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SENSITIVE

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DETAIL SPECIFICATION

SURFACE TREATMENTS AND INORGANIC COATINGS FOR METAL SURFACES OF WEAPONS SYSTEMS

This specification is approved for use by all
Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers the requirements for cleaning, surface treatment, and application of inorganic coatings for metallic surfaces of weapons systems parts.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 or 4 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3 or 4 of this specification, whether they are listed or not.

2.2 Government and non-government documents.

2.2.1 Specifications and standards. The following specifications and standards form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

Comments, suggestions, or questions on this document should be addressed to Commanding Officer, Naval Air Warfare Center Aircraft Division Lakehurst, System Standardization and PHS&T Branch, Code BL32600, Mail Stop 120-3, Route 547, Joint Base MDL, NJ 08733-5100 or emailed to LKE-NAVAIRDocComments@navy.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST online database at <https://assist.dla.mil>.

AMSC N/A

AREA MFFP

FEDERAL SPECIFICATIONS

- | | |
|----------|--|
| TT-N-95 | - Naphtha, Aliphatic |
| TT-C-490 | - Chemical Conversion Coatings and Pretreatments for Metallic Substrates (Base for Organic Coatings) |
| TT-I-735 | - Isopropyl Alcohol |

DEPARTMENT OF DEFENSE SPECIFICATIONS

- | | |
|---------------|---|
| MIL-PRF-680 | - Degreasing Solvent |
| MIL-DTL-5541 | - Chemical Conversion Coatings on Aluminum and Aluminum Alloys |
| MIL-PRF-8625 | - Anodic Coatings for Aluminum and Aluminum Alloy |
| MIL-DTL-13924 | - Coating, Oxide, Black, for Ferrous Metals |
| MIL-DTL-16232 | - Phosphate Coating, Heavy, Manganese or Zinc Base |
| MIL-C-17711 | - Coatings, Chromate, for Zinc Alloy Castings and Hot Dip Galvanized Surfaces |
| MIL-P-23408 | - Plating: Tin-Cadmium (Electrodeposited) |
| MIL-PRF-32295 | - Cleaner, Non-Aqueous, Low-VOC, HAP-Free |
| MIL-DTL-32459 | - Coatings, Anodic for Magnesium and Magnesium Alloys |
| MIL-DTL-32495 | - Powders for Cold Spray Deposition |
| MIL-DTL-32502 | - Coating, Cobalt-Phosphorous Alloy, Nanocrystalline (Electrodeposited) |
| MIL-PRF-32647 | - Zinc Nickel, Electroplating for Fasteners |
| MIL-DTL-32648 | - Zinc Nickel Plating, Low Hydrogen Embrittlement Electro-Deposition |
| MIL-PRF-32660 | - Plating, Zinc-Nickel Alloy, Low Hydrogen Embrittlement, Alkaline Electrodeposited |
| MIL-R-46085 | - Rhodium Plating, Electrodeposited |
| MIL-DTL-81706 | - Chemical Conversion Materials for Coating Aluminum and Aluminum Alloys |
| MIL-C-81751 | - Coating, Metallic-Ceramic |
| MIL-DTL-81772 | - Thinner, Aircraft Coating |
| MIL-DTL-83488 | - Coating, Aluminum, High Purity |
| MIL-PRF-85570 | - Cleaning Compounds, Aircraft Exterior |
| MIL-PRF-87937 | - Cleaning Compound, Aerospace Equipment |

DEPARTMENT OF DEFENSE STANDARDS

- | | |
|--------------|---|
| MIL-STD-865 | - Selective Brush Plating, Electrodeposition |
| MIL-STD-869 | - Thermal Spraying |
| MIL-STD-870 | - Cadmium Plating, Low Embrittlement, Electrodeposition |
| MIL-STD-889 | - Galvanic Compatibility of Electrically Conductive Materials |
| MIL-STD-1500 | - Cadmium-Titanium Plating, Low Embrittlement, Electrodeposition |
| MIL-STD-1501 | - Chromium Plating, Low Embrittlement, Electrodeposition |
| MIL-STD-1568 | - Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems |
| MIL-STD-1587 | - Material and Process Requirements for Aerospace Weapons Systems |

- MIL-STD-3021 - Materials Deposition, Cold Spray
- MIL-STD-7179 - Finishes, Coatings, and Sealants, for the Protection of Aerospace Weapons Systems and Support Equipment

DEPARTMENT OF DEFENSE HANDBOOK

- MIL-HDBK-1884 - Coating: Plasma Spray Deposition

(Copies of these documents are available online at <https://assist.dla.mil/>.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

AMERICAN WELDING SOCIETY (AWS)

- AWS C2.19/C2.19M - Specification for the Application of Thermal Spray Coatings to Machine Elements for OEM and Repair

(Copies of this document are available from www.aws.org.)

