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MILITARY SPECIFICATION

ANODIC COATINGS, FOR ALUMINUM AND ALUMINUM ALLOYS

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

1. SCOPE

1.1 Scope - This specification covers the requirements for electrolytically formed anodic coatings on aluminum and aluminum alloys for non-architectural applications.

1.2 Classification - Anodic coatings for aluminum and aluminum alloys shall be of the following types and classes as specified (see 6.2).

1.2.1 Types -

Type I - Conventional coatings produced from chromic acid bath (see 3.5).

Type II - Conventional coatings produced from sulphuric acid bath (see 3.6).

Type III - Hard coatings (see 3.7).

1.2.2 Classes -

Class 1 - Non-dyed (Natural, including dichromate sealing).

Class 2 - Dyed.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

FSC-MFFP

SPECIFICATIONS

Federal

QQ-A-250/4	Aluminum Alloy 2024, Plate and Sheet
QQ-A-250/11	Aluminum Alloy 6061, Plate and Sheet
QQ-A-250/12	Aluminum Alloy 7075, Plate and Sheet

Military

MIL-C-5541	Chemical Films and Chemical Film Materials for Aluminum and Aluminum Alloys

STANDARDS

Federal

Fed. Test Method Std. No. 141	Paint, Varnish, Lacquer, and Related Materials; Methods of Inspection, Sampling and Testing
Fed. Test Method Std. No. 151	Metals; Test Methods

Military

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

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

2.2 Other publications - The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

American Society for Testing and Materials Publications

ASTM B 117	Method of Salt Spray (Fog) Testing

American Society for Testing and Materials Publications (Cont'd)

ASTM B 137	Weight of Coating on Anodically Coated Aluminum
ASTM B 244	Measuring Thickness of Anodic Coatings on Aluminum with Eddy Current Instruments
ASTM D 2244	Method for Instrumental Evaluation of Color Differences of Opaque Materials

(Application for copies of A.S.T.M. Standards should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

3. REQUIREMENTS

3.1 Materials - The materials used shall be such as to produce coatings which meet the requirements of this specification.

3.1.1 Basis metal - The basis metal shall be sufficiently free from surface defects, caused by machining, cutting, scratching, polishing, buffing, roughening, bending, stretching, deforming, rolling, sandblasting, vaporblasting, etching, and inclusions, which will be detrimental to the functional use of the coating. It shall be subjected to such cleaning, etching, anodizing and sealing procedures as are necessary to yield coatings meeting all requirements of this specification (see 6.12).

3.2 Equipment and processes - The equipment and processes employed shall be such as to produce coatings which meet the requirements of this specification. Unless otherwise specified in the contract, order, or applicable drawing (see 6.2), process operating conditions shall be at the option of the supplier, subject to approval of the procuring activity.

3.3 General -

* 3.3.1 Unless otherwise specified in the contract, order or applicable drawing, parts and assemblies shall be anodized after all heat treatment, machining, welding, forming, and perforating have been completed.

* 3.3.2 Parts which contain non-aluminum materials such as steel, brass or organic substances, which would be attacked by chemical or electrolytic brightening (chemical or electropolishing) or anodizing solutions or would prevent the uniform formation of the anodic coatings on the aluminum surfaces or cause attack of the aluminum alloy, shall not be anodized as assemblies, unless the non-aluminum surfaces are masked or electrically insulated in a manner which produces satisfactory anodized parts.

3.3.3 Parts shall be so handled during all pretreatments, anodizing, and post treatments that mechanical damage or contamination will be avoided. Soiled parts shall be cleaned with such materials which will remove the soil without damaging the part or coatings.

3.3.4 Unless otherwise specified in the contract or purchase order, the aluminum and aluminum alloys shall be cleaned before subsequent anodic treatment. Alkaline cleaners when used shall be of the non-etching or inhibited type. Where an uninhibited alkaline etching solution is permitted in the fabrication of aluminum and aluminum alloy parts for the chemical removal or milling of excess metal, the basis metal shall then be treated in an acid deoxidizing bath to remove any characteristic surface smut. The basis metal shall be rinsed thoroughly with water prior to application of the anodic coatings. Abrasives containing iron such as steel wool, iron oxide rouge, and steel wire, which may become embedded in the metal and accelerate corrosion of aluminum and aluminum alloys, are prohibited as a means of mechanical cleaning, prior to anodizing (see 6.2).

3.3.5 When specified in the contract or order, parts fabricated to produce a highly reflective surface shall be chemically or electrochemically brightened prior to anodic coating. (See 6.14.)

3.3.6 Parts shall be free of all foreign substances, oxides and soils, such as greases, oil, paint and welding flux. Parts shall have oxide and other interfering film removed by the use of proper cleaning procedures so as to be cleaned and have water break free surfaces.

