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MIL-C-5541E
30 November 1990
SUPERSEDING
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28 February 1989

MILITARY SPECIFICATION

CHEMICAL CONVERSION COATINGS ON ALUMINUM AND ALUMINUM ALLOYS

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 two classes of chemical conversion coatings formed by the reaction of chemical conversion materials and the surfaces of aluminum and aluminum alloys This specification is intended specifically to provide components of military weapon systems with maximum corrosion resistance. The coating also provides a surface having better paint adhesion than uncoated aluminum. It is not intended as a general purpose coating for commercial and decorative applications, (see 6.1).

1 2 Classification. The chemical conversion coatings shall be of the following classes, as specified (see 6 2)

1.2.1 Classes.

Class 1 A - For maximum protection against corrosion, for surfaces to be painted or left unpainted, (see 6 1 1)

Class 3 - For protection against corrosion where lower electrical resistance is required, (see 6 1 2)

2. APPLICABLE DOCUMENTS

2 1 Government documents

2.1.1 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 listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to Commanding Officer, Systems Engineering and Standardization Department, (Code 53), Naval Air Engineering Center, Lakehurst, NJ 08733-5100, by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter

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SPECIFICATIONS

FEDERAL

QQ-A-250/4 -Aluminum Alloy 2024, Plate and Sheet

QQ-A-250/11 -Aluminum Alloy 6061, Plate and Sheet

MILITARY

MIL-P-23377 -Primer Coating, Epoxy Polyamide, Chemical and Solvent Resistant

MIL-C-81706 -Chemical Conversion Materials For Coating Aluminum and Aluminum Alloys

MIL-P-85582 -Primer Coatings Epoxy, Waterborne

STANDARDS

FEDERAL

FED-STD-141 -Paint, Varnish, Lacquer and Related Materials, Methods of Inspection, Sampling and Testing

MILITARY

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

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

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 issue of the DODISS cited in the solicitation Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM B117 - Salt Spray(Fog) Testing

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

2 3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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3. REQUIREMENTS

3 1 Chemical conversion materials The materials used to produce a chemical conversion coating shall be approved for the selected class, form and application method in accordance with the qualification requirements of MIL-C-81706 and been accepted for listing on the applicable Qualified Products List (see 6.3) Replenishing chemicals, such as fluorides, added to a bath to maintain its efficiency, shall in no way degrade the performance of the coating being applied.

3 2 Cleaning. Prior to coating, the base metal shall be mechanically and/or chemically cleaned such that a water break-free surface is obtained after rinsing (see 6 4) Abrasives containing iron such as steel wool, iron oxide, rouge or steel wire are prohibited for all cleaning operations as particles from them may become embedded in the metal and accelerate corrosion of the aluminum and aluminum alloys Treated parts which have become soiled shall be cleaned with materials which will remove the soil without damaging the base metal, the part, or the conversion coating If the coating is damaged, the damaged area shall be recleaned and recoated or the part shall be rejected

* 3.3 Application. Unless an application method is specified, the chemical conversion materials shall be applied nonelectrolytically by spray, brush or immersion after all heat treatments and mechanical operations such as forming, perforating, machining, brazing and welding have been completed Assemblies containing non-aluminum parts which may be attacked, embrittled, or damaged in any way by the conversion coating process shall not be coated as assemblies unless the non-aluminum parts are suitably masked

* 3 4 Rework Unless otherwise specified by the procuring activity, mechanically damaged areas from which the coating has been removed may be reworked The damaged areas shall be touched up with MIL-C-81706 material approved on the QPL for the applicable class and method of application. The rework area shall not exceed 5 percent of total item surface area If the area exceeds 5 percent, specific approval must be obtained from the procuring activity before the area can be reworked

3.5 Appearance. The conversion coating shall be as uniform in appearance as practical (see 6 6). It shall be continuous and free from areas of powdery or loose coating, voids, scratches, flaws and other defects or damages which will reduce the serviceability of parts or be detrimental to the protective value and paint bonding characteristics The size and number of contact marks shall be at a minimum, consistent with good practice. If specified, contact marks shall be touched up with MIL-C-81706 material approved on the QPL for the applicable class and method of application to prevent localized corrosion Clear (colorless) coating shall only be used when specifically authorized by the procuring activity, (see 6 2 and 6 6)

3.6 Corrosion resistance properties. At the end of 168 hours exposure to the 5 percent salt spray test specified in 4 5.1, specimen panels (see 4 3.3) treated with the applicable class of coating shall meet all of the following corrosion resistance requirements.