ASTM INTERNATIONAL

- ASTM D329 - Standard Specification for Acetone
- ASTM B545 - Standard Specification for Electrodeposited Coatings of Tin
- ASTM B600 - Standard Guide for Descaling and Cleaning Titanium and Titanium Alloy Surfaces
- ASTM B633 - Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel
- ASTM B679 - Standard Specification for Electrodeposited Coatings of Palladium for Engineering Use
- ASTM B700 - Standard Specification for Electrodeposited Coatings of Silver for Engineering Use
- ASTM A967/A967M - Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts
- ASTM D1193 - Laboratory Reagent Water
- ASTM D1732 - Standard Practices for Preparation of Magnesium Alloy Surfaces for Painting

(Copies of these documents are available from www.astm.org.)

SAE INTERNATIONAL

- SAE AMS2403 - Plating, Nickel, General Purpose
- SAE AMS2404 - Plating, Electroless Nickel
- SAE AMS2410 - Plating, Silver, Nickel Strike – High Bake

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SAE AMS2411	- Plating, Silver for High Temperature Applications
SAE AMS2416	- Plating, Nickel-Cadmium, Diffused
SAE AMS2418	- Plating, Copper
SAE AMS2422	- Plating, Gold
SAE AMS2423	- Plating, Nickel, Hard Deposit
SAE AMS2424	- Plating, Nickel, Low Stressed Deposit
SAE AMS2427	- Aluminum Coating Ion Vapor Deposition
SAE AMS2428	- Plating, Cobalt-Phosphorous, Nanocrystalline
SAE AMS2430	- Shot Peening
SAE AMS2432	- Shot Peening, Computer Monitored
SAE AMS2437	- Coating, Plasma Spray Deposition
SAE AMS2447	- Coating, Thermal Spray High Velocity Oxygen/Fuel Process
SAE AMS2448	- Application of Tungsten Carbide Coatings on Ultra High Strength Steels High Velocity Oxygen/Fuel Process
SAE AMS2451	- Plating, Brush General Requirements
SAE AMS2460	- Plating, Chromium
SAE AMS2461	- Plating, Zinc-Nickel Alloy (12 to 16% Ni)
SAE AMS2700	- Passivation of Corrosion Resistant Steels
SAE AMS2759/9	- Hydrogen Embrittlement Relief (Baking) of Steel Parts
SAE AMS2759/11	- Stress Relief of Steel Parts
SAE AMS3819	- Cloths, Cleaning for Aircraft Primary and Secondary Structural Surfaces
SAE AMS-C-8837	- Coating, Cadmium (Vacuum Deposited)
SAE AMS-C-81562	- Coatings, Cadmium, Tin-Cadmium and Zinc (Mechanically Deposited)
SAE AMS-M-3171	- Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion of
SAE AMS-P-81728	- Plating, Tin-Lead (Electrodeposited)
SAE AMS-QQ-N-290	- Nickel Plating (Electrodeposited)
SAE AMS-QQ-P-416	- Plating, Cadmium (Electrodeposited)

(Copies of these documents are available from www.sae.org.)

2.3 Order of precedence. Unless otherwise noted herein or in the contract, 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.

3. REQUIREMENTS

3.1 Materials and processes. Materials and processes shall conform to the applicable documents as specified herein. For aerospace weapon systems, refer to MIL-STD-1568 for additional corrosion prevention and control, and MIL-STD-1587 for additional materials and process information and requirements. Additional guidance may be found in the DoD Corrosion Prevention and Control Planning Guidebook (available on the Defense Acquisition University website <https://dau.edu>). Materials and processes not covered by applicable specifications and any deviations from the requirements herein shall not be used unless approved by the cognizant engineering authority (CEA) (see 6.4).

3.2 Finishing requirements. Unless otherwise specified, all fabrication operations, including thermal treatments and cleaning shall be completed prior to application of any surface treatment or coating processes.

3.3 Surfaces. Parts shall conform to dimensions and surface texture requirements as specified throughout preparation, cleaning, surface treatment and coating processes. All thicknesses shall be considered final unless otherwise specified. Part surfaces, following material removal by any mechanical or chemical methods, shall be inspected by specified procedures for conformance to design and drawing requirements and freedom from defects and imperfections.

3.4 Cleaning. Cleaning, prior to application of surface treatments and coatings, shall be as specified herein. Assemblies containing high strength steel (HSS) parts under sustained tensile stresses or parts containing crevices, which cannot be adequately protected (e.g., maskants, wax, tape, etc.) to prevent entrapment of cleaning solutions, shall not be cleaned as assemblies. The use of these cleaning methods shall not result in damage to the part such as pitting, intergranular attack or hydrogen embrittlement cracking. After cleaning, all parts shall be completely free of corrosion products, scale, paint, grease, oil, flux, and other foreign materials. Following cleaning operations, all parts shall be protected to ensure contaminants are not transferred to work surfaces and shall be inspected for compliance with design requirements. Any parts displaying non-compliant defects shall be rejected or dispositioned for additional CEA approved processing. If required after cleaning, parts shall be coated in accordance with the applicable specifications.