3.3.7 Unless otherwise specified in the contract, order or applicable drawing, anodic coatings shall not be applied to assemblies which will entrap the electrolyte in joints or recesses. Anodic coatings shall not be used for assemblies where the electrolyte cannot be removed. When authorized by the contract, order or applicable drawings, edges shall be masked to prevent electrolyte entry. Spot welded assemblies are examples of assemblies requiring edge masking. Residual electrolytes, especially sulphuric acid from Type II baths, will engender corrosion of aluminum. Where coating of assemblies is not authorized, parts of assemblies shall be anodic coated before assembling.

* 3.3.8 When approved by the procuring activity, mechanically damaged areas from which the anodic coating has been removed may be repaired, using chemical film materials and treatments meeting the requirements of MIL-C-5541 by Grade B (brush) application.

3.4 Types I and II coatings - Conventional anodic coatings conforming to Types I and II classification, as specified in the contract, order or applicable drawings, shall be prepared by any process or operation to produce the specified coating on aluminum and aluminum alloys. The applied anodic coating shall be uniform

in appearance, free from breaks, scratches, and other defects which will reduce the serviceability of anodized parts or assemblies (see 3.13).

3.5 Type I coatings - Type I coatings shall be the result of treating aluminum and aluminum alloys electrolytically in a bath containing chromic acid to produce a uniform anodic coating on the metal surface.

3.5.1 Unless otherwise specified in the contract, order or applicable drawing, Type I coating shall not be applied to aluminum alloys with a nominal copper content in excess of 5.0 percent, nominal silicon contents in excess of 7.0 percent or when the total allowable contents of nominal alloying elements exceed 7.5 percent. Heat treatable alloys which are to receive a Type I coating should be in a temper obtained by heat treatment such as -T4 or -T6 prior to anodizing.

3.6 Type II coatings - Type II coatings shall be the result of treating aluminum and aluminum alloys electrolytically in a both containing sulphuric acid to produce a uniform anodic coating on the metal surface.

3.7 Type III coatings - Type III coatings shall be the result of treating aluminum and aluminum alloys electrolytically to produce a uniform anodic coating on the metal surface. Hard coatings conforming to Type III classification, as specified in accordance with the contract, order or applicable drawing, shall be prepared by any process operation to produce a heavy dense coating of specified thickness on aluminum alloys (see 3.7.1). The applied anodic hard coating shall be uniform in appearance, free from breaks, scratches and other defects which will reduce the serviceability of parts (see 3.13).

3.7.1 Thickness - Thickness of Type III coatings shall be as specified in the contract, order, or applicable drawing. Hard coatings may vary in thickness from 0.0005 inch (0.5 mil) to more than 0.004 inch (4 mils). If a definite thickness is not specified in the contract, order or applicable drawing, the nominal thickness of the coating shall be 0.002 inch (2 mils). Unless otherwise specified, the thickness of the coating shall not vary by more than plus or minus ten percent. (See 6.15.4.)

* 3.7.2 Unless otherwise specified in the contract, order or applicable drawing, Type III coatings produced from the anodizing baths shall not be applied to aluminum alloys with a nominal copper content in excess of 5.0 percent or a nominal silicon content in excess of 8.0 percent. Alloys with a higher nominal silicon content than 8.0 percent may be anodized subject to approval of the procuring activity provided data is submitted by the supplier which shows that such coatings are equivalent to those obtained on alloys of lower silicon contents.

* 3.7.3 Unless otherwise specified in the contract, order or applicable drawing, Type III anodic coatings shall be furnished unsealed as Class 1 only. When unsealed, parts shall be thoroughly rinsed in cold, clean water and dried after anodizing (see 3.11).

3.8 Class 1 coatings - Class 1 anodic coatings of Types I, II and III shall not be dyed or pigmented. The greenish gray appearance of Type I coating shall not be considered a coloration, as well as the light gray to purplish gray color of anodic coatings which depends upon the alloy treated. The characteristic color imparted by the dichromate sealing technique shall also be considered as non-dyed coatings.

3.9 Class 2 coatings - Class 2 anodic coatings of Types I, II, and III shall be uniformly dyed or pigmented by exposure to a solution of a suitable type dye or stain. The color shall be uniform. The various dyes and pigments shall not be damaging to the anodic coatings.

3.9.1 Color - When dyed or pigmented coatings are required, the color shall be as specified by the contract, order, or applicable drawing (see 6.2).

3.10 Detail requirements -

3.10.1 Types I and II coatings -

3.10.1.1 Weight of coating - After sealing Types I and II coatings shall conform to the minimum weight requirements of Table I when tested in accordance with 4.6.1 (see 6.15.6).

TABLE I

TYPES I AND II ANODIC COATING WEIGHTS

Type	Milligrams per square foot (minimum)	
	Class 1	Class 2
I	200	500
II	600	2500

* 3.10.1.1.1 When Type II, Class 2 coatings are specified for identification purposes on parts such as rivets to be mechanically deformed, the minimum coating weight for Type II, Class 1 coatings shall apply.