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a. No more than 5 isolated spots or pits (see 6.7), none larger than 0 031 inches in diameter, per specimen panel Areas within 0.25 inches from the edges, identification markings, and holding points during processing or salt spray exposure shall be excluded Loss of color shall not be cause for rejection.

b. No more than 15 isolated spots or pits, none larger than 031 inches in diameter, on the combined surface area of all five specimen panels, subjected to the salt spray test.

3.7 Paint adhesion properties. When the production paint system or the paint system specified in 4 3.3.1 1 is applied to the applicable specimen panels (see 4.3 3), no intercoat separation shall occur between the paint system and the conversion coating or between the conversion coating and the base metal when tested in accordance with 4 5 2, (see 6.10) If the conversion coated parts do not require painting for end use, the paint adhesion test may be omitted if specifically authorized by the procuring activity (see 6.2).

3.8 Electrical contact resistance of Class 3 coatings If specified (see 6.2), electrical contact resistance testing shall be performed. The test method, frequency of testing, and required resistance values shall be specified by the procuring activity to suit the needs of a particular application

3.9 Workmanship The chemical coatings covered by this specification shall be produced by suitable treatments and processes to give uniformly coated products as specified herein

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 the specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements

4.1.1 Responsibility for compliance All items must meet all requirements of Section 3 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 of 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 acceptance of defective material.

4.2 Classification of inspection The inspection requirements specified herein are classified as follows

a Process control inspection (see 4.3)
b Quality conformance inspection (see 4.4)

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4 3 Process control inspection

* 4.3 1 Process control tests and solution analysis. To assure continuous control of the process, test specimens (see 4 3.3) shall be tested in accordance with Table I (see 4 3.1.1). In addition to the tests in Table I, solution analysis shall be performed on all the processing solutions in the conversion coating line (see 6.9) to verify that the chemical concentrations are within ranges established for optimum performance (see 4.3.1.1 and 4.3.2). Process control tests are conducted to determine compliance of the chemical conversion coatings with the requirements of this specification and are acceptable as evidence of the properties being obtained with the equipment and procedures employed.

Table I Process control tests.

Tests	Class	Number of Specimens	Specimen Preparation	Requirement Paragraph	Test Paragraph
Corrosion resistance	1A	5	4 3.3	3.6	4 5.1
	3	5	4 3.3	3.6	4 5 1
Adhesion, wet tape	1A	2	4.3.3 thru 4 3.3 1	3.7	4 5.2
	3	2	4.3 3 thru 4 3 3 1	3.7	4 5 2

4 3 1.1 Frequency of process control testing and solution analysis. Solution analysis shall be performed once every week. The process control tests specified in Table I shall be conducted on a monthly basis In addition, the interval between each monthly test shall not exceed 35 days If production in accordance with this specification is not performed for a period of 35 days or longer, process control tests and solution analysis shall be conducted at the restart of production

4 3 2 Solution analysis records. The processor shall maintain a record of the history of each processing bath, showing additions of replenishing chemicals to the bath and the results of all solution analyses performed Upon request of the procuring activity, such records, as well as reports of the test results, shall be made available These records shall be maintained for not less than one year after completion of the contract or purchase order

* 4 3 3 Process control specimen panels Specimen panels used for process control testing shall be 3 inches in width, 10 inches in length, with a minimum 0 020 inch nominal thickness. The specimen panels shall be processed with the hardware during an actual production run, including all pre- and post-treatment processes such as cleaning and rinsing, except as specified below Unless otherwise specified in the contract or order (see 6.2), either of the following alloy options for the process control specimen panels may be utilized:

Option 1 - A set of specimen panels shall be used for each alloy and temper treated during the monthly process control period

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Option 2 - The specimen panels shall be 2024-T3 aluminum alloy panels per QQ-A-250/4 for class 1A coatings and 6061-T6 aluminum alloy panels per QQ-A-250/11 for class 3 coatings If desired, 2024-T3 panels may be used in lieu of 6061-T6 panels for testing class 3 coatings (see 6 8). When castings are being processed and the cleaning procedures used are detrimental to the wrought specimen panels, the panels shall be cleaned in an appropriate manner (see 3 2) and conversion coated with the castings

* 4 3 3 1 Preparation of paint adhesion specimens Unless otherwise specified (see 6.2), the paint system to be used on the specimen panels for adhesion testing (see 4 5.2) shall be that used for the production work (applied and cured in the same manner as the production work) or the paint system specified in 4 3 3 1 1

4 3 3.1.1 Epoxy primer coatings Specimen panels shall be finished with one coat of a (VOC) compliant epoxy-polyamide primer conforming to either MIL-P-23377 or MIL-P-85582 In either case the primer shall be applied to a dry film thickness of 0 0006 to 0 0009 inch (0.6 to 0 9 mil) and dried in accordance with the applicable primer specification before testing in accordance with 4 5 2

4.3 4 Failure Failure to conform to any of the process control requirements specified in Table I shall result in immediate halt of production. The reason for failure shall be determined and corrected before production resumes All traceable and retrievable work from the time the failed process control specimens were conversion coated to the time when the failure was determined shall be rejected, unless the contractor can demonstrate that the items under review can meet the requirements of this specification Unless otherwise specified, parts which have been painted or incorporated into an assembly shall not be considered retrievable

4 4 Quality conformance (lot acceptance) inspection

4 4 1 Lot A lot shall consist of all conversion coated items of the same class, treated under the same conditions, and submitted for acceptance at one time Unless otherwise specified, the lot size shall not exceed the number of parts, articles, items or components resulting from a one day's production (see 6 2)

* 4 4.2 Sampling plan and acceptance criteria Samples for visual examinations shall be selected from each lot of treated articles, items, parts or components Unless otherwise specified in the contract or order (see 6.2), the sampling plan and acceptance criteria shall be as specified in inspection level II of MIL-STD-105 with an AQL of 1 5 percent defective

4 4 3 Visual lot examination. Samples selected in accordance with 4 4.2 shall be visually inspected for compliance with the requirements of 3 5 and 3 9

4 4.4 Failure Failure to conform to any of the quality conformance requirements shall result in rejection of the represented lot

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4.5 Test methods

4.5 1 Corrosion resistance test Five specimen panels prepared in accordance with paragraph 4 3 3 shall be used for corrosion resistance testing. After the coating application, the specimen panels shall be dried at 60-100°F for 24 hours. The panels shall then be subjected to a 5 percent salt spray test in accordance with ASTM B117 for 168 hours, except that the significant surface shall be inclined 6 degrees from the vertical. After exposure, test pieces shall be cleaned in running water, not warmer than 38°C (100°F), blown with clean, dry unheated air, and visually examined for conformance with paragraph 3.6.

4.5 2 Wet tape adhesion test. Two specimen panels prepared in accordance with 4 3.3 and 4 3 3 1 shall be tested for wet tape adhesion The test shall be conducted as described in method 6301 of FED-STD-141 to determine conformance with paragraph 3.7.

5 PACKAGING

5 1 The requirements of Section 5 are not applicable.

6 NOTES

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

6.1 Intended use

6.1 1 Class 1A. Class 1A chemical conversion coatings are intended to provide corrosion prevention when left unpainted as well as to improve adhesion of paint finish systems on aluminum and aluminum alloys. Coatings of this type may be used, for example, on tanks, tubing, and component structures where paint finishes are not required for the interior surfaces but are required for the exterior surfaces.