3.4.1 Organic contamination removal. The materials and processes used for organic contamination removal shall be designed and controlled to ensure that there are no subsequent corrosion effects during subsequent manufacturing or repair processes.

3.4.1.1 Organic soils. Organic soils shall be removed by emulsion cleaning, semi-aqueous immersion cleaning, alkaline or electrolytic alkaline cleaning (anodic only), solvent immersion, solvent spraying, solvent hand cleaning, vapor degreasing, or other methods approved by the CEA, whichever is more applicable to the composition of the part and soil to be removed.

3.4.1.2 Hand cleaning. Hand cleaning shall be performed using degreasing solvents (MIL-PRF-680 or MIL-PRF-32295), aliphatic hydrocarbons (such as aliphatic naphtha, TT-N-95, or paint thinner, MIL-DTL-81772 Type I), isopropyl alcohol (TT-I-735), or acetone (ASTM D329). Solvent hand cleaning shall be performed using a clean, lint free cloth (e.g., SAE AMS3819) to obtain a residue free surface. Final wiping after cleaning shall be performed

prior to solvent evaporation using a clean dry/lint free cloth to ensure that surface contaminants are removed.

3.4.2 Inorganic contamination removal. Inorganic contamination removal shall be in accordance with the procedures specified herein. When stress relief is specified by the CEA, the stress relief shall be performed in accordance with SAE AMS2759 prior to any chemical or electrochemical cleaning.

3.4.2.1 Aluminum and its alloys. Aluminum and its alloys shall be cleaned using chemical and/or mechanical means or as specified by the CEA. Mechanical cleaning using abrasives containing iron and its oxides, steel and copper alloy based materials shall not be used. Cleaners conforming to MIL-PRF-85570 or MIL-PRF-87937 are recommended for chemical cleaning of aerospace weapons systems.

3.4.2.2 Steels. Steels shall be cleaned using mechanical means, alkaline or electrolytic alkaline descaling, molten salt bath methods, acid pickling, or combinations thereof. High strength steels and high strength stainless steels heat-treated to an ultimate tensile strength (UTS) of 180 KSI (Rockwell C scale hardness of 40) or higher are susceptible to hydrogen embrittlement (HE) during cleaning and electroplating processes where hydrogen is evolved. Cleaning of steel parts in the heat treated condition having a hardness of HRC 40 or above shall not be done by acid pickling or direct current (cathodic) electro-cleaning unless specifically authorized by the CEA. Designs calling for the use of coatings or electroplating deposition processes that can result in HE shall specify specific processing requirements to both prevent and eliminate HE. Preventive measures may include reducing high residual surface tensile stresses by thermal stress relieving, imparting beneficial compressive stresses to the surface by shot peening and careful control of the coating deposition process to minimize the evolution of hydrogen during the deposition process. If specified, stress relief of high strength steel parts prior to exposure to potentially embrittling cleaning or coatings processes shall be in accordance with SAE AMS2759/11.

3.4.2.2.1 Elimination of hydrogen embrittlement. Elimination of HE (de-embrittlement) of high strength steels following coating deposition is accomplished by low temperature heating (baking) of the part or component in air for specific time periods. Hydrogen embrittlement relief following cleaning and coating processes that can result in HE shall be in accordance with SAE AMS2759/9 or as approved by the CEA. Machining or mechanical deformation shall not be performed prior to baking.

3.4.2.2.2 Heat treatment of steel. Heat treatment of steels, including requirements for furnace atmospheres for the prevention of surface contamination, compositional changes, intergranular attack, carburizing or decarburization, etc. and for the detection thereof, shall be in accordance with SAE AMS2759 or other appropriate Government or Industry specification as determined by the CEA.

3.4.2.3 Magnesium and its alloys. Magnesium and its alloys shall be cleaned in accordance with SAE AMS-M-3171 or by other processes approved by the CEA.

3.4.2.4 Titanium and its alloys. For removal of inorganic contamination, titanium and its

alloys shall be cleaned in accordance with ASTM B600 or by other processes approved by the CEA.

3.4.3 Flux removal. Flux removal shall be in accordance with the applicable welding, soldering, or brazing specification. If unspecified, then soldering, welding and brazing fluxes shall be removed by using hot water, soap and water, alcohol (TT-I-735), degreasing solvent (MIL-PRF-680) or other CEA approved methods that do not result in attack of the metal. Methyl alcohol shall not be used on magnesium or titanium alloys. Acid or alkaline materials shall not be used, unless approved by the CEA.

