

INCH-POUND

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MILITARY SPECIFICATION
COATINGS, ELECTROLESS NICKEL
REQUIREMENTS FOR

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 electroless (autocatalytic chemical reduction) deposition of nickel-phosphorous alloy coatings on metal and composite surfaces.

1.2 Classification

1.2.1 Classes. The nickel coatings shall be classified in accordance with the thermal treatment applied subsequent to plating.

Class 1 - As plated, no subsequent heat treatment: A bake for hydrogen embrittlement relief is not considered a heat treatment.

Class 2 - Heat treated to obtain required hardness: May be used on all metals not affected by heating to 500°F and above.

Class 3 - Aluminum alloys nonheat-treatable, and beryllium alloys processed to improve adhesion of the nickel deposit.

Class 4 - Aluminum alloys, heat-treatable, processed to improve adhesion of the nickel deposit.

Beneficial comments (recommendations, additions, deletions, and any pertinent data which may be of use in improving this document) should be addressed to: ASD/ENES, Wright-Patterson AFB OH 45433-6503, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A

MFFP-0457

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1.2.2 Grades. The nickel coatings shall be of the following grades:

Grade A - 0.0010-inch minimum thickness.

Grade B - 0.0005-inch minimum thickness.

Grade C - 0.0015-inch minimum thickness.

2. APPLICABLE DOCUMENTS

2.1 Government documents

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

SPECIFICATIONS

MILITARY

MIL-S-13165 - Shot Peening of Metal Parts

STANDARDS

MILITARY

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes

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

(Copies of specifications, standards, handbooks, drawings, publications, and other Government documents required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting activity.)

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

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AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

- ASTM B117 - Method Of Salt Spray (Fog) Testing
- ASTM B487 - Measurement of Metal and Oxide Coatings Thickness by Microscopical Examination of a Cross Section, Method for (DOD adopted)
- ASTM B499 - Standard Test Method for Measurement of Coating Thickness by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals (DOD adopted)
- ASTM B567 - Method for Measurement of Coating Thickness by the Beta Backscatter Method
- ASTM B568 - X-Ray Spectrometry (DOD adopted)
- ASTM B571 - Test Methods for Adhesion of Metallic Coatings
- ASTM B578 - Test Method for Microhardness of Electroplated Coatings
- ASTM E18 - Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials, Tests for (DOD adopted)
- ASTM E384 - Microhardness of Materials, Test Method for
- ASTM F519 - Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals (DOD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia PA 19103-1137.)

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

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

3. REQUIREMENTS

3.1 Materials

3.1.1 Metals and composites. Iron, copper, aluminum, nickel, cobalt, beryllium, titanium, and their alloys can be plated directly. Composites can be plated directly by using special pretreatments to prevent the basis material from contaminating the bath or to obtain adequate coating adhesion.

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3.1.2 Tensile strength. All steel parts having an ultimate tensile strength of 220,000 psi, or above, shall not be coated without approval of the procuring activity.

3.2 Precoating procedures

3.2.1 General requirements

3.2.1.1 Unless otherwise specified, the coating shall be applied after all basis metal heat treatments and mechanical operations such as machining, brazing, welding, forming and perforating of the part have been completed.

3.2.1.2 Parts, prior to plating, shall be degreased, abrasive and/or alkaline cleaned, and acid pickled as required to obtain maximum coating adhesion.

3.2.1.3 Hardness measurement. Prior to coating, steel parts shall be measured for hardness in accordance with ASTM E18.

3.2.2 Stress relief heat treatment. Prior to cleaning and coating, all steel parts having a hardness of Rockwell C40 or above, which have been machined, ground or surface hardened (includes cold worked but not shot peened surfaces), shall be given a stress-relief heat treatment at a temperature that will produce maximum stress relief without reducing the hardness to less than the specified minimum.

3.2.3 Shot peening. Prior to coating, all steel parts having a hardness of Rockwell C40 or above used in fatigue applications and/or subject to stress corrosion shall be shot peened in accordance with MIL-S-13165. Unless otherwise specified, the shot peening shall be accomplished on all surfaces for which the coating is required and all immediately adjacent surfaces when they contain notches, fillets or other abrupt changes of section size where stresses will be concentrated.

