Engineering and Technical Services for Joint Group on Acquisition Pollution Prevention (JG-APP) Pilot Projects

Joint Test Protocol HM-P-1-1

For the Validation of Alternatives to Chrome Conversion Coatings for Aluminum Alloys 2024, 6061, 7075, and Ion Vapor Deposited Aluminum on Steel

May 21, 1996

Contract Number DAAA21-93-C-0046
Task No. N.072
CDRL No. A005

Prepared by
National Defense Center for Environmental Excellence (NDCEE)
Operated by Concurrent Technologies Corporation

Engineering and Technical Services for Joint Group on Acquisition Pollution Prevention (JG-APP) Pilot Projects

Joint Test Protocol
HM-P-1-1

For the Validation of Alternatives to Chrome Conversion Coatings for Aluminum Alloys 2024, 6061, 7075, and Ion Vapor Deposited Aluminum on Steel

May 21, 1996

Contract Number DAAA21-93-C-0046
Task No. N.072
CDRL No. A005

Prepared by:

National Defense Center for Environmental Excellence (NDCEE)
operated by Concurrent Technologies Corporation (*CTC*)
1450 Scalp Avenue
Johnstown, PA 15904

PREFACE

This report was prepared by Concurrent Technologies Corporation (*CTC*) through the National Defense Center for Environmental Excellence (NDCEE) under Contract Number DAAA21-93-C-0046. This report was prepared on behalf of, and under guidance provided by the Joint Group on Acquisition Pollution Prevention (JG-APP) through the Joint Pollution Prevention Advisory Board (JPPAB). The structure, format, and depth of technical content of the report was determined by the JPPAB, Government contractors, and other Government technical representatives.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

On 15 September 1994, the Joint Logistics Commanders (JLCs) chartered the Joint Group on Acquisition Pollution Prevention (JG-APP) to coordinate joint service activities affecting pollution prevention issues identified during a weapon system's acquisition process. The primary objectives of the JG-APP are:

- Reduce or eliminate Hazardous Materials (HazMats) by fostering joint service cooperation
- Avoid duplication of efforts in actions required to reduce or eliminate HazMats and share technology.

The focus of the JG-APP is on contractor design, manufacturing, and remanufacturing locations with technology transfer to the sustainment community.

Hughes Missile Systems Company (HMSC), located in Tucson, Arizona, is one of the pilot sites. Technical meetings have taken place between JG-APP, HMSC, Defense Contract Management Command (DCMC), affected program managers, and other technical representatives that have led to the preparation of this Joint Test Protocol (JTP).

The purpose of the JTP is to document the requirements and critical tests necessary to qualify potential alternatives to a HazMat and process. A Joint Test Report (JTR) will document the data and results of the testing to minimize duplication of effort.

At HMSC, eliminating chrome in chemical conversion coatings is the process to change. There are three applications for chemical conversion coatings; increase corrosion resistance, improve paint adhesion, and increase corrosion resistance while minimizing electrical resistance. Table 1 summarizes the target HazMats, process and material, applications, specifications, and the affected programs.

Table 1. Target HazMat Summary

Target HazMats	Process/ Material	Application	Current Specification	Affected Programs	Candidate Substrates
Chrome - 7850 lb/yr	Chemical Conversion Coatings	Corrosion Resistance	MIL-C-5541 MIL-C-81706	Navy: Std Missile, Phalanx, RAM, Tomahawk Air Force: ACM, AMRAAM Army: TOW, Stinger	2024, 6061, 7075 Aluminum alloys, and Ion Vapor Deposition of Aluminum on Steel
		Paint Adhesion	MIL-C-5541 MIL-C-81706	Navy: Std Missile, Phalanx, RAM, Tomahawk Air Force: ACM, AMRAAM Army: TOW, Stinger	2024, 6061, 7075 Aluminum alloys, and Ion Vapor Deposition of Aluminum on Steel
		Electrical Resistance	MIL-C-5541 MIL-C-81706	Navy: Std Missile, Phalanx, RAM, Tomahawk Air Force: ACM, AMRAAM Army: TOW, Stinger	2024, 6061, 7075 Aluminum alloys, and Ion Vapor Deposition of Aluminum on Steel

2. TESTING REQUIREMENTS

All potential alternatives must meet the following performance requirements in order to qualify as valid replacements for chrome in chemical conversion coatings on aluminum and aluminum alloys. This test protocol covers the requirements for three groups of chemical conversion coatings. Each group provides a critical coating characteristic desired in system designs. The three groups of coatings follow:

Group 1 – Unpainted surfaces requiring maximum corrosion resistance
Group 2 – Painted surfaces requiring maximum paint to substrate adhesion
Group 3 – Unpainted surfaces requiring lower electrical resistance.

A joint group consisting of technical representatives from JG-APP, the affected program managers, representatives of the Sustainment Community, and other government technical representatives identified application, performance, and operational impact (supportability) requirements. This group then identified and defined critical tests with descriptions, methodologies, and acceptance criteria to qualify the alternatives against these requirements.

Tables 2, 3, and 4 contain the requirement and test matrices for chemical conversion coatings. These matrices summarize each requirement, test, and pass/fail criteria. Chemical conversion coatings covered in this test protocol only pertain to aluminum, aluminum alloys, and aluminum coated substrate materials.

Tests will be conducted in a manner that will eliminate duplication and maximize use of each test coupon. For example, where possible, more than one test will be performed on each panel. The amount of tests and type that can be run on any one panel will be determined by the destructiveness of the test.

2.1. Group 1 Coating Application

2.1.1. Group 1 Coating Application Requirement and Test Matrix

Group 1 chemical conversion coatings prevent corrosion on parts that do not require painting for end use. The following identified tests verify acceptable performance of chemical conversion coatings as Group 1 coatings.

Table 2. Common Test Requirements for Maximum Corrosion Resistance

Requirement	JTP Section	Test	Pass/Fail Criteria
General	3.1.1 3.1.2	Appearance Reparability/ Compatibility	Uniform, continuous, free of powder Same as Wet Tape and Salt Spray
Corrosion Resistance	3.1.3	Salt Spray	a. No spots or pits over 0.031 in. in diameter; b. No more than 3 spots/pits on any one specimen; c. No more than 6 spots/pits on combined surface of all specimens
	3.1.4	Heat Degradation	Same as Salt Spray
	3.1.5	Stress Corrosion	No cracking or breaking of specimen