3.4.4 Metallic surface contamination. To prevent dissimilar material transfer, abrasives (paper, cloth, grinding wheels, abrasive blasting media, etc.) used on one metallic material shall not be used on another metallic surface unless the two metals or alloys are in the same alloy group (e.g., steel-steel, aluminum-aluminum, etc.), determined to be compatible by the CEA (e.g., MIL-STD-889), or the abrasive is suitably reconditioned. To prevent particle fragment embedment and subsequent decontamination treatments, shot peening of nonferrous alloy parts should be performed using ceramic shot, glass beads or stainless steel shot. If steel shot is used for peening of parts made of aluminum, magnesium, corrosion resistant steel, and titanium alloys, these alloys shall be cleaned (decontaminated) post-peening to remove all iron contaminants in accordance with SAE AMS2430, SAE AMS2432 or by a method approved by the CEA.

3.4.5 Rinsing. When either significantly acidic ($\text{pH} < 5$) or significantly alkaline ($\text{pH} > 8$) materials are employed, the cleaned parts shall be given a thorough rinse that removes all acid or alkali prior to the coating operations. Information on controlled contaminant levels of rinse water can be found in ASTM D1193. Cleaning and rinsing processes shall be in accordance with approved CEA controlled specifications.

3.5 Methods of coating application. Coatings shall be applied in conformance to applicable specifications by electrodeposition, vacuum deposition, mechanical deposition, metallic compound deposition, thermal spraying methods, hot dip methods, ion vapor deposition, cold spray or other methods approved by the CEA. Coatings may be applied by sputtering, if specified and approved by the CEA.

3.5.1 Electrodeposition restrictions. For high strength steels and stainless steels, electrodeposited coatings shall follow the restrictions outlined in 3.4.2.2.

3.5.2 Thermal spraying. Thermal spraying or thermal spray coating (TSC) refers to a group of coating processes in which finely divided metallic or nonmetallic materials are deposited in a molten or semi-molten condition to form a coating. The coating material may be in the form of powder, ceramic-rod, wire, or molten materials. These coating processes may be further classified as combustion spray, flame spray, plasma spray, high velocity oxygen fuel (HVOF), electric arc spray, etc.

3.5.2.1 Thermal spray coating process specifications. Thermal spray coatings shall be applied in accordance with procedures defined within SAE AMS2447 (HVOF), SAE AMS2448 (HVOF), SAE AMS2437 (plasma spray), MIL-STD-869 (flame spray), AWS C2.19/C2.19M, or

other process specifications approved by the CEA. Qualification and quality control of thermal spray coating procedures shall meet the requirements specified in the applicable process specification or as approved by the CEA. MIL-HDBK-1884 provides information and guidance in the coating of parts using plasma spray processes.

3.5.2.2 Thermal spray powder and wire. Wire and powder used to produce thermal spray coatings shall conform to the material specification requirements of the process specifications listed under 3.5.2.1 or as specified and approved by the CEA.

3.5.2.3 Thermal spray restrictions. Surface preparation including cleaning and grit blasting shall be as specified in the applicable process specification or documented work instruction approved by the CEA. Preheating of workpiece surfaces and maximum workpiece surfaces temperatures shall be maintained in accordance with the applicable process specification. Use of thermal spray bond coats for the purposes of improving bond strength or to mitigate large differences in thermal expansion between the thermal spray over-coating and the substrate material shall be approved by the CEA. Coating material shall be deposited onto the designated surfaces to the thickness specified in the operation sheet for each part. Finished coating thickness shall be as specified on the drawing or specification.

3.5.3 Cold spray metallization. Cold spray metallized coatings shall be in accordance with MIL-STD-3021 and MIL-DTL-32495 as defined in MIL-STD-1587 when used for dimensional restoration or as a corrosion protective coating. Surfaces shall be cleaned in accordance with the process defined in MIL-STD-3021 and damage requiring dimensional restoration shall be prepared by blending to a repair-specific depth ratio as determined by the CEA. The surface preparation, powder handling, and cold spray process variables shall be set for each application or family of applications to ensure that cold spray operations are repeatable, consistent, and documented in accordance with MIL-STD-3021.

3.5.4 Hot-dip coating. Coatings may only be applied by the hot dip method when approved by the CEA.

3.5.5 Brush plating. When approved by the CEA, brush plating may be used to improve surface properties such as corrosion resistance, wear resistance, as an under coat/bond coat or to repair damaged surfaces or platings, or when conventional plating methods are impracticable. Brush plating shall be used in accordance with MIL-STD-865 or SAE AMS2451. Brush plating is particularly useful for plating localized areas in-situ, especially on large parts or assemblies, and for minimizing masking and for touch-up of contact marks. Brush plated chrome coatings have substantially lower hardness values than conventional hard chrome plating, resulting in a lower abrasion resistance, and should only be used if specifically approved by the CEA.