3.3 Coating properties

3.3.1 General requirements

3.3.1.1 Manufacturers are given latitude in the selection of specific plating bath formulations used for the chemical deposition of an amorphous nickel-phosphorous metallic compound provided the coating obtained meets the requirements of this specification.

3.3.1.2 Equipment, solutions, and process procedures shall be subject to the approval of the procuring activity.

3.3.2 Thickness. Unless otherwise specified, minimum thickness of the nickel coating shall be 0.0010 inch (0.026 mm) (grade A) for aluminum based alloys, 0.0005 inch (0.013 mm) (grade B) for copper, nickel, cobalt, titanium and beryllium alloys, and 0.0015 inch (0.039 mm) (grade C) for iron-based alloys.

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3.3.3 Adhesion on metals. The coating adhesion after completion of all processing and thermal treatments shall be such that when examined at a magnification of 4X, the coating shall not show separation from the basis metal when tested in accordance with ASTM B571 as specified in 4.5.2. It also shall be impossible to detach any area of the coating with a sharp instrument on the outside radius of the bent-test specimen. Formation of cracks that do not result in loss of plating adhesion is acceptable.

3.3.4 Corrosion resistance. Grade A coatings on aluminum alloys and grade C coatings on iron alloys after plating and all required thermal treatments shall show no visual evidence of corrosion of the basis metal when tested in accordance with 4.5.5.

3.4 Postcoating procedures

3.4.1 Hydrogen embrittlement relief bake. Within 4 hours after coating, coated class 1 and class 2 steel parts that have a hardness of Rockwell C40 or above shall require a hydrogen embrittlement relief bake at $375^{\circ}\text{F} \pm 25^{\circ}\text{F}$ for not less than 3 hours. Parts, including carburized parts, that will decrease in hardness by heating to $375^{\circ}\text{F} \pm 25^{\circ}\text{F}$ shall be heated to $275^{\circ}\text{F} \pm 15^{\circ}\text{F}$ for not less than 5 hours. When tested in accordance with 4.5.4, the baked parts shall not crack or fracture.

3.4.2 Heat treatments

3.4.2.1 Class 2 hardness coatings. Class 2 coatings shall have a minimum hardness of 800 knoop or equivalent vickers when tested in accordance with 4.5.3. Class 2 coatings on steel parts that have a hardness of Rockwell C40 or above are required to be tested in accordance with 4.5.4 without cracking or fracture. The hardness can be achieved by heating the part (see 4.5.4 and 6.3) within 4 hours after coating.

3.4.2.2 Class 3 coatings. Coated nonheat-treatable aluminum parts shall be heated for 1 to 1.5 hours at $375^{\circ}\text{F} \pm 15^{\circ}\text{F}$ to improve adhesion of nickel deposit.

3.4.2.3 Class 4 coatings. Coated heat-treatable aluminum alloys shall be heated between 240°F to 260°F for 1 to 1.5 hours to improve adhesion of nickel deposit.

(NOTE: These alloy types and grades may undergo microstructural changes when heated to 375°F .)

3.5 Identification marking. When specified, the coated parts shall be marked with a fluid not affected by water, or rub off, or smear during shipment or storage; and shall carry a tag giving the following information:

- a. Basis material
- b. Number of this specification.
- c. Class and grade of coating.

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3.6 Workmanship

3.6.1 Basis material. The basis material shall be free from defects that will be detrimental to the utility, appearance, or serviceability of the finished product or part and coating.

3.6.2 Nickel coating. The nickel coating shall be smooth, adherent, and free from visible blisters, pits, nodules, porosity, cracks and other defects. All details of workmanship shall conform to the best practices for high quality coating.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) 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 this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the government to accept defective material.

4.2 Classification of inspection. The inspection requirements specified herein are classified as quality conformance inspection (see 4.4).

4.3 Inspection conditions. Unless otherwise specified, all inspections shall be performed in accordance with the methods of inspection specified in 4.5.