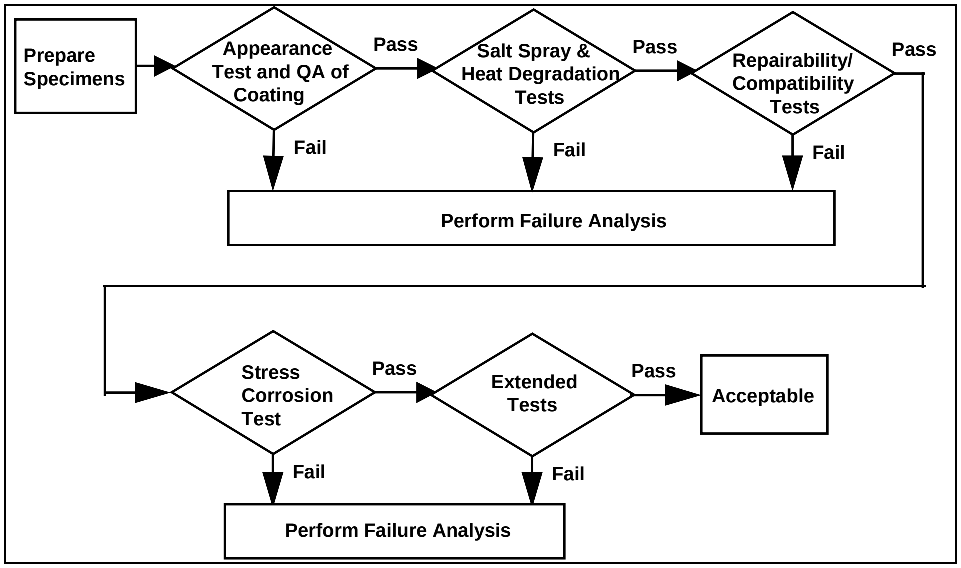
Table 2A. Extended Test Requirements for Maximum Corrosion Resistance

Requirement	JTP Section	Test	Pass/Fail Criteria
Corrosion Resistance	3.1.6	Electrochemical Measurement	N/A
Fuels Resistance	3.1.7	Fuels Resistance	No coating defects

2.1.2. Group 1 Coating Application Test Flow Diagram

The relationships between the groups of tests identified in the Group 1 Coating Application Requirement and Test Matrix is detailed on the following page in Figure 1.

Figure 1. Group 1 Application Test Flow Diagram



2.2. Group 2 Coating Application

2.2.1. Group 2 Coating Application Requirement and Test Matrix

Group 2 chemical conversion coatings increase adhesion on parts requiring paint or primer for end use that normally exhibit poor adhesion on the bare substrate. The following tests verify acceptable performance of chemical conversion coatings as Group 2 coatings.

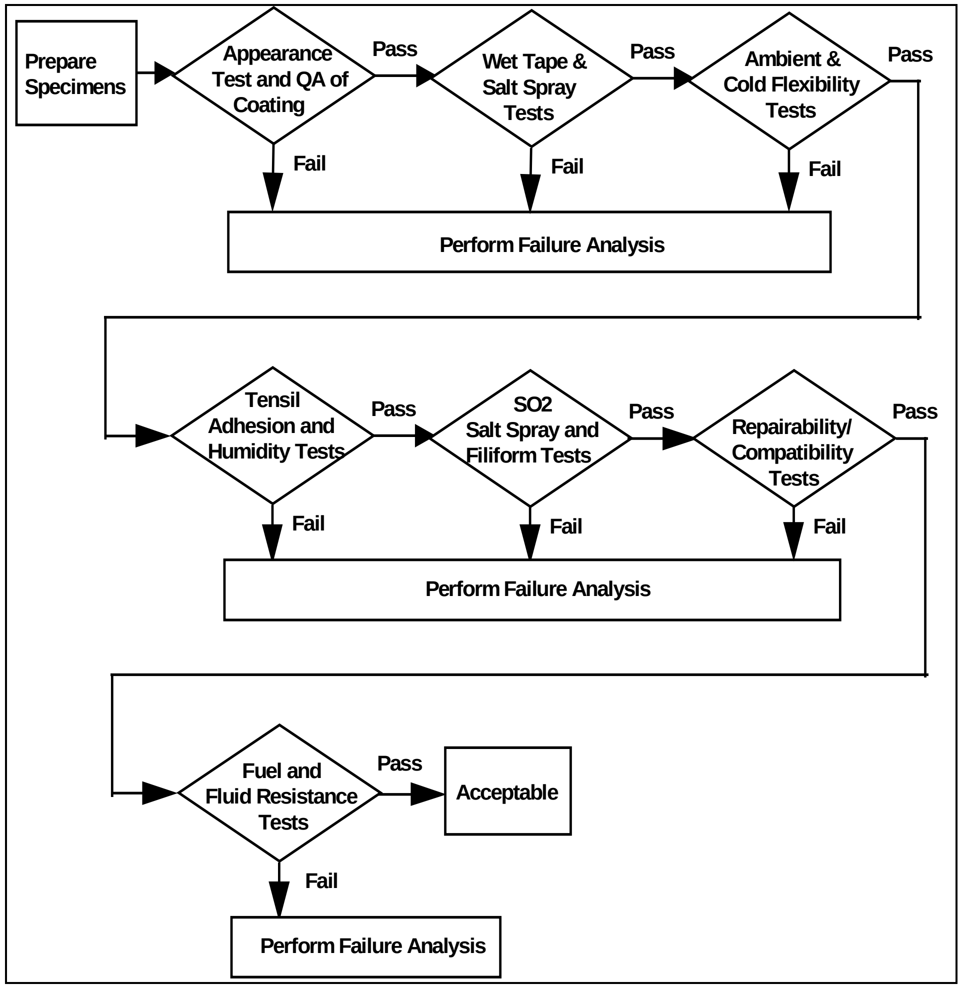
Table 3. Common Test Requirements for Maximum Paint Adhesion

Requirement	JTP Section	Test	Pass/Fail Criteria
General	3.2.1	Reparability/ Compatibility	Same as Wet Tape and Salt Spray
	3.2.2	Humidity Resistance	No blistering, dark stains, softening, or loss of adhesion
Adhesion	3.2.3	Wet Tape Adhesion	No loss of adhesion
	3.2.4	Adhesion, Tensile	N/A
	3.2.5	Flexibility	No cracks at indenters corresponding to 10% for ambient impact; No cracks at 2 inch diameter for low temperature
Corrosion Resistance	3.2.6	Salt Spray	No blistering or lifting of coating No excessive substrate corrosion
	3.2.7	SO_2/Salt	No blistering or lifting of coating No excessive substrate corrosion
	3.2.8	Filiform	No filaments greater than 1/4 inch Majority of filaments less than 1/8 inch
Fluids Resistance	3.2.9	Fluid Resistance	No blisters, dark stains or softening
	3.2.10	Fuels Resistance	No blisters, dark stains or softening

2.2.2. Group 2 Coating Application Test Flow Diagram

The relationships between the groups of tests identified in the Group 2 Coating Application Requirement and Test Matrix is detailed on the following page in Figure 2.

Figure 2. Group 2 Application Test Flow Diagram



2.3. Group 3 Coating Application

2.3.1. Group 3 Coating Application Requirement and Test Matrix

Group 3 chemical conversion coatings prevent corrosion in electrical and electronic applications requiring lower electrical resistance and do not require painting for end use. Group 3 coatings differ from Group 1 coatings in that they are generally thinner and therefore have less resistance to corrosion, but they also have less electrical resistance. The following identified tests verify acceptable performance of chemical conversion coatings as Group 3 coatings.