3.6 Metallic coatings/plating.

3.6.1 Cadmium and cadmium alloys.

3.6.1.1 Cadmium. Electrodeposited cadmium shall be in accordance with SAE AMS-QQ-P-416 or MIL-STD-870. Other cadmium coatings shall be in accordance with SAE AMS-C-8837 or SAE AMS-C-81562. Unless otherwise specified in the contract or order, cadmium coatings shall be Class 1 thickness (0.0005 inch) Type II (supplementary

chromate treatment) and the screw threads on parts shall be plated to Class 2 thickness (0.0003 inch). Unless otherwise specified in the contract or purchase order, cadmium coatings shall be post-treated with the conversion coating required by the cadmium coating specification.

3.6.1.1.1 Cadmium coatings shall not be used for the following applications:

- a. On parts that will be exposed to temperatures greater than 450 °F (232 °C). At these temperatures cadmium is ineffective as a protective coating and can cause embrittlement of high strength steel.
- b. As a plating or coating on titanium parts or on parts that will contact titanium parts (mating surfaces, fasteners, bushings, work tools, etc.). Cadmium plating and transfer of cadmium onto titanium parts can cause solid or liquid embrittlement of the titanium.
- c. On surfaces that contact hydraulic fluids, fuels, lubricating oil and other petroleum based fluids.
- d. On parts that contact electrically conductive composite materials such as graphite epoxy composites, unless specifically approved by the CEA.
- e. In confined spaces, where the presence of organic materials may give off corrosive or damaging vapors such as organic acids (acetic acid, oxalic acid, formic acid, etc.). These damaging vapors can result in the spontaneous formation of cadmium whiskers (e.g., blooming of cadmium plated fasteners).

3.6.1.1.2 Parts containing recesses or entrapments. Parts containing recesses or entrapments that cannot be adequately masked to prevent the retention of cleaning and plating fluids shall be vacuum cadmium plated in accordance with SAE AMS-C-8837 or another coating process approved by the CEA.

3.6.1.2 Cadmium-titanium. Cadmium-titanium plating shall be in accordance with MIL-STD-1500.

3.6.1.3 Nickel-cadmium. Nickel-cadmium plating shall be in accordance with SAE AMS2416.

3.6.1.4 Tin-cadmium. Electrodeposited tin-cadmium shall be in accordance with MIL-P-23408. Other tin-cadmium coatings shall be in accordance with SAE AMS-C-81562.

3.6.2 Tin and tin-lead. A plating of tin or tin-lead may be used on parts that are subsequently soldered. Tin plating shall be applied in accordance with ASTM B545, and tin-lead plating shall be in accordance with SAE AMS-P-81728.

3.6.3 Aluminum. At temperatures greater than 450 °F, aluminum and aluminum alloy coatings shall be used where the properties of these materials present distinct protective advantages in comparison with other coatings and platings. Aluminum and aluminum alloy coatings are also used for corrosion resistance and galvanic compatibility. Aluminum and

aluminum alloy coatings shall be in accordance with MIL-DTL-83488 or SAE AMS2427. Unless otherwise specified by the CEA, aluminum coatings shall be post-treated with an authorized conversion coating as specified in 3.7.2.3.

3.6.4 Zinc and zinc alloys.

3.6.4.1 Zinc. Zinc plating shall be in accordance with ASTM B633, and zinc coating shall be as specified in SAE AMS-C-81562. Unless otherwise specified by the CEA, zinc plating or coating shall have a minimum thickness of 0.001 inch and shall be post-treated with an authorized conversion coating as specified by MIL-C-17711. Zinc plating and coating shall not be used for the following applications:

- a. Parts for aerospace and missile systems, unless specifically approved by the CEA.
- b. Parts where corrosion products might interfere with other design requirements.
- c. Grounding contacts where the increased electrical resistance of zinc-plated surfaces would be detrimental.

3.6.4.2 Low hydrogen embrittling zinc-nickel (LHE Zn-Ni). LHE Zn-Ni is an environmentally friendly alternative to cadmium that provides equivalent corrosion protection for ferrous alloys including high strength steels. LHE Zn-Ni coatings shall be in accordance with MIL-PRF-32660, MIL-DTL-32648 or other CEA approved specification (e.g., SAE AMS2461) and may be applied where corrosion resistance and galvanic compatibility is required or where there are restrictions with the application of cadmium. LHE Zn-Ni does not imply that HE does not occur and shall require an HE relief bake in accordance with AMS2759/9. In addition to the above, zinc-nickel coatings should be considered for use in applications at temperatures between 450 °F and 600 °F. If Type and Class is not specified for MIL-PRF-32660, Type II and Class 1 (0.0005 inch, minimum thickness) shall be applied, respectively. If Type and Class is not specified for MIL-DTL-32648, Type II and Class 2 (0.0003 inch, minimum thickness) shall be applied, respectively.

3.6.4.2.1 Zn-Ni use for fasteners. For corrosion protection of fasteners, zinc-nickel has been found to give better corrosion performance than cadmium plating. Zinc-nickel in accordance with MIL-PRF-32647 should be evaluated by the CEA as an alternative to cadmium plating in accordance with SAE AMS-QQ-P-416.