* 3.10.1.2 Corrosion resistance - When specified in the contract, order or applicable drawing, the corrosion resistance for anodic coating shall be determined (see 6.2). Sealed anodic coatings shall be capable of protecting the substrate metal when specimens are subjected to the corrosion resistance test specified in 4.6.3 (see 6.3). The specimens shall show no more than 5 isolated spots or pits, none

larger than 1/32 inch in diameter, in a 30 square inch area, except in those areas within 1/16 inch from the edges, corners, identification markings and holding during processing.

3.10.1.3 Light fastness resistance - When specified in the contract, order or applicable drawing, the light fastness resistance for Class 2 dyed anodic coatings shall be determined. The items or separate specimens shall show no more fading or discoloration than would be equivalent to a color difference of 5 units when subject to the light fastness resistance test specified in 4.6.4.

3.10.2 Type III coatings -

3.10.2.1 Thickness of coating - Type III coatings shall conform to the specified thickness requirements when tested in accordance with 4.6.2 (see 3.7.1).

3.10.2.1.1 Weight of coating - The weight of coating may be determined in lieu of the thickness of coating (see 3.10.2.1), at the option of the procuring activity. For Type III unsealed coatings, 4320 milligrams per square foot is equivalent to 0.001 inch thickness when tested in accordance with 4.6.2.1 (see 6.2).

3.10.2.2 Abrasion resistance - The anodized coatings applied by any process for unsealed Type III coating shall have a hard abrasion resistant finish. The items or separate specimens shall be subject to the abrasion test specified in 4.6.5. For 2024 aluminum alloy and other copper bearing alloys, the anodic coating loss shall not exceed 40 milligrams. Anodic coating loss of all other aluminum alloys shall not exceed 20 milligrams when subject to the abrasion test.

3.11 Sealing -

3.11.1 Types I and II - All Types I and II anodic coatings shall be completely sealed unless otherwise specified in the contract, order or applicable drawing by oxide hydration or absorption of metallic salt inhibitors with nonionic wetting agents (see 6.2).

3.11.1.1 Class 1 - Sealing shall be accomplished by immersion in a sealing medium such as a 5 percent aqueous solution of sodium dichromate (pH 5.0 to 6.5) for 15 minutes at 178 to 212° F, boiling deionized water, nickel acetate or other suitable chemical solutions. If not otherwise specified, sealing should be in a water solution of the sodium dichromate heated at 208 to 212° F for enhancing corrosion resistance of the anodic coating.

3.11.1.2 Class 2 - Sealing shall be accomplished by immersion in a sealing medium such as a hot aqueous solution containing nickel or cobalt acetate, boiling deionized water or other suitable chemical solutions.

3.11.2 Type III - Type III coatings shall not be sealed where the main function of application is to obtain the maximum degree of abrasion or wear resistance. Where Type III coatings are used for exterior non-maintained applications with corrosion resistance and reduced abrasion resistance, the coatings shall be sealed. Sealing for such Type III coatings shall be accomplished by immersion in a medium such as boiling deionized water, in hot aqueous 5 percent sodium dechromate, in a hot aqueous solution containing nickel or cobalt acetate or other suitable chemical solutions (see 6.2).

* 3.12 Dimensions of coated articles - Articles or parts shall comply with the dimensional requirements of the applicable drawings after application of the anodic coating. (For interference in close fits of parts or assemblies see 6.15.5.)

* 3.13 Workmanship - The anodic coating shall be continuous, smooth, adherent, uniform in appearance and shall be free from powdery areas, loose films, discontinuities such as breaks and scratches, or other damage. The size and number of contact marks shall be at a minimum consistent with good practice. The location of contact marks shall be in areas of minimum exposure to service environmental conditions when important to the function of the part. The color, if applicable, shall be a reasonably close approximation to that of a sample consisting of a treated piece or pieces agreed upon as a standard by the supplier and the procuring activity, if so agreed upon or specified in the contract or purchase order.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection - Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in the specifications where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Quality conformance tests - The quality conformance inspection shall consist of an examination for the acceptability of the quality control methods used by the supplier and an examination and testing of the quality conformance samples as specified under 4.6.

* 4.2.1 Control - The supplier should maintain a permanent record of the history of each processing bath, showing all additions of chemicals to the bath, the results of all analysis performed and the quantity of parts of each kind anodized in the bath. Upon request of the procuring activity, such records shall be made available to the Government.

4.2.1.1 Process control - The equipment, procedures and operations employed by the supplier shall be capable of producing high quality anodic coatings on aluminum and aluminum alloys as specified in this document. Upon request of the procurement body such capability shall be demonstrated by the supplier.

