC COUPLES.

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TABLE IV. PREVENTION OF DISSIMILAR METAL CORROSION

Preventive Measure	Example
(1). Select metals which form a permissible couple in table I.	Use nickel, not naval brass, in contact with silver.
(2). Interpose a metal which reduces the potential difference between the two metals.	Tin plate brass to be used next to aluminum.
(3). Design the metal contact so the relative area of the cathodic (more noble) metal is the smaller.	Stainless steel screws in aluminum chassis.
(4). Apply corrosion inhibitor such as zinc chromate primer MIL-P-8585 or zinc chromate paste MIL-P-8116.	Use zinc chromate inhibitor when assembling steel screws in aluminum.
(5). Interpose an insulating barrier or nonhygroscopic gasket between the dissimilar metals.	In structural joints, interpose tape MIL-T-23142. In components, use organic insulants such as conformal coating MIL-I-46058.
(6). Apply insulating organic coating to surface of each metal.	Coatings such as vinyl zinc chromate primer MIL-P-15930, epoxy primer MIL-P-52192, insulating coating MIL-C-46057, MIL-V-173, MIL-I-46058.
(7). Seal joint area with moisture-proof coating or organic sealant.	In structural joints, sealant such as MIL-S-7124. In components, coatings such as MIL-V-173 or MIL-I-46058.

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(a) When reference is made to a metal, it is the metal on the surface, regardless of whether solid, plated, laminated or dipped.
(b) Dissimilar metal contacts with magnesium shall be avoided. If it is necessary to have magnesium in contact with another metal, it shall be finished in accordance with 5.5.3.1.
(c) Graphite acts as a metal and shall be so considered for purposes of determining dissimilar metal contact. Solid film lubricants containing graphite shall not be used.
(d) Standard tin or nickel plated hardware may be mounted on aluminum chassis without further protection or insulation, except that nickel plated parts shall not be used in contact with aluminum in exterior applications.
(e) The anodic layer on aluminum is ordinarily insulating, but may lose this quality after exposure to humidity. Anodize should not be depended upon for prevention of dissimilar metal contact.

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 entrapment. The effect of joining temperatures and materials shall be considered before selection of the joining technique is made.

5.7.1 Adhesive Bonding. Adhesives shall be in accordance with requirement 23 of MIL-STD-454. They shall not emit volatile products nor attack nearby equipment nor 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. Dissimilar metal contacts shall be overcoated with insulating organic coating to prevent corrosion. To minimize corrosion 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, and cadmium in accordance with table II, except that cadmium shall not be used in enclosed areas. Rivets, bolts, and threaded fasteners shall be assembled with wet zinc chromate primer in accordance with MIL-P-8585 or coated with zinc chromate paste in accordance with MIL-P-8116 or other sealant approved by the procuring activity. Threads shall be avoided in soft metals such as aluminum and magnesium. When it is necessary to thread into aluminum, zinc chromate paste in accordance with MIL-P-8116 or qualified graphite-free dry film antiseize compounds shall be used

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Every effort shall be made to avoid the use of steel inserts in magnesium; if metal inserts are required, assemblies into magnesium shall be made using zinc chromate paste in accordance with MIL-P-8116 or non-curing polysulfide sealant in accordance with MIL-S-11030. At any joint involving dissimilar metals, measures shall be taken to prevent galvanic corrosion. Locking compounds in accordance with MIL-S-3927 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 coating to prevent corrosion.

5.7.2.1 Crevice Corrosion. To prevent corrosion in crevices, particularly joints in corrosion resistant steel, under washers and at threaded fasteners where there is lack of oxygen, such joints shall be sealed with polysulfide, polyurethane, epoxy, silicone rubber or similar sealant. Marker tapes applied to metallic components shall be applied only on surfaces previously coated with varnish in accordance with MIL-V-173.

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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 shall be in accordance with MIL-S-6872, MIL-S-45743, MIL-S-46844, and requirement 5 of MIL-STD-454. Solder shall be in accordance with QQ-S-571. Soldering over gold shall be avoided wherever possible. If necessary to solder over gold, care shall be taken to minimize formation of brittle gold-solder compound by one or more of the following methods: use extremely pure (99.99+) gold; use thin plate; use minimum soldering time at minimum temperature. Soldered joints shall be protected with moisture-proofing coating such as MIL-V-173 or MIL-I-46058.