3.6.5 Chromium. Chromium plating is used for all surfaces subject to wear or abrasion, except where other surface hardening processes, such as nitriding or carburizing are used, or where other wear and abrasion resistant coatings are specified. Chromium plating shall be in accordance with SAE AMS2460 or MIL-STD-1501. Unless otherwise specified in the contract or order, chromium plating shall be Class 2 (engineering) thickness not less than 0.002 inch. If a Class 1 (corrosion) coating is specified, and the chrome plated surfaces will not be subjected to lubricants during use, a nickel undercoat shall be applied in accordance with SAE AMS2403 or SAE AMS-QQ-N-290 having a minimum thickness of 0.00015 inch and a maximum thickness of 0.015 inch. To minimize galling damage, chromium plating shall be used on only one of the two contacting surfaces. Chrome plating that was sealed (e.g., vacuum impregnation) during

initial manufacturing design may use nickel under plate as a substitute during maintenance/repair.

3.6.6 Nickel.

3.6.6.1 Electrodeposited nickel. Unless otherwise specified in the contract, or when used as an undercoating, the electrodeposited nickel thickness shall be not less than 0.00052 inch, except where maximum corrosion protection is required, and the minimum thickness shall be not less than 0.002 inch. Plating shall be in accordance with SAE AMS2403 (general purpose nickel Plating) when corrosion or oxidation resistance, or buildup of surfaces is required. Plating shall be in accordance with SAE AMS2423 (hard nickel plating) when wear resistance is required. Where applications require low residual stress in the plated nickel, plating shall be in accordance with SAE AMS2424 (low stress nickel plating).

3.6.6.1.1 Nickel plating is specifically useful for the following applications:

- a. To minimize the effects of crevice corrosion with un-plated corrosion-resistant steel or stainless steel in contact with other stainless steel.
- b. As an undercoat for other functional coatings.
- c. To restore dimensions by rebuilding worn surfaces.
- d. For resistance to sand erosion.

3.6.6.1.2 Nickel plating shall not be used for the following applications:

- a. Where temperatures exceed 1000 °F (538 °C).
- b. When in contact with aluminum or aluminum alloy coating, except when approved by the CEA.

3.6.6.2 Electroless nickel. Electroless nickel coatings shall be in accordance with SAE AMS2404. When electroless nickel is used for corrosion protection or wear resistance, the thickness shall be not less than 0.0015 inch and shall be not greater than 0.003 inch, or as specified by the CEA.

3.6.7 Silver. Silver plating shall be performed in accordance with SAE AMS2410, SAE AMS2411 or ASTM B700 as specified by the design requirements and approved by the CEA. Silver and silver plating shall not be used in the following applications:

- a. On or in contact with titanium parts and fasteners. Also, silver plated hardware, clamps, tools, fixtures and jigs shall not be used for fabrication or assembly of titanium components or structures.
- b. On or in contact with nickel base alloy parts exposed to temperatures above 1000 °F (538 °C) in service.
- c. On or in contact with aluminum alloys due to the potential for galvanic corrosion unless a corrosion mitigation strategy has been approved by the CEA.

- d. On or in contact with any metallic material where the service temperature could cause the potential risk of solid metal embrittlement or liquid metal embrittlement as determined by the CEA.

3.6.8 Gold. Electrolytic plating of gold shall be in accordance with SAE AMS2422, except all stress relief of steel parts prior to gold plating (if required) shall be performed in accordance with SAE AMS 2759/11. Gold shall not be used as a plating for, or in contact with, any metallic material (e.g., titanium) where the service temperature could cause the potential risk of solid metal embrittlement or liquid metal embrittlement as determined by the CEA.

3.6.9 Palladium. Palladium plating shall be in accordance with ASTM B679.

3.6.10 Rhodium. Rhodium plating shall be in accordance with MIL-R-46085.

3.6.11 Copper. Copper plating shall be in accordance with SAE AMS2418.

3.6.12 Cobalt-phosphorous alloy. When approved for use by the CEA, nano-crystalline cobalt-phosphorous alloy electroplating shall be performed in accordance with SAE AMS2428 or MIL-DTL-32502.

3.6.13 Metallic-ceramic coating. Metallic-ceramic coatings shall be in accordance with MIL-C-81751.

3.7 Surface treatments and oxide coatings.

3.7.1 Post treatment. Most sacrificial metallic coatings, anodic coatings, and phosphate coatings require a passivation of the metallic coating, anodic coating, or phosphate coating prior to surface treatment. For optimum corrosion and adhesion performance, a post treatment of these processes (also referred to as sealing, conversion coating, etc.) shall be required unless a deviation is authorized by the CEA.

3.7.2 Coatings for aluminum and aluminum alloys. Unless otherwise specified, all aluminum and aluminum alloys, including clad aluminum alloy surfaces, shall be either anodized to produce coatings conforming to MIL-PRF-8625 or shall receive a chemical conversion treatment using materials from MIL-DTL-81706 to produce coatings conforming to MIL-DTL-5541. Unpainted chemical conversion treatments shall be subject to the temperature limitations in MIL-DTL-5541.