4.2.1.2 Frequency of tests - The tests, listed in Table II, for process control shall be made once each month or more frequently if required by the Government. In all cases, the results of tests made to determine conformance of anodic coatings on aluminum and aluminum alloys to the requirements of this specification for definite contracts or purchase orders are acceptable as evidence of the properties being obtained with the equipment and procedures employed.

4.2.1.3 Process control specimens - Test specimens for process control shall be prepared in accordance with 4.4.2.1, 4.4.2.2, and 4.4.2.3 as applicable, for the tests detailed in Table II.

TABLE II

PROCESS CONTROL TESTS AND SPECIMENS

Test	For Coating Types	Alloy for Specimen	Conforming To	Requirement Paragraph	Reference Paragraph
Coating weight	I, II	2024-T-4	QQ-A-250/4	3.10.1.1-3.10.1.1.1	4.6.1
Corrosion resistance		2024-T-4		3.10.1.2	4.6.3
Light fastness		2024-T-4		3.10.1.3	4.6.4
Coating thickness	III	2024-T-4	QQ-A-250/4	3.10.2.1-3.10.2.1.1	4.6.2
Abrasion resistance				3.10.2.2	4.6.5
Coating thickness		6061-T-4	QQ-A-250/11	3.10.2.1-3.10.2.1.1	4.6.2
Abrasion resistance				3.10.2.2	4.6.5
Coating thickness		7075-T-6	QQ-A-250/12	3.10.2.1-3.10.2.1.1	4.6.2
Abrasion resistance				3.10.2.2	4.6.5

4.3 Lot - A lot shall consist of all articles, items, parts or components with anodic coatings of the same type and class, approximately the same size, shape, thickness and color submitted for acceptance at one time. The lot size shall not exceed the number of parts, articles, items or components resulting from one eight-hour production.

4.4 Sampling - Unless otherwise specified, sampling plans and procedures in the determination of the acceptability of coated parts and articles submitted by a supplier shall be in accordance with the provisions set forth in MIL-STD-105.

4.4.1 Quality conformance samples -

4.4.1.1 Visual examination and dimensions of coated articles - Samples for visual examination and dimensions of coated articles shall be selected from each lot of coated parts and articles in accordance with the provisions of MIL-STD-105. Acceptance Criteria shall be Inspection Level II, Acceptable Quality Level (AQL) of 1.5 percent defective.

4.4.1.2 Finished products - Random samples for weight thickness, corrosion resistance, light fastness resistance and abrasion resistance shall be selected from each lot of coated parts and articles, except for small parts (see 4.4.1.3) in accordance with MIL-STD-105, Inspection Level S-2, acceptance number of zero for tests of 4.6.

4.4.1.3 Small parts - When small parts such as rivets or machine screws are bulk anodized in containers as Type II, Class 2; specimens shall be selected at random from each lot in accordance with Inspection Level S-3 of MIL-STD-105 to determine minimum coating weight (see 3.10.1.1.1). Acceptance of parts treated together shall be based on an Acceptable Quality Level (AQL) equivalent of 6.5 percent defective. The finished small parts shall not be sampled for corrosion resistance (see 4.6.3).

4.4.2 Quality conformance specimen preparation - When the work or articles are of such form, size, and value as to prohibit use thereof, or are not readily adaptable to the test specified herein, specimens of the same composition and heat treatment as the work being inspected shall be anodized concurrently and on the same anodizing rack or hook with the articles represented, to be used for required tests. Where aluminum alloy castings are being coated, the specimens may be cut from scrap castings or cast as separate specimens.

4.4.2.1 Specimens for thickness and anodic coating weight - If separate specimens for thickness and anodic coating weight are required, they shall be aluminum alloy panels not less than 3 inches in length and width, 0.032 inch thick, and of the same composition and temper as the production work and anodized concurrently.

4.4.2.2 Specimens for corrosion resistance and light fastness tests - If separate specimens for corrosion resistance and light fastness tests are required, they shall be aluminum alloy panels, 0.032 inch thick, not less than 10 inches in length and 3 inches in width, with the length transverse to the rolling direction, and shall be cut from adjacent areas of the same sheet. Specimens shall be of an alloy of the same composition and temper as the production work and anodized concurrently.

4.4.2.3 Specimens for abrasion resistance test - If separate specimens for abrasion resistance test are required, they shall be aluminum alloy panels 4 inches by 4 inches, and 0.032 inch thick, and shall be cut from adjacent areas of the same sheet, similar in composition and temper to the production work and anodized concurrently.

4.5 Quality conformance examination -

4.5.1 Coated articles - Samples selected in accordance with 4.4.1.1 shall be inspected and visually examined for compliance with the requirements of 3.1.1 before anodizing, unless otherwise specified, and of 3.13 after anodizing and sealing.

4.5.2 Dimensional examination - Samples selected in accordance with 4.4.1.1 shall be inspected for dimensional requirements for compliance with 3.12, unless otherwise specified by the procuring activity (see 6.15.5).