4.3.1 Inspection lot. A lot shall consist of coated parts of the same type and class, same basis material, and of approximately the same size and shape, coated under the same conditions and by means of the same coating process, and submitted for acceptance at one time.

4.3.2 Separate specimens. When the coated parts are of such form as to be not readily adaptable to a test specified herein, or at the discretion of the inspector for

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destructive tests for the sampling of small lot sizes, the test may be made by the use of separate specimens coated concurrently with the parts represented. The separate specimens shall be of a basis material equivalent (see 6.6) to that of the parts represented. For example, a cold-rolled steel surface shall not be used to represent a hot-rolled steel surface; owing to the impracticability of forging or casting separate test specimens, hot-rolled steel specimens may be used to represent forged and cast steel parts. The separate specimens shall be strips approximately 1-inch wide, 4-inches long, and 0.04-inch thick except those required for determination of embrittlement relief (see 4.5.4). These specimens shall be introduced into a lot at regular intervals prior to the cleaning operations preliminary to coating and shall not be separated therefrom until after completion of the processing.

4.4 Quality conformance inspection. Quality conformance inspections shall consist of sampling plans A, B, C, D, and E.

4.4.1 Sampling plan A - Sampling procedures for visual examination and nondestructive tests of coating thickness. Samples shall be selected from each lot (see 4.3.1) and acceptance of the lot shall be determined in accordance with inspection level II and acceptable quality level (AQL) 1.5 of MIL-STD-105. Periodic microscopic destructive thickness and adhesion tests shall be performed as a referee method to verify comparable nondestructive tests for the purpose of process control assurance.

4.4.1.1 Visual inspection. Each of the sample parts selected in accordance with 4.4.1 shall be examined visually for conformance to requirements of 3.6.2.

4.4.1.2 Thickness (nondestructive tests). Each of the sample parts selected in accordance with 4.4.1 shall be inspected, and the coating thickness measured in several locations on each part in accordance with 4.5.1.2. The part shall be considered nonconforming if one or more measurements fail to meet the specified minimum thickness.

4.4.2 Sampling plan B - Sampling procedures for evaluating hydrogen embrittlement relief destructive test - Class 1 and 2. A hydrogen embrittlement relief test shall be run once per month on a random sample of 4 parts as specified in 4.5.4.

4.4.3 Sampling plan C - Sampling procedure for adhesion tests. A random sample of 4 parts shall be selected from each inspection lot which has more than 15 parts (see 4.3.1), or 4 separately coated specimens shall be prepared in accordance with 4.3.2 to represent each inspection lot. If the number of parts in an inspection lot is 15 or less, the number of parts in the sample shall be 2 or 3 as determined by the procuring activity.

4.4.3.1 Adhesion. Each part, or specimen shall be tested as specified in 4.5.2. Failure of one or more of the test specimens shall constitute failure of the lot.

4.4.4 Sampling plan D - Sampling procedure for hardness test.

- Class 2. A hardness test shall be run once a month, on four randomly selected parts representing the months production, or on four separately coated specimens as specified in 4.5.3. The amount of testing may be reduced provided the results in the consecutive months indicate a uniform product meeting the test requirements is being produced, and providing the manufacturer agrees to maintain the same manufacturing procedures or develops alternative acceptable manufacturing procedures.

4.4.5 Sampling Plan E. Sampling procedure for destructive tests of coating thickness. At least once per calendar quarter, a coated part, or a separately coated specimen prepared in accordance with 4.3.2, shall be tested in accordance with 4.5.1.1 to verify the adequacy of the nondestructive methods of thickness testing.

4.5 Methods of inspection

4.5.1 Thickness test

4.5.1.1 Microscopic method. The coating thickness shall be determined in accordance with ASTM B487.

4.5.1.2 Nondestructive instrumental methods. The instrument used, its calibration, and its operation for testing given parts shall be such that the coating thickness shall be determined with ± 10 percent of its true thickness, or the instrument shall be of a type approved by the procuring activity (see 6.4). The coating thickness shall be determined in accordance with ASTM B499, ASTM B568, and ASTM B567. Periodic verification of the instrumental methods must be made in accordance with 4.5.1.1.