3.7.2.1 Anodic coatings. Anodic coatings are preferred for aluminum parts subject to wear, abrasion, erosion, or severe corrosion conditions.

3.7.2.1.1 Anodic coatings for corrosion resistance. Parts anodized in accordance with MIL-PRF-8625 Type I or II shall be sealed or post-treated with a corrosion-resistant finish approved by the CEA. Parts that require painting or bonding after anodization shall follow the sealing process specified in the contract or purchase order. Sealing processes can have a significant effect on the adhesion of primers and polymeric coatings. Where maximum corrosion resistance is desired, hot water seal shall not be used unless authorized by the CEA. Type I or

Type IIB (if approved by the CEA) are the preferred anodize for fatigue-critical applications.

3.7.2.1.2 Anodizing for wear resistance. Hard anodic coatings shall conform to MIL-PRF-8625, Type III. Hard anodic coatings shall be used on parts where the functional purpose is to provide a wear or abrasion resistant surface. It should be noted that hard anodic coatings may have a detrimental effect on the fatigue life of aluminum alloys. Sealing of hard anodize coatings for increased corrosion resistance may have a detrimental effect on hardness or wear resistance and should be specifically approved by the CEA.

3.7.2.2 Plasma electrolytic oxidation (PEO) coatings. Where appropriate, the CEA may authorize the use of plasma electrolytic oxidation (PEO) coatings as an alternative to MIL-PRF-8625 hard anodic coatings. The PEO coatings shall, at a minimum, meet the same requirements as MIL-PRF-8625 Type III coatings. Sealing of these PEO coatings with a thermosetting organic resin for increased corrosion resistance may be authorized by the CEA providing that the cure temperature does not impact the temper of the aluminum alloy.

3.7.2.3 Conversion coatings.

3.7.2.3.1 Aircraft applications. All non-clad aluminum and aluminum alloys used in locations classified as exterior aircraft surfaces by MIL-STD-7179 shall be conversion coated using materials from MIL-DTL-81706 to produce coatings conforming to MIL-DTL-5541, Class 1A.

3.7.2.3.2 Electrical applications. Chemical conversion coatings using materials from MIL-DTL-81706 to produce coatings conforming to MIL-DTL-5541, Class 3 shall be used on electrical parts where low electrical contact resistance is required. Other surface treatments for low electrical resistance and corrosion protection may be used when approved by the CEA.

3.7.3 Coatings for magnesium and magnesium alloys.

3.7.3.1 Anodic coatings. All magnesium alloys shall be anodized in accordance with ASTM D1732 Class II, SAE AMS-M-3171 Type VII or a CEA approved alternative (e.g., MIL-DTL-32459). Anodized magnesium surfaces may be stripped and re-anodized, when approved by the CEA.

3.7.3.2 Conversion coating. SAE AMS-M-3171 treatments shall only be used for temporary protection, touch-up of damaged anodic coatings, or preparation for painting where anodic coatings cannot be used. For magnesium castings anodized with Tagnite MIL-DTL-32459, touchup shall be performed using MIL-DTL-32459, Type V (Brush Tagnite) or a CEA approved alternative. All other surfaces that have the anodic or chemical film removed or damaged shall be touched up using the SAE AMS-M-3171, Type I or Type VI process.

3.7.4 Coatings for ferrous metals.

3.7.4.1 Phosphate coatings. When approved for use on steel parts, phosphate treatments shall be in accordance with MIL-DTL-16232 or TT-C-490, Type I or II. Unless otherwise specified by the CEA, all phosphate coatings shall be post-treated with a rinse, such as chromate. Phosphate treatments are used on surfaces when it is impractical to apply a better

performing corrosion control coating or where a different coating will interfere with part function.

3.7.4.2 Black oxide. When approved by the CEA, black oxide coatings may be applied to ferrous metals. Black oxide coatings shall be applied in accordance with MIL-DTL-13924.

3.7.5 Passivation treatment for stainless steels. Stainless steels (200, 300, 400 series) and precipitation-hardened stainless steels shall undergo passivation to remove free iron or other contaminants from the surface. For aerospace applications, stainless steel parts shall be passivated in accordance with SAE AMS2700. For all other applications, stainless steel parts shall be passivated in accordance with ASTM A967/A967M or SAE AMS2700 (other methods may be approved by the CEA). Passivation shall be followed by thoroughly rinsing and drying the part. Carburized or nitrided surfaces shall not be subjected to passivation. Passivation is also not required for stainless steels that are subsequently plated or coated.

3.7.6 Surface treatments for other steel alloys. Other steel alloys that are not coated or plated shall be finished as specified by the CEA.