5.7.5.1 Soldering Flux. Soldering flux shall be in accordance with QQ-S-571 types R or RMA, or MIL-F-14256 types W or A. The lowest acid content flux that will accomplish the purpose shall be selected. Flux residues shall be removed by cleaning after soldering, with care not to roughen surfaces of adjacent parts.

5.7.6 Welding, Structural. Fusion and resistance welding shall be in accordance with the following: gas and arc welding of aluminum, MIL-W-8604; gas and arc welding of magnesium, MIL-W-18326; gas and arc welding of steel and corrosion resistant alloys, MIL-W-8611; resistance welding, 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-13380.

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 electron-beam 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 "purple plague" (see 3.10) 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.

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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 VI. 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 immediately after making the electrical bond or ground. Attention is directed to table VII.

TABLE VI. 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 3
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 3
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
Magnesium	Bare; clean immediately before bonding and coat joint area immediately afterward
Nickel and corrosion resistant steel	Bare; difficult to bond because of adherent oxide film
Silver	Bare
Solder	Bare
Tin	Bare

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TABLE VII. 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, or other contaminants.

(5) Bond shall be made by means of bus-strap or shear-splice joint when practicable.

(6) Bonds made by conductive gaskets or adhesives, and involving dissimilar metal contact, shall be sealed with organic sealant.

(7) If bond is made by use of steel star washer on aluminum, the washer shall be cadmium plated and shall be inserted with zinc chromate paste in accordance with MIL-P-8116 to minimize galvanic corrosion.

(8) A combination environmental and electromagnetic seal, such as wire or other metal form in an elastomer, shall be preferred.

(9) 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 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 bonded areas shall be low electrical resistance chromate type in accordance with MIL-C-5541. It is thin, fragile and easily damaged by abrasion, and bond should be made immediately after application of chemical film.

5.8.2 Bonding Dissimilar Metals. Where electrical bond is made between dissimilar metals, as defined in table III, 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.

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NOTE: If bond is made by use of 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 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-16555. At the time the 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 fumes therefrom 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.

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 gaskets of monel or silver are used in conjunction with aluminum or magnesium.

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;
(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.

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

(a) Materials (unless hermetically sealed, impregnated or encapsulated) shall have minimum moisture absorption, and not 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.

TABLE VIII. EFFECT OF MOISTURE ON NONMETALLIC MATERIALS

Electrical Properties

Increases surface conductivity
Increases loss angle
Increases capacitance
Increases dissipation factor
Reduces volume resistivity
Reduces dielectric strength

Physical and Mechanical Properties

Swelling
Distortion
Decomposition
Change in strength
Wicking and moisture retention

Fungal Resistance

Encourages fungal growth

5.11 FUNGUS RESISTANCE. 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 IX. 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 by the procuring activity. Resistance to fungus shall be established by method 508 of 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.

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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.

TABLE IX. FUNGINERT MATERIALS

Funginert in All Grades And Conditions	Some Grades Funginert; Establish by Test Per MIL-STD-810
Acrylonitrile-vinyl chloride copolymer	Acetal resins
Asbestos	Cellulose acetate
Ceramics	Cellulose acetate butyrate
Chlorinated polyether	Epoxy glass fiber laminates
Glass	Epoxy resin
Metals	Melamine-formaldehyde
Mica	Natural rubbers
Plastic laminates:	Phenol-formaldehyde
Silicone glass fiber	Poly methyl methacrylate
Phenolic nylon fiber	Poly vinyl chloride
Diallyl phthalate and polyethylene terephthalate	Poly vinyl chloride acetate
Polyacrylonitrile	Poly vinyl fluoride
Polyamide	Plastic laminates using:
Polycarbonate	Cotton filler
Polyethylene	Linen filler
Polymonochlorotrifluoroethylene	Paper filler
Polypropylene	Wood-flour filler
Polystyrene	Synthetic rubbers
Polytetrafluoroethylene	Urea-formaldehyde
Polyethylene terephthalate	
Poly vinylidene chloride	
Silicone resin	

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, clean, with an unbroken surface and glazed. Where practicable, fungicide should be incorporated into the coating for optics.