Table 4. Common Test Requirements for Lower Electrical Resistance

Requirement	JTP Section	Test	Pass/Fail Criteria
General	3.3.1	Appearance	Uniform, continuous, free of powder
	3.3.2	Reparability/ Compatibility	Same as Wet Tape and Salt Spray
Corrosion Resistance	3.3.3	Salt Spray	a. No spots or pits over 0.031 in. in diameter; b. No more than 3 spots/pits on any one specimen; c. No more than 6 spots/pits on combined surface of all specimens
	3.3.4	Heat Degradation	Same as Salt Spray
	3.3.5	Stress Corrosion	No cracking or breaking of specimen
Electrical Resistance	3.3.8	Contact Electrical Resistance	5,000 micro-ohms - 3 sigma std deviation prior to salt spray 10,000 micro-ohms - 3 sigma std deviation after salt spray

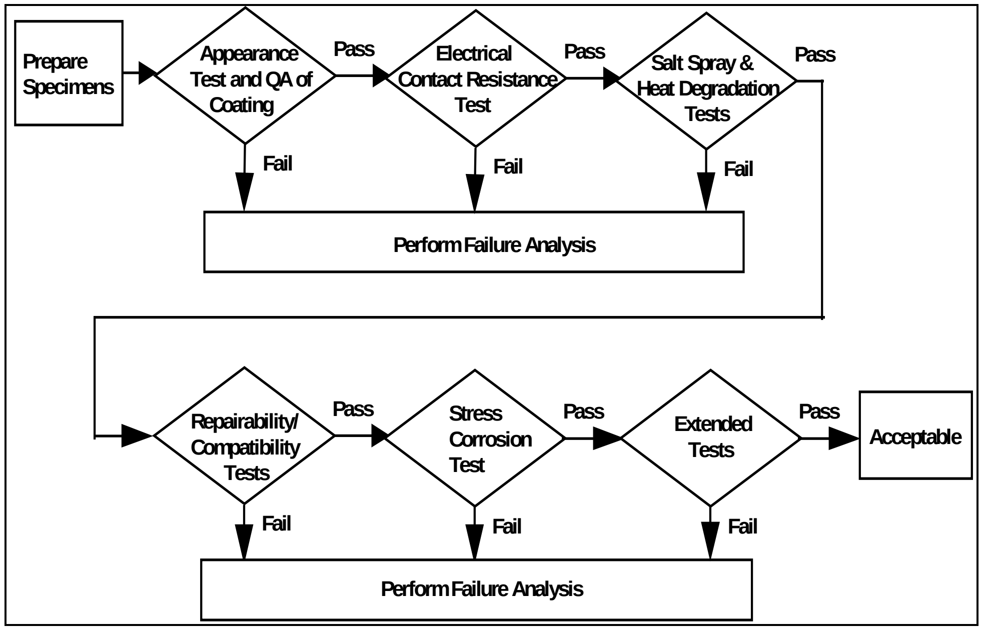
Table 4A. Extended Test Requirements for Lower Electrical Resistance

Requirement	JTP Section	Test	Pass/Fail Criteria
Corrosion Resistance	3.3.6	Electrochemical Measurement	N/A
Fuels Resistance	3.3.7	Fuels Resistance	No coating defects

2.3.2. Group 3 Coating Application Test Flow Diagram

The relationships between the groups of tests identified in the Group 3 Coating Application Requirement and Test Matrix is detailed on the following page in Figure 3.

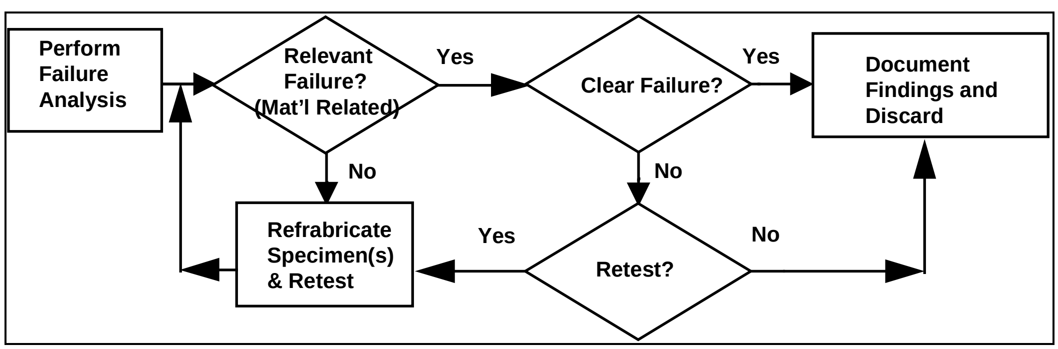
Figure 3. Group 3 Application Test Flow Diagram



2.4. Failure Analysis

When conducting the tests identified in this JTP, it is important to analyze any specimen that failed testing to determine the cause. Marginal test results must be either overcome by retesting or documented before discarding the "alternative".

Figure 4. Failure Analysis Flow Diagram



3. TEST DESCRIPTIONS

The tests described in this section include explanations of unique methodologies, equipment, instrumentation, and data analysis. Test methodologies include the types of samples, the number of test runs, testing parameters and conditions, and acceptance criteria.

The substrate types that will be used for these procedures are aluminum alloy 2024, aluminum alloy 6061, aluminum alloy 7075, and ion vapor deposition of aluminum on steel. Tests are to be performed, except when otherwise cited below, on test specimens 3 ± 0.25 inches wide by 6 ± 0.25 inches long and made with the same material, temper treatment, and surface finish used in the actual part production. Material thickness should represent the material thickness used in production, but is typically no less than 0.020 inches. Specimens should be processed using production run procedures to include all pre- and post-treatment steps such as cleaning, rinsing, and painting, if applicable. Testing requires completely dried or cured coatings before beginning. Age all specimens appropriately before beginning tests.

There are two types of control specimens that should be utilized during testing. The first are specimens prepared using the conversion coating process being replaced, and is used in all the tests for comparison purposes. The second type of control specimens are those generated from each batch of test panels to confirm consistency between batches. This type of control may not need to be used if all test specimen are prepared at one time.

Repair techniques are essential for the successful implementation of an alternative conversion coating. Repairs are characteristically less than five percent of the part surface area. Compatibility of the touch-up coating with the existing coating is essential.

3.1. Unpainted Surfaces Requiring Maximum Corrosion Resistance

Group 1 chemical conversion coatings prevent corrosion on parts that do not require painting for end use. The following defined tests verify acceptable performance of chemical conversion coatings as Group 1 coatings.