3.8 Shot-peening and other residual compressive stress-inducing treatments. Shot-peening, in accordance with SAE AMS2432 and other computer controlled compressive stress-inducing treatments may be used to meet design fatigue requirements, if approved by the CEA. Shot peening in accordance with SAE AMS2430 and other stress-reducing treatments may be used to enhance fatigue properties or stress corrosion cracking resistance. The maximum temperatures for use on any part shall not exceed the limits listed in SAE AMS2430 to eliminate any detrimental effects to the previous processing, unless otherwise authorized by the CEA. Procedure details shall be prepared and listed on the applicable drawings or applicable reference documents for parts. Specific attention shall be paid to use of recognized procedures, equipment, materials, and control methods.

3.9 Non-destructive inspection. Many cleaning methods, surface treatments, surface modification processes and coatings/platings can cause defects or masking of the presence of defects or both. The importance of inserting appropriate non-destructive inspections (NDI) throughout the manufacturing or repair processing cannot be underestimated. Detailed requirements for the execution of an effective NDI Program are beyond the scope of this specification (MIL-HDBK-6870 can be used to determine key elements of an effective NDI Program). The CEA is responsible for ensuring appropriate NDI procedures are scheduled throughout the manufacturing or repair processes at critical inspections points within the sequence of manufacturing processes. NDI requirements shall be established and adhered to during system development, test, production, and sustainment through the life cycle of the weapons system.

3.10 Temperature limitations. Unless otherwise specified or approved by the CEA, the service temperature of the coating and/or items in direct contact with the coating shall not exceed the limits in Table I. The actual maximum temperature may be below the value listed in Table I, depending on the materials in the part stack-up.

TABLE I. Maximum service temperatures of various coatings.

COATING MATERIAL	MAXIMUM TEMPERATURE °F <u>1/</u>	NOTES
Silver	1200	<u>2/</u>
Nickel	1000	
Metallic Ceramic	950	<u>3/</u>
Aluminum	925	<u>3/</u>
Zinc-Nickel	600	
LHE Zinc-Nickel	600	
Zinc	500	
Cadmium	450	<u>4/</u>
Tin-lead	350	<u>5/</u>
Tin-Cadmium	345	<u>5/</u>
Tin	330	<u>5/</u>
<u>1/</u> The actual maximum temperature may be below the value listed in Table I depending on the materials in the part stack-up.		
<u>2/</u> Shall not be used on titanium parts or in contact with titanium parts exposed to temperatures greater than 350 °F in service.		
<u>3/</u> Above 950 °F there may be an unfavorable effect upon the fatigue strength of the steel base metal due to diffusion.		
<u>4/</u> Shall not be used on or in contact with titanium parts or fasteners (see 3.6.1.1.1 (b)).		
<u>5/</u> Pure tin or tin containing materials that undergo a solid-state transformation shall not be used on parts that are used at subzero temperatures.		

3.11 Workmanship. Parts and assemblies shall be the result of use of the best processes covered herein, as demonstrated by serviceability of the parts.

4. VERIFICATION

4.1 Inspection. Items subject to this specification shall meet all requirements of this specification. The methods of cleaning metal surfaces, application of surface treatments and all materials entering into the processes shall be subject to inspection as specified in the contract or purchase order (see 6.6).

4.2 Previous approval. Acceptance or approval of material, surface treatment, or corrosion preventive process during the course of manufacture shall not guarantee the acceptance of the finished product.

5. PACKAGING

This section is not applicable to this specification.

6. NOTES

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

6.1 Intended use. The surface treatments and coatings prescribed by this specification are primarily intended for use on metal surfaces of aerospace weapons systems, electrical, electronic and other systems.

6.2 Ordering data. This section is not applicable to this specification.

6.3 Definitions. The terms “coating” and “plating” as used in this document may be used interchangeably. However, the term “coating” is generally applied to materials on metal surfaces deposited by non-electrodeposition processes, whereas “plating” generally refers to those materials deposited electrolytically.

6.4 CEA. The CEA is the term applied to the engineering organization responsible for the design of the item being cleaned and coated.

6.5 Deviation from requirements. Any deviations from the requirements of this specification must be identified and supported with technical data and approved by the CEA.

6.6 Inspection information.

6.6.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

6.6.2 Responsibility for compliance. The inspection set forth in this specification should become a part of the contractor’s overall inspection system or quality program. The absence of any inspection requirements in the specification does not relieve the contractor of the responsibility of assuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling in quality conformance does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to acceptance of defective material.

6.7 Subject term (key word) listing.

Anodic coatings
Ceramic coatings
Corrosion control
Metallic coatings
Plating

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

CONCLUDING MATERIAL

Custodians:

Army - MR
Navy - AS
Air Force - 20
DLA - CC

Preparing activity:

Navy - AS

(Project MFFP-2022-002)

Review activities:

Army - AR, AV, EA, MI
Navy - OS

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at <https://assist.dla.mil>.