4.6 Quality conformance tests -

4.6.1 Anodic coating weight - If the surface area is measurable random items, or separate specimen panels prepared in accordance with 4.4.2.1, shall be selected in accordance with 4.4.1.2 from each lot. For small parts as rivets or machine screws dyed for identification pruposes, specimens shall be selected in accordance with 4.4.1.3 from each lot. The selected items or prepared specimen panels shall be tested for anodic coating weight either in accordance with ASTM B 137, Weight of Coating on Anodically Coated Aluminum, or the method specified in 4.6.1.1, at the option of the supplier, to determine conformance to the requirements of 3.10.1.1 or 3.10.1.1.1, as applicable, for the specified minimum weight of the Type I or Type II coatings. The item or separate specimen panel shall be considered defective if the coating weight fails to meet the specified minimum weight and the lot represented shall be rejected.

4.6.1.1 Method - Anodic-coating weight determinations shall be accomplished in the following manner:

(a) The test panel or specimen of material to be tested shall be weighed following the anodizing treatment. An analytical balance or other instrument sensitive at least to 10 percent of the net anodic-coating weight on the panel or specimen of material shall be used. Specimens shall be cleaned and dried for 30 minutes at 200° F and allowed to cool to room temperature before weighing.

(b) Immediately following weighing, the test panel or specimen of material shall be stripped by immersion in a phosphoric-chromic acid solution for 5 mihutes at 212° F (100° C). The solution shall consist of the following:

Phosphoric acid, 85 percent	35 milliliters
Chromic acid (CrO_3)	20 grams
Water to make	1,000 milliliters

The panel or specimen shall be removed from the solution, washed in distilled water, dried, and weighed. The 5-minute exposure shall be repeated until the coating is completely removed, which is indicated by the panel or specimen's weight remaining constant. The stripping solution shall be discarded after 1 liter of the solution has dissolved 5 grams of the anodic coating.

(c) After final weighing, the total surface area of the test specimen shall be accurately determined.

(d) The unit film weight shall be determined by subtracting the weight in milligrams of the stripped panel or specimen from its weight in milligrams prior to stripping and dividing by the surface area expressed in square feet.

4.6.2 Anodic coating thickness - If the surface face is suitable, random items or separate specimen panels prepared in accordance with 4.4.2.1, shall be selected in accordance with 4.4.1.2 from each lot. The separate items or prepared specimen panels shall be tested for anodic coating thickness in accordance with ASTM B 244, Measuring Thickness of Anodic Coatings on Aluminum with Eddy Current Instruments, Method 520, or Method 521 of Fed. Test Method Std. No. 151, at the option of the supplier to determine conformance to the requirements of 3.10.2.1. If either ASTM B 244 or Method 520 of Fed. Test Method Std. No. 151 is used, the thickness shall be computed as the average of not less than eight measurements. If one or more of the items or panels fails to meet the specified thickness range for the Type III coatings (see 3.7.1) the lot represented shall be rejected. In case of dispute, anodic coating thickness shall be determined by measurement of a perpendicular cross section of the anodized specimen using a metallographic microscope with a calibrated eyepiece.

* 4.6.2.1 Anodic coating weight for Type III coating - At the option of the supplier, samples for anodic coating thickness as detailed in 4.6.2 may be used to determine the anodic coating weight for Type III coatings. The separate items or prepared panels shall be tested as detailed in 4.6.1 to determine conformance to the requirement of 3.10.2.1.1. The item or separate panel shall be considered defective if the coating weight fails to meet the minimum weight per specified thickness and the lot represented shall be rejected.

* 4.6.3 Corrosion resistance - When processed parts are such that they may be conveniently adapted for the corrosion resistant test, the actual parts may be selected for test in accordance with 4.4.1.2 in lieu of separate test panels prepared in accordance with 4.4.2.2 of sheet samples. The selected items or specimen test panels shall be tested for corrosion resistance in accordance with the method specified in 4.6.3.1.

4.6.3.1 Method - Specimens shall be washed in distilled or deionized water, dried with a soft cloth and then subjected to a 5 percent salt spray test in accordance with Method 811 of Fed. Test Method Std. No. 151 or ASTM B 117, Method of Salt Spray (Fog) Testing, except that the significant surface shall be inclined approximately 6 degrees from the vertical. Specimens with Types I and II coatings shall be exposed for 336 hours. After exposure, specimens shall be examined and compared with unexposed specimens for the effects of corrosion to determine compliance with 3.10.1.2. Corrosion on the specimen in excess of that permitted by 3.10.1.2 shall be cause for rejection of the lot.