6 1 2 Class 3 Class 3 chemical conversion coatings are intended for use as a corrosion preventive film for electrical and electronic applications where lower resistant contacts, relative to Class 1A coatings, and anodic coatings in accordance with MIL-A-8625, are required (see 6.1.2.1). The primary difference between a Class 1A and Class 3 coating is thickness, since current passes more readily through a thinner current resistant barrier(coating). Coating thickness is varied by immersion time, and as a result, the same conversion material can be listed on QPL-81706 for both classes Because Class 3 coatings are thinner, they are more susceptible to corrosion than Class 1A coatings. If it is required to paint areas surrounding electrical contacts, Class 3 coatings will improve adhesion of paint systems on aluminum and aluminum alloys

6 1 2.1 Electrical resistance testing. When under a nominal electrode pressure of 200 psi, Class 3 coatings are qualified per MIL-C-81706 to have a resistance no greater than 5,000 microhms per square inch as supplied and 10,000 microhms per square inch after 168 hours of salt spray exposure In addition to the coating or coating thickness (see 6 1.2), other variables heavily influence resistance values when using the test method specified in MIL-C-81706 or other similar methods. The following two variables may have a greater effect on electrical resistance values than the conversion coating thickness

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6 1.2 1 1 Surface roughness of the specimen panel Panels having rough surfaces will yield lower resistance values when subjected to a contact electrode pressure due to coating fracture This reasoning can also be applied to the contact electrode

6 1 2.1.2 Flatness of the contact electrode If an electrode with a given surface area is not flat, the actual contact area will be lower than the theoretical value Smaller contact area will result in a higher resistance value. The same reasoning can be applied to the specimen panel

6 2 Ordering data. Acquisition documents should specify the following:

a. Title, number and date of this specification

b. Class of coating (see 1.2 1)

c. Method of application, if restricted (see 3.3)

d Clear coatings, if desired (see 3.5).

e. Omit the paint adhesion test, if permitted (see 3 7)

f If electrical resistance testing is required for Class 3 coatings, (see 3.8 and 6 1 2)

g When electrical resistance testing is required, specify the required resistance values, frequency of testing, and test method (see 3.8 and 6 1.2)

h Alloy and temper of the process control specimen panels, if different than that specified in 4 3 3

i Paint finish system for treated parts, if applicable (see 4 3 3 1)

j Lot size, if different from that specified (see 4 4 1).

k Sampling plan, if different from that specified (see 4 4.2)

6 3 Interchangeability. The various products approved in accordance with MIL-C-81706 and listed on QPL-81706 will provide equivalent coatings within each class insofar as performance of the chemical conversion coating is concerned to the provisions of the document, but are not interchangeable from a chemical standpoint, that is, different materials can not be mixed. The materials from one supplier shall not be mixed or used to strengthen an existing solution from another material supplier As the chemical coating materials are proprietary products, the ingredients, processes, the method of application (spray, brush, or immersion), and the equipment required for application of coating may vary. Coating contractors and military activities should take this into account in acquisition, in the design of parts and the establishment of facilities Detail drawing of parts requiring treatment in accordance with this specification should specify the Class 1A or 3 and any paint finishing systems required to meet the performance desired If the coating class is not specified, Class 1A is recommended

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* 6 4 Cleaners Use of a non-etch cleaner is preferred, particularly on wrought alloys. If an etch is used, caution should be taken to prevent pitting or intergranular attack. This is particularly important when using an alkaline etch because the aluminum tends to be more soluble than its alloying elements and existing intermetallics, such as copper, may be further exposed As a result, alkaline etching should be avoided (particularly when cleaning assembled structures) If an alkaline etch is used, it should always be followed by an acid neutralization step

6 5 Abrasion resistance. The abrasion resistance of chemical coatings is relatively low. Coatings are reasonably durable when subjected only to moderate handling, but are readily removed by severe wear or erosion. However, cold forming operations, when performed with care, can generally be performed on treated metals without appreciable damage to the coatings