3.1.1. Appearance Test

Test Description

The conversion coating shall be as uniform in appearance as practical. Evaluate conversion coatings by observing color, uniformity of appearance, and smoothness. The coating shall be continuous and free from areas which will reduce the serviceability of parts or the protective characteristics of the coating, Using the coating manufacturer’s guidance, acceptable color levels for a particular coating system can be developed utilizing color chips. If a clear coating is used, 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. A drop of chemical solution that when in contact with the basis metal results in the spot test solution changing color may be used to determine the presence of a protective colorless film.

Test Methodology

Parameters	Coated part
Type and Number of Panels	All/All
Trials Per Panel	1
Acceptance Criteria	Uniform, continuous, free of powder

3.1.2. Repairability/Compatibility Test

Test Description

This test determines whether a repair process or technique can provide minimal adhesion and corrosion resistance characteristics. It also determines that two coating types are compatible when used together. Prepare test specimen by coating two-thirds of the standard 3 inches by 6 inches panel (i.e. 3 inches by 4 inches) with the basic conversion coating. Then using the repair process or technique, coat the opposite two-thirds of the panel such that one-third of the panel has only the base coating, one-third has only the touch-up coating, and one-third has the touch-up coating on top of the base coating. Perform the wet tape test (see Section 3.2.3.) without a scribe, and then the salt spray test (see Section 3.1.3.). The wet tape and salt spray test acceptance criteria apply.

Test Methodology

Parameters	24 hours in distilled water and 336 hours 5% salt spray
Type and Number of Panels	All/3
Trials Per Panel	1
Acceptance Criteria	Same as Wet Tape and Salt Spray

3.1.3. Salt Spray Test

Test Description

Use this test to determine coating resistance to corrosion over a specified time in a controlled corrosive environment. Test specimens are placed in the salt spray chamber at a 15° to 30° angle from the vertical. Specimen are placed to permit free settling of fog on all specimens, but preventing salt solution from one specimen from dripping on any other specimen. The salt solution is verified to be 5% ± 1% by weight, with a pH between 6.5 to 7.2, and a temperature of 35+1.1 -1.7° C (95+2 -3° F). No scribe required. Expose specimens for 336 hours ± 30 minutes. After exposure, the specimens are cleaned in running water, not warmer than 38° C and blown dry with clean, dry, unheated air. The specimens are evaluated for surface corrosion spots or pits on a daily basis and at the end of the test period. Areas within 0.25 inches from edges, identification marks, and holding points during processing or salt spray exposure are excluded from inspection.

Test Methodology

Parameters	5% salt solution/336 hours
Type and Number of Panels	All/3
Trials Per Panel	1
Acceptance Criteria	a. No spots or pits over 0.031 inches in diameter b. No more than 3 spots/pits on any one specimen c. No more than 6 spots/pits on combined surface of all specimens

3.1.4. Heat Degradation Test

Test Description

Use this test to determine the affect of high temperatures on the corrosion resistance of chemical conversion coatings. Bake specimen at each of three temperatures, and at not less than 65 ± 5° C (150 ± 10° F) for 3 hours ± 10 minutes, 93 ± 5° C (200 ± 10° F) for 3 hours ± 10 minutes, and 163 ± 5° C (325 ± 10° F) for 30 minutes ± 2 minutes discounting time to ramp to temperature. Expose the specimens to salt spray testing according to Section 3.1.3 above. The salt spray test failure criteria apply.

Test Methodology

Parameters	150° ± 10° F for 3 hours, 200° ± 10° F for 3 hours, and 325° ± 10° F for 30 minutes
Type and Number of Panels	All/3
Trials Per Panel	1
Acceptance Criteria	Same as Salt Spray

3.1.5. Stress Corrosion Test

Test Description

This test determines susceptibility of 2XXX and 7XXX aluminum alloys to stress-corrosion cracking. Prepare tension specimen with the reduced section 0.125 ± 0.001 inches in diameter. The test shall be performed in the short-transverse direction. The intention is to orient the specimen so that the applied tensile stress is perpendicular to the metal flow lines and in the short-transverse direction relative to the grain structure. Stress tension specimens in "constant strain"-type fixtures. Specimen shall be exposed to the alternate 10-minute immersion – 50-minute drying cycle (± 1 minute) in 3.5 ± 0.1% NaCl solution. The test duration shall be 10 days ± one hour for 2XXX alloys or 20 days ± one hour for 7XXX alloys, unless cracking occurs sooner. Stress specimens to one or more levels as required to determine comparative stress corrosion resistance. The application of a stress less than about 103 Mpa (15 ksi) is not practicable. Visually inspect specimen each working day for evidence of cracking using low magnifications. Perform final examination at a magnification of at least 10X on all surviving specimen after cleaning them in concentrated (70 ± 1%) nitric acid (HNO_3) at room temperature followed by a water rinse. It may be necessary to section and metallographically examine fractured or cracked tension specimens to verify that stress corrosion cracking was the cause of failure. A specimen fails testing if it fractures or exhibits cracking.

Test Methodology

Parameters	Constant strain-load, 3.5% Salt Solution
Type and Number of Panels	2024-T3 and 7075-T6 / 3
Trials Per Panel	1
Acceptance Criteria	No cracking or breaking of specimen

Unique Equipment and Instrumentation

Stressing frame producing constant strain.

Data Analysis

Daily and end of test inspection results documented. Include metallographic examination result if performed.

3.1.6. Electrochemical Measurement Test

Test Description

This test simulates the actual corrosion process, and determines the corrosion resistance characteristics of coating systems and materials. Using electrode potential of a specimen as an anode in an electrolyte bath, uniform corrosion rates can be determined. The test solution shall consist of 58.5 ± 0.1 g of NaCl 19 ± 1 ml of 30% hydrogen peroxide reagent per 1 L of aqueous solution. (This solution is 1 M with respect to the concentration of sodium chloride.) The temperature of the test solution shall be maintained at 25 ± 2° C (77 ± 1° C). The test specimen and reference electrode are immersed in the appropriate quantity of test solution. The test specimens are connected to the positive terminal of the equipment for measuring potential, and the reference electrode is connected to the negative terminal. Mask all areas of the specimen that are not to be exposed. The potential of each specimen shall be measured at 5-minute intervals for a period of 1 hour or recorded continuously using the output of a high-impedance voltmeter. Record the measurements with an indication of whether they represent individual values or averages. If averages, include the number of values and the standard deviation. Convert the electrochemical measurements to uniform corrosion rates and compare to the salt spray test results.

Test Methodology

Parameters	NaCl and Hydrogen peroxide solution at 25° C
Type and Number of Panels	All/3
Trials Per Panel	1
Acceptance Criteria	N/A

Unique Equipment and Instrumentation

Electrolysis Test Cell.

Data Analysis

Report corrosion resistance rating and compare to salt fog test results.

3.1.7. Fuels Resistance Test

Test Description

This test determines the conversion coating resistance to certain fuels. Immerse test specimen into each of the fuels listed below. Immediately examine for coating defects after test completion. Tests are conducted for 14 days ± 2 hours.