4.6.4 Light fastness resistance - When processed parts are such that they may be conveniently adapted for the radiation test, the actual part may be selected for test in accordance with 4.4.1.2 in lieu of separate test panels prepared in accordance with 4.4.2.2 of sheet and dyed. The selected items or prepared specimen test panels shall be tested for light fastness resistance by exposure to ultra-violet radiation in accordance with either Method 6151 or 6152 of Fed. Test Method Std. No. 141, for a period of 200 hours, except that the specimens will be exposed continuously to light without water spray. After exposure the tested specimens shall be compared with duplicate specimens not exposed to a light source for the same period of time to determine compliance with 3.10.1.3. If there is any visual indication of appreciable fading or discoloration of the semi-metallic luster or when determined by ASTM D 2244, Method for Instrumental Evaluation of Color Differences of Opaque Materials, as compared with the unexposed specimens, the dyed anodic films shall be considered unsatisfactory and the lot represented by the specimens shall be rejected (see 6.8 and 6.9).

* 4.6.5 Abrasion resistance - When processed parts are such that they may be conveniently adapted for the abrasion test, the actual part may be selected for test in accordance with 4.4.1.2 in lieu of separate test panels prepared in accordance with 4.4.2.3. The selected items or specimen test panels shall be tested in accordance with Method 6192 of Fed. Test Method Std. No. 141 using CS-17 wheels with 1000 gram load. The wheels shall revolve on the anodic coating at a speed of 70 revolutions per minute (RPM) for 10,000 cycles. After abrading, the specimens shall be weighed to the nearest milligram and the weight loss obtained to determine compliance with the requirements of 3.10.2.2. If the amount of the coating abraded is more than specified, the coating shall be considered unsatisfactory and the lot represented by the specimens shall be rejected.

5. PREPARATION FOR DELIVERY

5.1 The requirements of Section 5 are not applicable to this specification.

6. NOTES

6.1 Intended use -

* 6.1.1 Types I and II - The conventional Types I and II anodic coatings are intended to improve surface corrosion protection under severe service conditions or as a base for paint systems. Anodic coatings can be colored with a large variety of dyes and pigments. Types I and II coatings provide better corrosion protection at higher cost than the chromate chemical conversion systems (MIL-C-5541). Repair of mechanically damaged areas by the use of materials conforming to MIL-C-5541 (see 3.3.8) will not restore abrasion resistance but provide an effective means of reestablishing corrosion resistance.

* 6.1.2 Type III - The hard anodic Type III coatings are intended to provide wear and abrasion resistance surfaces with improved corrosion protection due to greater thickness and weight than the conventional anodic coatings. Sealing of hard coatings is not recommended unless corrosion resistance is also a factor. Wear resistance is reduced by sealing. Coatings form an excellent base for most types of paint systems, adhesives and dry film lubricants. Hard coatings may reduce fatigue strength. These factors should be considered in proposed use of parts subjected to cyclic loads. Generally, these hard coatings should not be used on parts or portions of parts which normally during rework would require restoring of dimensional tolerances because of wear of hard coated surfaces.

6.1.2.1 Hard coatings are used in such applications as valves, sliding parts, hinge mechanisms, cams, gears, swivel joints, pistons, rocket nozzles, insulation plates, blast shields, etc.

6.2 Ordering data - Requisitions, contracts and purchase orders should specify the following:

(a) Title, number and date of this specification.

(b) Type of anodic coating, (see 1.2.1, 3.5, 3.6, 3.7).

(c) Class of anodic coating, (see 1.2.2, 3.7.3, 3.9.1).

(d) Special process operating conditions, if applicable (see 3.2).

(e) Special cleaning and fabrication requirements (see 3.3.1, 3.3.4, 3.3.5, and 3.3.7).

(f) Type III coating thickness, if applicable (see 3.7.1).

(g) Color of Class 2 coating, if applicable (see 3.9.1, 3.13).

(h) Color requirement for small parts identification, if applicable (see 3.10.1.1.1).

(i) Light fastness resistance, if applicable (see 3.10.1.3).

(j) Coating weight for thickness, Type III, if substituted (see 3.10.2.1.1).

(k) Special sealing requirements (see 3.11).

(l) Special sampling plans (see 4.4).

6.2.1 When either Type or class of anodic coating or both, are not specified on drawings, except for hard coatings, then either Type I or Type II, Class 1 or Class 2 anodic coating may be furnished at the option of the supplier within the limits of this specification.

6.3 Definition of term "capable of" - The term "capable of" as used in this specification means that the test need not be performed by the supplier of the anodic coating. However, should subsequent testing by the procuring activity establish the material does not meet these requirements the anodic coated articles will be rejected (see 3.10.1.2).

6.4 Painting - When anodized coatings are required to be painted, the parts should be dried and painted as promptly as possible, during which time, exposure to contamination should be kept to a minimum. Prior to painting, wiping, buffing or mechanical operations on anodized or sealed parts shall be minimized. This may damage the relatively soft outside layer of the anodic coating and make the coat susceptible to subsequent paint adhesion failures. Sealing solutions such as sodium dichromate, sodium molybdate, nickel acetate, sodium acetate should be used with caution on items or parts to be painted as they tend to promote poor adhesion when tested by immersion in water.