6 6 Visual appearance. The simplest way to evaluate a conversion coating is to observe color, uniformity of appearance, smoothness and adhesion to the base metal (see 3.5). Visual examination is performed to assure that proper cleaning and coating procedures were used such that a coating with sufficient protection exists over the entire part Materials qualified under MIL-C-81706 produce coatings that range in color from clear to iridescent yellow or brown. It may be possible to develop acceptable color levels for a particular coating system by use of color chips The following circumstances may exist which relate to color uniformity.

a When several alloys are processed with the same conversion chemical, color may vary from alloy to alloy

b. Due to the high level of impurities and oxidation on the surfaces of aluminum welds and castings, color may not be as uniform as that obtained by treating wrought alloys

c. Dark spots may result from dripping or rundown of the conversion chemicals when the parts are lifted out of the treatment tank. A small amount of spotting will not result in coating degradation but should be minimized by quickly rinsing the parts after treatment, and use of proper racking techniques

Visual examination will not reveal if the protective value of the coating has been impaired by contamination or by overheating during drying. If a clear coating is required, inspection difficulties may arise because visual inspection does not reveal the presence of a coating The existence of a coating can be verified by using a simple spot test specified in ASTM B 449.

6 7 Determination of a corrosion spot or pit. As a general rule, a corrosion spot or pit usually displays a characteristic tail or line (see 3.6)

6 8 Specimen panels (2024-T3) Due to high copper content, 2024-T3 aluminum alloy panels are more susceptible to salt spray failure than 6061-T6 aluminum alloy panels (see 4 3 3)

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6.9 Chemical analysis of the conversion solution. As a minimum, chemical analysis of the conversion solution should consist of concentration, pH, and temperature evaluations to determine that the bath is within the ranges specified by the chemical manufacturer. It should be noted that many conversion materials do not react sufficiently with aluminum surfaces at low temperatures Conversion coating parts in an unheated facility (ie. a hangar) during colder periods of the year would not be recommended

6 10 Paint adhesion Coated parts should be allowed to dry in accordance with the chemical manufacturer's recommendation before they are subsequently painted or adhesion failures may occur. When coated parts are stored for extensive periods before painting, they should be cleaned in accordance with 3 2 to reactivate the surface by removing dust particles Excessively thick coatings may result in paint adhesion problems (blistering) due to higher amounts of soluble material under the paint

* 6.10 1 Paint compatibility. Compatibility problems between conversion coatings and certain Chemical Agent Resistant Coatings (CARC) have been reported.

6.11 Temperature effects on corrosion protection Unpainted conversion coatings will commence losing corrosion resistance properties if exposed to temperatures of 60°C(140°F) or above, during drying, subsequent fabrication, or service In general, as temperature and exposure times increase, the corrosion protection of unpainted conversion coated parts decreases The reduction is believed to result from the coating dehydrating and the resulting insolubility of the chromates within the coating

* 6 12 Changes from previous issue. The margins of this specification are marked with asterisks to indicate where significant 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

6 13 Subject term (key word) listing.

Aluminum
Aluminum Alloys
Chemical Conversion Coatings
Chromate Conversion Coatings

Custodians:
Army - MR
Navy - AS
Air Force - 11

Review activities.
Army - MI, AR, ER, AV
Navy - OS, SH
Air Force - 99

User activities.
Army - AT, ME
Navy- YD
Air Force - 80

Preparing activity:
Navy - AS
(Project No. MFFP-0466)

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INSTRUCTIONS

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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER	2. DOCUMENT DATE (YYMMDD)
	MIL-C-5541E	30 Nov 90

3. DOCUMENT TITLE
Chemical Conversion Coatings on Aluminum and Aluminum Alloys

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

a. NAME	b. TELEPHONE (Include Area Code)	
Commanding Officer NAEC, SESD Code 53	(1) Commercial (908) 323-7481	(2) AUTOVON
c. ADDRESS (Include Zip Code) Lakehurst, NJ 08733-5100	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340	

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