Test Methodology

	JP8+100	**JP10**	**RJ4**
Parameters	14 days immersion, 140 ± 10° F	14 days immersion, 140 ± 10° F	14 days immersion, 140 ± 10° F
Type and Number of Panels	All/3	All/3	All/3
Trials Per Panel	1	1	1
Acceptance Criteria	No coating defects	No coating defects	No coating defects

3.2. Painted Surfaces Requiring Maximum Paint to Substrate Adhesion

Group 2 chemical conversion coatings increase paint adhesion on parts requiring paint or primer for end use that normally exhibit poor adhesion on the bare metal. The following defined tests verify acceptable performance of chemical conversion coatings as Group 2 coatings. Test panels shall be primed and painted using the same application and cure processes as are used in the production of the actual weapon system hardware. If forced drying of organic coatings is permitted, these test panels shall be prepared using forced drying in accordance with weapon system manufacturing process documentation. Color and gloss changes, if any, will be noted by visual inspection and recorded.

3.2.1. Repairability/Compatibility Test

Test Description

This test determines whether a repair process or technique can provide minimal adhesion and corrosion resistance characteristics. It also determines that two coating types are compatible when used together. Prepare test specimen by coating two-thirds of the standard 3 inches by 6 inches panel (i.e. 3 inches by 4 inches) with the basic conversion coating. Then using the repair process or technique, coat the opposite two-thirds of the panel such that one-third of the panel has only the base coating, one-third has only the touch-up coating, and one-third has the touch-up coating on top of the base coating. Perform the wet tape test (see Section 3.2.3.), and then the salt spray test (see Section 3.2.3.). The wet tape and salt spray test acceptance criteria apply.

Test Methodology

Parameters	24 hours in distilled water and 336 hours 5% salt spray
Type and Number of Panels	All/3
Trials Per Panels	1
Acceptance Criteria	Same as Wet Tape and Salt Spray

3.2.2. Humidity Resistance Test

Test Description

This test method covers the procedure for exposing organically coated films to a moisture-saturated atmosphere at a controlled temperature and with a continuous condensation on the test film. Coated specimens are placed at approximately 15° angle from vertical in an enclosed chamber at 100 ± 1% relative humidity and 49 ± 2° C (120 ± 3° F). Droplets of condensation should be visible on the specimens at all times. Test duration is 30 days ± 2 hours. At the end of the exposure period, the panels are wiped dry and rated for changes in color, blistering, softening, or loss of adhesion. The panels are rated from 5 to 10 minutes after being out of the chamber. The panels may also be rated again after 24 hours.

Test Methodology

Parameters	30 days, 100% humidity, 120° F
Type and Number of Panels	All/3
Trials Per Panel	1
Acceptance Criteria	No blistering, dark stains, softening, or loss of adhesion

Unique Equipment and Instrumentation

Humidity Chamber.

3.2.3. Wet Tape Adhesion Test

Test Description

This test method establishes acceptability of inter-coat and surface adhesion of an organic coating immersed in distilled water by applying pressure sensitive tape over a scribed area of the coating. A lattice is scribed into the specimen so that the six cuts are 2 mm apart, making sure the coating has been scribed all the way to the substrate. All cuts are about 3/4 inch (20 mm) long. The scribed specimen is soaked in distilled water. Dry the specimen with a soft cloth. A piece of pressure sensitive tape is placed over the incision and smoothed out. The tape is then removed rapidly at approximately 180° angle. The incision area is inspected for loss of adhesion.

Test Methodology

Parameters	24 hours at room temperature
Type and Number of Panels	All/3
Trials Per Panel	1
Acceptance Criteria	No loss of adhesion

3.2.4. Flat-Wise Tensile Test

Test Description

This test measures coating adhesion. The loading fixture of a Flat-wise Tensile Adhesion Tester is secured to the surface of a coated panel with adhesive. A perpendicular tensile force is then increased on the loading fixture until a patch of coating material is detached (failure). The nature of the failure is then qualified and recorded by the percent of adhesive and cohesive failures, the layers and interfaces involved, and the maximum tensile load.

Test Methodology

Parameters	Coated specimen
Type and Number of Panels	All/3
Trials Per Panel	3
Acceptance Criteria	N/A

Unique Equipment and Instrumentation

Flat-wise Tensile Adhesion Tester.

Data Analysis

Report flat-wise tensile strength and time of occurrence.

3.2.5. Flexibility Tests (Ambient Impact, Low Temperature)

Test Description

AMBIENT IMPACT:

This test method covers the procedure for rapidly deforming a coating and its substrate at ambient conditions (75 ± 10° F and 50 ± 1% humidity) by the impact of weighted spheres. A panel coated with conversion coating and primer (but no topcoat) is placed coated side down (reverse) in the testing apparatus. A 3.6 ± 0.1 pound weight with specified diameter indenters is dropped from a measured height. The panel is then inspected for cracks where the impact occurred using a 10X magnification.

LOW TEMPERATURE:

Low temperature (-54 ± 3° C (-65 ± 5° F)) flexibility is determined by use of a conical mandrel. A panel coated with conversion coating and primer (but no topcoat) is placed, coated side away, over a conical mandrel and bent. The panel is then inspected for cracks using a 10X magnification. Measure the distance from the farthest end of the crack to the small end of the mandrel. Acceptance criteria is no cracking at the specified diameter.

Test Methodology

	Impact	Low Temperature
Parameters	At 75 ± 10° F, 50% humidity	At -65 ± 5° F
Type and Number of Panels	All/3	All/3
Trials Per Panel	1	1
Acceptance Criteria	No cracks at indenters corresponding to 10%	No cracks at 2 inch diameter

Unique Equipment and Instrumentation

- Paul N. Gardner Impact Tester or equivalent
- Conical Mandrel Test Apparatus.

Data Analysis

For ambient impact test, report height from which weighted ball is dropped and minimum percent elongation corresponding to largest diameter indenter at which no cracking occurs. For low temperature test, report mandrel dimensions and distance from small end of mandrel to the farthest end of any crack. Compute percent elongation. If coating system marginally passes flexibility tests, then concerns about meeting system thermal cycling requirements will need to be addressed.

3.2.6. Salt Spray Test

Test Description

This test determines coating resistance to corrosion over a specified time in a controlled corrosive environment. Coated test specimens are scribed with an "X" and suspended in a salt spray chamber at an angle of 15° to 30° from the vertical. Specimen are placed to permit free settling of fog on all specimens, but preventing salt solution from one specimen from dripping on any other specimen. The salt solution is verified to be 5% ± 1% NaCl by weight, with a pH between 6.5 and 7.2, and a temperature of 35+1.1 – 1.7° C (95+2 -3° F). The salt spray chamber is then closed and the specimens are exposed to an atomized salt spray environment for 2,016 ± 2 hours. After exposure, the specimens are cleaned in running water, not warmer than 38° C and blown dry with clean, dry, unheated air. The specimens are evaluated for surface corrosion spots or pits and extensive corrosion in the scribe. Areas within 0.25 inches from edges, identification marks, and holding points during processing or salt spray exposure are excluded from inspection.