6.5 Electrolytic action - Severe attack by the electrolyte on castings or welds may be occasioned either by unsound castings, improper welding practice, difference in composition between the weld and the basis metal or, particularly in the case of the sulfuric acid process, the retention of the solution in cracks, crevices, or irregular surfaces. Severe attack by the electrolyte may also be caused by contaminants in the electrolyte, particularly chlorides, or by improper racking of the parts.

6.6 Anodizing rate - Aluminum and aluminum alloys may be conveniently grouped by anodizing rate, especially in the case of the chromic acid process (Type I) for conventional coatings. However, either the chromic (Type I) or the sulphuric acid process (Type II) will anodize mixed loads satisfactorily, depending upon local processing preference. Suppliers are cautioned that, especially in the sulfuric acid process, the anodizing time will have to be sufficiently long to assure that the slower anodizing alloys have at least a minimum coating thickness. In some cases, this may result in improper coatings on the fast anodizing alloys.

6.7 Color match - FED-STD-595 may be used as a guide for specifying color of anodic coatings. The color standards in FED-STD-595 are intended for paint finishes and should be used for approximate comparison only with the anodic coatings. (See 6.2.)

6.8 Dyeing or coloring -

6.8.1 Anodic coatings for Class 2 application should not be allowed to dry before dyeing or coloring.

6.8.2 Anodic coatings to be dyed or colored should be preferably coated by the Type II anodizing treatment.

6.8.3 Dyed or colored coatings should not be allowed to remain in rinse waters for more than 5 minutes before sealing.

6.9 Light-fastness - The following black dyes have been found satisfactory by the Department of the Army in post-anodic processing of Type II coating to meet the requirements of light-fastness (see 3.10.1.3) when tested in accordance with 4.6.4. They are listed for information only.

Manufacturer's Designation	Manufacturer	Manufacturer's Address
Oxanal Fast Black RLN	Ciba Co., Inc.	631 Greenwich Street New York, N.Y. 10014
Black OA	Sandoz Chemical Works, Inc.	63 Van Dam Street New York, N.Y.
D&H Aluminum Deep Black MLW	American-Hoechst Corp.	Mountainside, N.J.
Nigrosine Crystals #12525J plus Metanil Yellow	Allied Chemical Corp., National Aniline Division	40 Rector Street New York, N.Y. 10006

6.10 Weathering machines - Other sources of ultra-violet radiation may be used for determination of the light-fastness of the Class 2 anodized coatings provided they meet the requirements and are of equal intensity to those detailed in Methods 6151 and 6152 of Fed. Test Method Std. No. 141 (see 4.6.4).

6.11 Lapping - The hard Type III anodic coatings generally have increased surface roughness as well as having the property of being softer on the top surface than down in the core of the coating toward the basis metal. Such coatings may be processed oversized and then lapped or honed down to the final desired dimension.

6.12 Defects - If harmful defects are revealed as a result of anodizing, this condition should be brought to the attention of the procuring activity.

* 6.13 Coating baths - For information, it should be noted that processes providing other coating electrolytes for the conventional coatings may be aqueous solutions containing oxalic acid, boric acid plus ammonium borate, and nitrides. There are proprietary processes requiring coating electrolytes other than sulphuric acid for the hard Type III coatings; for example the various Alumilites, the Martin Hard Coat, the Sanford, the Hardas and others. One of the Alumilite processes requires an aqueous solution containing both sulfuric and oxalic acids for the bath. Other baths used less frequently and for special purposes employ sulfosalicylic, sulfamic or sulfophthalic acid solutions.

* 6.14 Chemical brightening and polishing - Chemical brightening can be beneficial by improving the appearance and corrosion resistance, in smoothing the metallic surface by removing certain contaminants and in enhancing the continuity of the anodic coatings on aluminum alloys. (See 3.3.5.)

6.15 Design information -

* 6.15.1 Surface dimension of parts - On specifying the thickness of coatings, especially for the hard Type III coatings, allowance must be made for dimensional increase. Both a machining dimension and a coated dimension should be placed on applicable drawings. An increase in dimension, equal to one half of the thickness of the applied coating, can be expected for each surface coated due to surface growth. For example, for a 0.004 inch (4 mils) coating on close tolerance parts, a pre-machining allowance of 0.002 inch (2 mils) per surface must be made prior to hard coating. If close fits are specified in design drawings, buildup in thickness caused by anodic coatings, especially Type III, may result in interference on assembly.