4.5.2 Adhesion test. The test specimen shall be bent 180° over a mandrel diameter 4 times the thickness (0.4 inch minimum) of the specimen.

4.5.3 Hardness tests. Vickers-hardness measurements shall be in accordance with ASTM E384. Knoop-hardness measurements shall be in accordance with ASTM B578.

4.5.4 Embrittlement relief. Compliance with 3.4.1 and 3.4.2.1 shall be determined with samples of plated parts. Parts--spring pins, lock rings, and so forth--that are installed in holes or rods shall be similarly assembled using the applicable parts specifications or drawing tolerances which impose the maximum sustained tensile load on the plated part. The selected samples shall be subjected to a sustained tensile load equal to 115 percent of the maximum design yield load for which the part was designed. Parts that require special fixtures, extreme loads to comply with the above requirements, or where the maximum design yield load is not known, may be represented by separate test specimens. The separate specimens shall be of a type specified in ASTM F519 and tested as required therein. The articles, parts or test

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specimens shall be held under load for a least 200 hours and then examined for fracture. The lot shall be rejected if any coated article, part, or test specimen shows cracking or fracture of the basis metal.

4.5.5 Corrosion test. Coated-test specimens shall be exposed to a neutral salt-spray test in accordance with ASTM B117 for 100 hours. The separate test specimens used for salt-spray testing shall be 4 inches by 6 inches.

5. PACKAGING

5.1 Coated surfaces shall be protected from damage during shipment and storage.

6. NOTES

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

6.1 Intended uses. The coating is intended for use when hard and smooth surfaces are required on coated parts. Excellent uniform deposits are produced on irregular parts. Coated parts--that is, those parts used in air compressors, missile-fuel injector plates, pumps, reciprocating surfaces, and so forth are protected from oxidation, corrosion and wear. With aluminum electronic devices, not only is product contamination prevented, but the coated parts facilitate soldering when used in conjunction with a mildly activated (RMA) or activated (RA) rosin flux. Coated parts of stainless steel similarly facilitate brazing.

6.2 Acquisition requirements. Acquisition documents should specify the following:

- a. Title, number and date of the specification.
- b. Class and grade, and heat treatment or condition (see 1.2 and 3.5).
- c. Issue of DODISS to be cited in the solicitation, and if required, the specific issue of individual documents reference (see 2.1.1 and 2.2).

6.3 Heating schedule for class 2 coating.

6.3.1 Required hardness can be achieved by heating using the following schedule:

| <u>°F Temperature</u> | <u>Hours</u> |
|-----------------------|--------------|
| 500 | 4 or more |
| 550 | 2 or more |
| 650 | 1 to 1.5 |
| 750 | 0.5 to 1 |

6.4 Nondestructive thickness measurements. Thickness measurements of electroless nickel coatings containing more than 8 percent phosphorous are sufficiently nonmagnetic to be measured for thickness in accordance with ASTM B499, "Method of Measurement of Coating Thickness by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals," if deposited on a magnetic basis metal. When measuring heat-treated coatings containing more than 8 percent phosphorous, the instrument should be calibrated against heat-treated standards of known coatings thickness or equivalent calibration foils. Heat treatment increases coating magnetism. Measurement of electroless nickel coatings containing less than 8 percent phosphorous by a magnetic method is not recommended.

6.5 Subject term (key word) listing

Nickel

Electroless (autocatalytic chemical reduction)

6.6 Equivalent material. Equivalent basis material includes chemical composition and surface finish prior to coating application.

6.7 Recycled material. It is encouraged that recycled material be used when practical as long as it meets the requirements of the document (see 3.1).

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

Custodians:

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Army - MR

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I RECOMMEND A CHANGE:

1. DOCUMENT NUMBER
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2. DOCUMENT DATE (YYMMDD)
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COATINGS, ELECTROLESS NICKEL REQUIREMENTS FOR

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME (Last, First, Middle Initial)

b. ORGANIZATION

c. ADDRESS (Include Zip Code)

d. TELEPHONE (Include Area Code)
(1) Commercial
(2) AUTOVON
(if applicable)

7. DATE SUBMITTED
(YYMMDD)

8. PREPARING ACTIVITY

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