Test Methodology

Parameters	15° – 30° angle in 5% salt solution at 6.5 – 7.2 pH/ 2,016 hours
Type and Number of Panels	All/3
Trials Per Panel	1
Acceptance Criteria	No blistering or lifting of coating No excessive substrate corrosion

Unique Equipment and Instrumentation

Salt Spray (Fog) Test Cabinet.

Data Analysis

Inspect test specimens visually. Record rating of failure.

3.2.7. SO_2/Salt Test

Test Description

Use this test to determine coating resistance to corrosion. A coated panel is scribed with an "x". The panels are placed in the salt spray chamber at a 15° to 30° angle from the vertical. The salt solution is verified to be 5% ± 1%, pH is verified to be 2.5 to 3.2 at 35+1.1 – 1.7° C (95+2 -3° F), and 1 cm^3/min ft^3 of cabinet volume of SO_2. Expose specimens for 504 ± 2 hours and evaluate for surface corrosion and creepage from scribe on a daily basis. Specimens showing any blistering, pitting, lifting of the coating system, or excessive substrate corrosion fail testing. Extensive corrosion in the scribe or extending from the scribe is not allowed. Exclude areas within 0.25 inches from edges, identification marks, and holding points during processing or salt spray exposure.

Test Methodology

Parameters	15° – 30° angle in 5% SO_2 solution at 6.5 – 7.2 pH/ 504 hours
Type and Number of Panels	All/3
Trials Per Panel	1
Acceptance Criteria	No blistering or lifting of coating No excessive substrate corrosion

Unique Equipment and Instrumentation

- Salt Spray (Fog) Testing Chamber
- Equipment and materials required to add SO_2 to Chamber.

Data Analysis

Rating of failure at scribe and rating of unscribed areas.

3.2.8. Filiform Test

Test Description

Coated test panels will be scribed with an "X" so that the substrate is exposed. The panels will then be placed vertically in a desiccator containing 12 N hydrochloric acid for one hour (± 1 minute). The panels will be placed within 5 minutes in a humidity cabinet maintained at 40 ± 1.5° C (104 ± 3° F), and 80% ± 5% humidity for 1,008 ± 2 hours. After exposure, carefully remove coating to examine filiform growth. No filaments should be greater than 1/4 inch.

Test Methodology

Parameters	12 N HCl for 1 hour, 104° F, 80% humidity for 1,008 hours
Type and Number of Panels	All/3
Trials Per Panel	1
Acceptance Criteria	No filaments greater than 1/4 inch Majority of filaments less than 1/8 inch

Unique Equipment and Instrumentation

Humidity cabinet.

Data Analysis

Record filiform corrosion on unscribed area and creepage from scribe.

3.2.9. Fluid Resistance Tests

Test Description

This test method determines the effects of certain fluids on organic finishes resulting in any objectionable alteration in the surface such as discoloration, change in gloss, blistering, softening, swelling, loss of adhesion, or other special conditions. Test panels will be separately immersed for the specified period of time in lubricating oil and in hydraulic fluid. Other fluids may be substituted based on program requirements. Four hours after removal, the panels will be examined for blistering, softening, dark staining, or other film defects. Test duration is 24 hours ± 10 minutes.

Test Methodology

	Hydraulic Fluid	**Lubricating Oil**
Parameters	Immerse 24 hours, 150 ± 5° F	Immerse 24 hours, 250 ± 5° F
Type and Number of Panels	All/3	All/3
Trials Per Panel	1	1
Acceptance Criteria	No blisters, dark stains or softening	No blisters, dark stains or softening

Unique Equipment and Instrumentation

Pencil hardness equipment.

Data Analysis

Visual inspection, hardness before and after will be reported.

3.2.10. Fuel Resistance Test

Test Description

This test method determines the effects of certain fluids on organic finishes resulting in any objectionable alteration in the surface such as discoloration, change in gloss, blistering, softening, swelling, loss of adhesion, or other special conditions. Test panels will be separately immersed in the fluids listed below for seven days. Four hours after removal, the panels will be examined for blistering, softening, dark staining, or other film defects. Test duration is 14 days ± 2 hours.

Test Methodology

	JP8+100	**RJ4**
Parameters	Immerse 14 days, 140 ± 10° F	Immerse 14 days, 140 ± 10° F
Type and Number of Panels	All/3	All/3
Trials Per Panel	1	1
Acceptance Criteria	No blisters, dark stains or softening	No blisters, dark stains or softening

Unique Equipment and Instrumentation

Pencil hardness equipment.

Data Analysis

Visual inspection, hardness before and after will be reported.

3.3. Unpainted Surfaces Requiring Lower Electrical Resistance

Group 3 chemical conversion coatings prevent corrosion in electrical and electronic applications requiring lower electrical resistance and do not require painting for end use. The following defined tests verify acceptable performance of chemical conversion coatings as Class 3 coatings.

3.3.1. Appearance Test

Test Description

The conversion coating shall be as uniform in appearance as practical. Evaluate conversion coatings by observing color, uniformity of appearance, and smoothness. The coating shall be continuous and free from areas which will reduce the serviceability of parts or the protective characteristics of the coating, Using the coating manufacturer's guidance, acceptable color levels for a particular coating system can be developed utilizing color chips. If a clear coating is used, 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. A drop of chemical solution that when in contact with the basis metal results in the spot test solution changing color may be used to determine the presence of a protective colorless film.

Test Methodology

Parameters	Coated part
Type and Number of Panels	All/All
Trials Per Panel	1
Acceptance Criteria	Uniform, continuous, free of powder

3.3.2. Repairability/Compatibility Test

Test Description

This test determines that a repair process or technique can provide minimal adhesion and corrosion resistance characteristics. It also determines that two coating types are compatible when used together. Prepare test specimen by coating two-thirds of the standard 3 inches by 6 inches panel (i.e. 3 inches by 4 inches) with the basic conversion coating. Then using the repair process or technique, coat the opposite two-thirds of the panel such that one-third of the panel has only the base coating, one-third has only the touch-up coating, and one-third has the touch-up coating on top of the base coating. Perform the wet tape test (see Section 3.2.3.) without a scribe, and then the salt spray test (see Section 3.3.3.). The wet tape and salt spray test acceptance criteria apply.