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5.12 TEMPERATURE RESISTANCE. Materials shall be selected which maintain their desired properties throughout the temperature range anticipated as established by the applicable group in MIL-STD-446. 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 avoidance of outgassing and the effect of coatings on electrical properties. Certain combinations of materials shall be avoided; examples are listed in table X.

5.13.1 Outgassing. Materials, as installed in the equipment, shall not liberate corrosive or toxic 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 in closed compartments.
(c) Where practical, the use of neoprene, phenolic, polysulfide and vinyl shall be avoided in closed areas.
(d) Cadmium shall not be used in closed compartments.

5.14 FLAME AND ARC RESISTANCE. Materials shall be in accordance with requirements 3 and 26 of MIL-STD-454.

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 employed. Rubber shall be in accordance with MIL-R-3065 or MIL-S-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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TABLE X. EXAMPLES OF INCOMPATIBLE MATERIALS

Material	Attacks, or Is Otherwise Incompatible With
Acid	Acrylic, alkyd, cellulosic, polyamide, polyester, polyethylene, urethane
Alkali	Acrylic, alkyd, cellulosic, polyester
Ammonia	Cadmium, copper, zinc, cobaltous chloride humidity indicators
Copper, iron, manganese	Rubber
Cyanoacrylate sealant	ABS, cellulosic, methylmethacrylate, polycarbonate, vinyl
Diester oil	Polychloroprene (neoprene), vinyl
Hydrocarbon solvents	Acrylic, cellulosic, polycarbonate, polystyrene, silicone
Organic vapors	Cadmium, zinc
Paper, cardboard	Brass, copper, silver
Polyvinylchloride	Zinc, aluminum, magnesium, brass, copper, lead, tin, tin-lead, gold plate over brass
Silicone oil or grease	Most organic coatings

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5.16 OILS, GREASES, AND LUBRICANTS. Oils and greases shall be selected which 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 methods 507 (humidity) and 509 (salt fog) of MIL-STD-810. Lubricants containing graphite shall not be used.

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-L-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 Moisture Displacing Compound. Where close tolerance precludes other protective finish, or for field repair, the penetrating oils and protective compounds in accordance with MIL-C-23411 may be used to coat metal surfaces against moisture, fingerprints and corrosion.

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 in accordance with MIL-L-46010 or air dry solid film lubricant in accordance with MIL-L-23398 (provided it is graphite-free) shall be preferred.

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 FIBROUS MATERIALS. Fibrous materials shall not be used except when completely encapsulated or impregnated to prevent moisture absorption.

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5.19 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-T-18142. The use of cork shall be avoided. When used, cork shall be treated with class I mildew inhibiting agent in accordance with MIL-T-12664.

5.20 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-P-46076, MIL-R-46092, or MIL-P-46847, or as approved by the procuring activity.

5.21 CONFORMAL COATINGS. Unless otherwise specified, conformal coatings for moisture resistance and insulation shall be in accordance with MIL-C-46057, 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.

5.22 INSULATORS, INSULATING AND DIELECTRIC MATERIALS. Insulators, insulating and dielectric materials shall be in accordance with requirement 11 of MIL-STD-454.

5.22.1 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.

5.23 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).

5.23.1 Attack by Packaging Materials. In addition to avoiding the incompatible materials listed in table X, special care shall be taken to avoid enclosing incompatible materials within a package or compartment. Attention is called to the following:

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(a) Wood (sometimes used for shelves and boxes) emits harmful gases. Oak, cedar and chestnut are especially bad.
(b) Cushioning materials often give off sulfurous or acidic vapors, attacking silver, cadmium and other metals.
(c) Organic, 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.

5.23.2 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.

Copies of specifications, standards, drawings and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.

Copies of this standard for military use may be obtained as indicated in the foreword to, and the general provisions of, the Index of Military Specifications and Standards.

The title and identifying symbol should be stipulated when requesting copies of of military standards.

Custodian:
Army-MI

Preparing activity:
Army-MI
Project No. 1400-A019

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(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)*
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	☐ MANUFACTURER
	☐ OTHER *(Specify)*: _____

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional	b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
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