* 6.15.1.1 In the case of small blind holes and tapped holes, coating thickness can vary from no film to a full normal coating. Unless otherwise specified, any tapped hole or non-tapped hole 1/4 inch or less in diameter may be furnished free of the anodic coating if the item is to be required for Type I, Class 2; Type II or Type III coating. Holes, both tapped and not tapped, 1/4 inch or less of items to be treated to produce a Type I, Class 1 coating, shall be anodized. Holes, both tapped and not tapped, over 1/4 inch shall be anodized. Parts with Type II coatings, external or internal, with a total tolerance of 0.0004 inch or less, if lapped, honed or stoned to size after anodizing, must be subsequently treated in accordance with MIL-C-5541 to provide surface protection. Discoloration on the surface that has been sized is acceptable (see 6.11). The designer is cautioned to require adequate thread and hole sealing operations in subsequent assemblies as may be required to produce the necessary corrosion resistance.

* 6.15.2 Thread dimensions - All anodic coatings will affect thread dimensions for external and internal threads; the major and minor dimeter will be increased 2 times the amount of growth (see 6.15.1). The pitch diameter for threads having an including angle of 60° will increase 4 times the amount of growth. For threads having an including angle other than 60° the pitch diameter will increase 2 times the amount of growth (see 6.15.1) divided by the sine 1/2 the included angle.

* 6.15.3 Fabrication - Successful use of anodic coatings, especially the hard Type III, depends on proper product design. Because of the manner of formation, anodic coatings will develop voids at sharp corners and edges. Sharp edges and corners are difficult to anodize satisfactorily and in general should be avoided. All edges and inside corners should be radiused prior to anodizing. Chamfering should not be used unless resulting sharp edges are radiused. In general, to avoid any uncoated edges or inside corners, the piercing and blanking operations should comply with the radii of curvature for nominal coating thicknesses as in Table III.

TABLE III

Nominal coating thickness inch	Radius of curvature on edge and inside corner
0.001	approximately 1/32 inch
0.002	approximately 1/16 inch
0.003	approximately 3/32 inch
0.004	approximately 1/8 inch

* 6.15.4 Coating thickness - Thickness of the heavy Type III coating can be controlled to extremely close tolerances. Anodized coating can be obtained with tolerances of as little as ±0.0001 inch (0.1 mil). With all anodizing processes used primarily for engineering rather than for decorative purposes, a number of highly specialized techniques are used for operation control. One method that may be employed is to carefully measure the coated part while still wet and replace it in the bath for a fixed period of treatment. Calculations based upon a calculated rate of coating per unit of processing time may be used as the basis for determining the exact duration of processing required for the specific alloy being coated.

* 6.15.5 Coating dimensions - Table IV gives thickness ranges of anodic coatings that can be applied on aluminum and aluminum alloys. All anodic coatings are harder than the substrate material. If interference is required for assembly and is accomplished by force fitting Type I and some Type II coatings are too thin, too soft and too brittle to overcome abrasion resistance. With Type III coatings however, assembly may be accomplished by grinding, lapping or otherwise removing the surplus coating. Coatings of all types are brittle and may crack and spall due to force fittings.

TABLE IV

THICKNESS RANGES OF ANODIC
COATINGS ON ALUMINUM AND ALUMINUM ALLOYS

Type coating	Thickness range - inch
I	0.00005 to 0.0003
II	0.00010 to 0.0010
III	0.0005 to 0.0045

6.15.6 Coating weight - thickness relationship -

6.15.6.1 Table V gives typical minimum thickness in inch of anodic coatings formed on some wrought and cast alloys that could comply with the minimum weight for coating requirements in accordance with Table I for Types I and II, Class 1.

TABLE V

Alloy Designation	Thickness of coating - inch	
	Type I	Type II
1100	0.000029	0.000093
2024-T4	-	0.000125
2024-T6	0.000044	-
3003	0.000035	0.000103
6061-T6	0.000034	0.000099
7075-T6	0.000040	0.000105
5052	0.000033	0.000098
5056	0.000021	-
Alclad 2014-T6	0.000045	-
Alclad 7075-T6	0.000041	-
195-T6	-	0.000107
356-T6	-	0.000102
214	-	0.000086

* 6.15.6.2 Type II - Exterior surfaces processed from sulphuric acid electrolytes (Type II) that are cleaned regularly a thickness of at least 0.0004 inch (approximately 2450 milligrams per square foot) will assure high resistance to weathering. For exterior parts that are handled frequently or kept without maintenance, a minimum thickness of 0.0007 inch (approximately 5000 milligrams per square foot) should be required. For ordinary applications for interior service, coatings 0.0004 inch thick are ample. Where abrasive resistance is not a factor and parts are not normally handled, thickness of 0.00013 to 0.00025 inch (900 to 1700 milligrams per square foot) may be adequate.

6.15.6.3 Type III - For applications using a hard coating, a thickness of 0.001 to 0.004 inch (approximately 5750 to 6000 milligram per square foot for every 0.001 inch thickness) is satisfactory.

6.16 Changes from previous issue - The margins of this specification are marked with an asterisk to indicate where changes (additions, modifications, corrections, deletions) from the previous issue were made. This was done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content irrespective of the marginal notations and relationship to the last previous issue.

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