Test Methodology

Parameters	24 hours in distilled water and 168 hours 5% salt spray
Type and Number of Panels	All/3
Trials Per Panels	1
Acceptance Criteria	Same as Wet Tape and Salt Spray

3.3.3. Salt Spray Test

Test Description

Use this test to determine coating resistance to corrosion over a specified time in a controlled corrosive environment. Test specimens are placed in the salt spray chamber at a 15° to 30° angle from the vertical. Specimen are placed to permit free settling of fog on all specimens, but preventing salt solution from one specimen from dripping on any other specimen. The salt solution is verified to be 5% ± 1% by weight, with a pH between 6.5 to 7.2, and a temperature of 35 + 1.1 -1.7° C (95+2 -3° F). No scribe required. Expose specimens for 168 hours ± 30 minutes. After exposure, the specimens are cleaned in running water, not warmer than 38° C and blown dry with clean, dry, unheated air. The specimens are evaluated for surface corrosion spots or pits on a daily basis and at the end of the test period. Areas within 0.25 inches from edges, identification marks, and holding points during processing or salt spray exposure are excluded from inspection.

Test Methodology

Parameters	5% salt solution/168 hours
Type and Number of Panels	All/3
Trials Per Panel	1
Acceptance Criteria	a. No spots or pits over 0.031 inches in diameter b. No more than 3 spots/pits on any one specimen c. No more than 6 spots/pits on combined surface of all specimens

3.3.4. Heat Degradation Test

Test Description

Use this test to determine the affect of high temperatures on the corrosion resistance of chemical conversion coatings. Bake specimen at each of three temperatures, and at not less than 65 ± 5° C (150 ± 10° F) for 3 hours ± 10 minutes, 93 ± 5° C (200 ± 10° F) for 3 hours ± 10 minutes, and 163 ± 5° C (325 ± 10° F) for 30 minutes ± 2 minutes discounting time to ramp to temperature. Expose the specimens to salt spray testing according to Section 3.1.3. above. The salt spray test failure criteria apply.

Test Methodology

Parameters	150° ± 10° F for 3 hours, 200° ± 10° F for 3 hours, and 325° ± 10° F for 30 minutes
Type and Number of Panels	All/3
Trials Per Panel	1
Acceptance Criteria	Same as Salt Spray

3.3.5. Stress Corrosion Test

Test Description

This test determines susceptibility of 2XXX and 7XXX aluminum alloys to stress-corrosion cracking. Prepare tension specimen with the reduced section 0.125 ± 0.001 inches in diameter. The test shall be performed in the short-transverse direction. The intention is to orient the specimen so that the applied tensile stress is perpendicular to the metal flow lines and in the short-transverse direction relative to the grain structure. Stress tension specimens in “constant strain”-type fixtures. Specimen shall be exposed to the alternate 10-minute immersion – 50-minute drying cycle (± 1 minute) in 3.5 ± 0.1% NaCl solution. The test duration shall be 10 days ± one hour for 2XXX alloys or 20 days ± one hour for 7XXX alloys, unless cracking occurs sooner. Stress specimens to one or more levels as required to determine comparative stress corrosion resistance. The application of a stress less than about 103 Mpa (15 ksi) is not practicable. Visually inspect specimen each working day for evidence of cracking using low magnifications. Perform final examination at a magnification of at least 10X on all surviving specimen after cleaning them in concentrated (70 ± 1%) nitric acid (HNO_3) at room temperature followed by a water rinse. It may be necessary to section and metallographically examine fractured or cracked tension specimens to verify that stress corrosion cracking was the cause of failure. A specimen fails testing if it fractures or exhibits cracking.

Test Methodology

Parameters	Constant strain-load, 3.5% Salt Solution
Type and Number of Panels	2024-T3 and 7075-T6/3
Trials Per Panel	1
Acceptance Criteria	No cracking or breaking of specimen

Unique Equipment and Instrumentation

Stressing frame producing constant strain.

Data Analysis

Daily and end of test inspection results documented. Include metallographic examination result if performed.

3.3.6. Electrochemical Measurement Test

Test Description

This test simulates the actual corrosion process, and determines the corrosion resistance characteristics of coating systems and materials. Using electrode potential of a specimen as an anode in an electrolyte bath, uniform corrosion rates can be determined. The test solution shall consist of 58.5 ± 0.1 g of NaCl 19 ± 1 ml of 30% hydrogen peroxide reagent per 1 L of aqueous solution. (This solution is 1 M with respect to the concentration of sodium chloride.) The temperature of the test solution shall be maintained at 25 ± 2° C (77 ± 1° C). The test specimen and reference electrode are immersed in the appropriate quantity of test solution. The test specimens are connected to the positive terminal of the equipment for measuring potential, and the reference electrode is connected to the negative terminal. Mask all areas of the specimen that are not to be exposed. The potential of each specimen shall be measured at 5-minute intervals for a period of 1 hour or recorded continuously using the output of a high-impedance voltmeter. Record the measurements with an indication of whether they represent individual values or averages. If averages, include the number of values and the standard deviation. Convert the electrochemical measurements to uniform corrosion rates and compare to the salt spray test results.

Test Methodology

Parameters	NaCl and Hydrogen peroxide solution at 25° C
Type and Number of Panels	All/3
Trials Per Panel	1
Acceptance Criteria	N/A

Unique Equipment and Instrumentation

Electrolysis Test Cell.

Data Analysis

Report corrosion resistance rating and compare to salt fog test results.

3.3.7. Fuels Resistance Test

Test Description

This test determines the conversion coating resistance to certain fuels. Immerse test specimen into each of the fuels listed below. Immediately examine for coating defects after test completion. Tests are conducted for 14 days ± 2 hours.

Test Methodology

	JP8+100	**JP10**	**RJ4**
Parameters	14 days immersion, 140 ± 10° F	14 days immersion, 140 ± 10° F	14 days immersion, 140 ± 10° F
Type and Number of Panels	All/3	All/3	All/3
Trials Per Panel	1	1	1
Acceptance Criteria	No coating defects	No coating defects	No coating defects

3.3.8. Contact Electrical Resistance Test

Test Description

This test determines the electrical contact resistance of coated materials. Use copper or silver electrodes with the upper electrode one square inch in area and the lower electrode somewhat larger (less than 1 1/2 inch square). Use electrodes sufficiently flat that when applying a load without a specimen, light is not visible between the contacting surfaces. Apply a load of 200 +/- 2 pounds. Zero out the probe electrical resistance with the two electrodes loaded and without a specimen. Make eight measurements on each of three specimens as shown in Figure 5 before and after salt spray exposure. Expose test specimens to salt spray as described in paragraph Section 3.3.3. above. The average of test specimen measurements before salt spray exposure shall not exceed 5,000 microhms with 3 sigma standard deviation less than 1,000 microhms. The average of test specimen measurements after 168 hours of salt spray exposure shall not exceed 10,000 microhms with 3 sigma standard deviation less than 2,000 microhms.

Test Methodology

Parameters	200 +/-2 lbs
Type and Number of Panels	All/3
Trials Per Panel	8
Acceptance Criteria	5,000 microhms with 3 sigma standard deviation prior to salt spray 10,000 microhms with 3 sigma standard deviation after salt spray

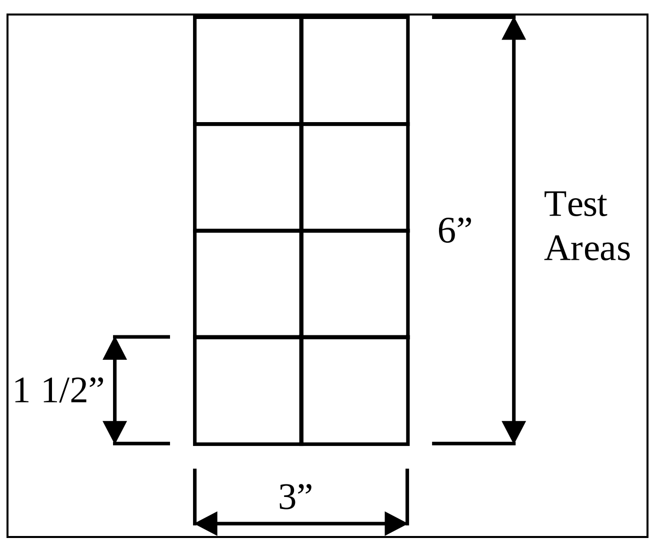
Unique Equipment and Instrumentation

Contact resistance probe with load capability.

Data Analysis

Report all measurements and calculations before and after salt spray.

Figure 5. Positions for Probe Measurements



4. REFERENCE DOCUMENTS

The following documents in Table 5 were referenced in the development of the JTP.

Table 5. Reference Documents

JTP Requirement	JTP Section Cross-Reference	Reference Document	Title	Date	Applicable Section(s) of Reference Document
Wet Tape Test	3.1.2, 3.2.1, 3.2.3 3.3.2	FED-STD-141B	Paint, Varnish, Lacquer & Related Materials, Methods of Inspection, Sampling & Testing	24 Jan 1986	Method 6301.2
Appearance, Salt Spray, Adhesion, Electrical Contact Resistance	3.1.1, 3.1.2, 3.1.3, 3.3.1, 3.3.2, 3.3.3, 3.3.8	MIL-C-5541E	Chemical Conversion Coatings on Aluminum and Aluminum Alloys	30 Nov 1990	All
Adhesion, Flexibility, Filiform, Fluid Resistance, Salt Spray	3.2.3, 3.2.5, 3.2.8, 3.2.9, 3.2.6	MIL-P-23377G	Primer Coatings: Epoxy, High-Solids	30 Sep 1994	All
Fluids Test	3.2.8	MIL-L-23699E	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	23 Nov 1994	All
Appearance, Salt Spray, Adhesion, Electrical Contact Resistance	3.1.1, 3.1.2, 3.1.3, 3.3.1, 3.3.2, 3.3.3, 3.3.8	MIL-C-81706	Chemical Conversion Materials for Coating Aluminum and Aluminum Alloys	13 Nov 1979	All
Fuels Resistance Test	3.1.7, 3.2.10, 3.3.7	MIL-T-83133D	Turbine Fuels, Aviation, Kerosene Types (JP-8)	29 Jan 1992	All
Fluids Resistance Test	3.2.9	MIL-H-83282C	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft	25 Mar 86	All

Table 5. continued next page

Table 6. Reference Documents (continued)

JTP Requirement	JTP Section Cross-Reference	Reference Document	Title	Date	Applicable Section(s) of Reference Document
Adhesion, Ambient Flexibility, Low Temperature Flexibility, Fluid Resistance, Humidity,	3.2.3, 3.2.4, 3.2.5, 3.2.9, 3.2.2	MIL-C-85285B	Coating: Polyurethane, High-Solids	22 Oct 1990	All
Adhesion, Ambient Flexibility, Salt Spray, Filiform, Fluid Resistance	3.2.3, 3.3.4, 3.2.5, 3.2.6, 3.2.8, 3.2.9	MIL-P-85582B	Primer Coatings: Epoxy, Waterborne	31 Aug 1994	All
Salt Spray Test	3.1.2, 3.1.3, 3.2.1, 3.2.6, 3.3.2, 3.3.3	ASTM B-117	Standard Test Method of Salt Spray (Fog) Testing	30 Mar 1990	All
Appearance, Salt Spray, Adhesion	3.1.1, 3.1.2, 3.1.3, 3.3.1, 3.3.2, 3.3.3,	ASTM B 449	Chromate Treatments on Aluminum	29 Dec 1967	All
Low Temperature Flexibility Test	3.2.5	ASTM D-522	Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings	15 Mar 1992	Method A
Scribed Test Panels	3.2.1, 3.2.6	ASTM D-1654	Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments	15 Oct 1992	All
Humidity Test	3.2.2	ASTM D-2247	Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity	15 May 1992	All

Table 5. continued next page

Table 7. Reference Documents (continued)

JTP Requirement	JTP Section Cross-Reference	Reference Document	Title	Date	Applicable Section(s) of Reference Document
Ambient Impact Flexibility Test	3.2.4	ASTM D-2794	Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)	15 Sep 1992	All
Wet Tape Adhesion Test	3.1.2, 3.2.1, 3.2.3, 3.3.2	ASTM D-3359	Standard Test Methods for Measuring Adhesion by Tape Test	15 May 1992	Method A
Adhesion (Tensile) Test	3.2.4	ASTM D-4541	Standard test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers	29 Nov 1985	All
Stress Corrosion Test	3.1.5, 3.3.5	ASTM G-47	Standard Test Method for Determining Susceptibility to Stress-Corrosion Cracking of High-Strength Aluminum Alloy Products	30 Mar 1990	All
Stress Corrosion Test	3.1.5, 3.3.5	ASTM G-49	Preparation and Use of Direct Tension Stress-Corrosion Test Specimens	28 Jun 1985	All
Electro-chemical Measurement	3.1.6, 3.3.6	ASTM G-69	Measurement of Corrosion Potentials of Aluminum Alloys	26 Jun 1981	All

Table 5. continued next page

Table 8. Reference Documents (continued)

JTP Requirement	JTP Section Cross-Reference	Reference Document	Title	Date	Applicable Section(s) of Reference Document
Electro-chemical Measurement	3.1.6, 3.3.6	ASTM G-102	Calculation of Corrosion Rates and Related Information from Electro-chemical Measurements	24 Feb 1989	All
SO_2 Salt Fog	3.2.7	ASTM G-85	Modified Salt Spray (Fog) Testing	3 Jan 1985	All
SO_2 Salt Fog, Humidity	3.2.7, 3.2.2	Sverdrup Technology, Inc. Technical Report: TEAS Ref #9600461-70U	Primer Coatings: Epoxy, High-Solids	5 Mar 1996	All
SO_2 Salt Fog, Humidity	3.2.7, 3.2.2	Sverdrup Technology, Inc., Technical Report	Polyurethane Coatings: Low Volatile Organic Compound (VOC) Content for Aerospace Weapons	5 Mar 1996	All