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

Joint Test Protocol
PW-P-1-1

for Validation of Alternatives to Zinc Chromate Primer for Galvanic Corrosion Protection for Inserts and Fasteners in Aircraft Engines

June 20, 1996
(Revised May 11, 1998)

Contract No. 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

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Submitted by

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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.

THIS REVISED JOINT TEST PROTOCOL (JTP) REFLECTS A CLARIFICATION TO THE EXECUTION OF THE TESTING PROCEDURES DISCUSSED IN THE PREVIOUS VERSION OF THE JTP DATED JUNE 20, 1996. THESE CLARIFICATIONS ARE DISCUSSED BELOW AND ARE HIGHLIGHTED BY THE REVISION MARKS IN THE BORDER OF THE MODIFIED PAGES OF THIS DOCUMENT. NO OTHER CHANGES HAVE BEEN MADE.

JTP Section No.	Original Test Procedure	Modification to Procedure	Rationale
3.2 - Hot Corrosion Test	Expose Aluminum alloys 2024-T3, C355-T6P, 6061-0 and Magnesium alloy AZ31B-0 to 750 ± 5 °F for 8 hours minimum.	Expose Aluminum alloys 2024-T3, C355-T6P, 6061-0 and Magnesium alloy AZ31B-0 to 450 ± 5 °F for 8 hours minimum.	These alloys are not used in engine applications where temperature exceeds 450 °F. The 750 °F temperature is significantly higher than the maximum recommended use temperature for these alloys. At 750 °F, these alloys may even melt.
3.3 & 3.4 - Water Resistance/ Adhesion Test and Fuel/Engine Oil Resistance Test	Use 3 test specimens per primer per alloy and conduct 3 tape tests.	Use 1 test specimen per primer per alloy and conducted 3 tape tests on each specimen.	P&W maximized the use of the test specimen to reduce the total number of panels required without reducing the tape test. It took 4 months and $29K to procure all the panels even after P&W supplied two magnesium blocks to get test panels. More test panels would have adversely impacted cost and schedule on this program. P&W met the key JTP requirement for 3 tape tests per primer per alloy.
3.3 & 3.4 - Water Resistance/ Adhesion Test and Fuel/Engine Oil Resistance Test	Pass/Fail criteria: No peel away of coating from alloy.	Acceptable if peel away is same or less than baseline zinc chromate primer	When the test was conducted, P&W found that even the baseline zinc chromate primer had peel away from alloy. The alternative should be acceptable as long as it performs the same or better than the baseline.
3.6 - Salt Spray Test	Use 3 test specimens per primer per alloy & scribe each panel (total of 3 scribes)	Use 2 test specimens per primer per alloy. Make 2 scribes on one panel and 1 scribe on the other panel for a total of 3 scribes.	P&W maximized the use of the test specimen to reduce total number of panels required without reducing the tape test. It took 4 months & $29K to procure all the panels even after P&W supplied two magnesium blocks to get test panels. More test panels would have impacted cost & schedule on this program. P&W met the key JTP requirement for 3 scribes on two test panels per primer per alloy.
3.6 - Salt Spray Test	Pass/fail Criteria: Acceptable if no sign of white corrosion after 250 hours	Pass/fail Criteria: Acceptable if no sign of white corrosion after 250 hours for aluminum alloys. For magnesium alloy, alternate is acceptable as long as its performance is comparable to zinc chromate primer for 250 hours salt spray exposure of inserts & fasteners.	For acerage repair, P&W uses PWA 36490 Rockhard resin over magnesium alloy. Zinc chromate is used on inserts & fasteners only to provide 250 hrs of salt spray exposure protection. Therefore, alternatives should be compared with the currently used zinc chromate for galvanic corrosion protection of inserts & fasteners. For data collection purpose, P&W evaluated acerage repair with zinc chromate primer & alternatives.
3.7 - Salt Quench with Intermediate Heating Test	Preheating to 300 °F, artificial sea water, closed container for 1 week, immediate heating at 450 °F for 20 hours, and reheating to 300 °F, artificial sea water, closed container for 1 week.	Preheating to 300 °F, artificial sea water, closed container for 1 week, immediate heating at 380-400 °F for 20 hours, and reheating to 300 °F, artificial sea water, closed container for 1 week.	Severe oxidation of zinc chromate primer was observed (primer color changed from dark yellow to dark black) when test panel was heated at 450 °F for 20 hours, indicating thermal degradation of the baseline primer. To prevent thermal degradation, temperature was dropped from 450 °F to 380 °F.

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1.0. 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 (HazMat) 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. This Joint Test Protocol (JTP) contains the critical requirements and tests necessary to qualify potential alternatives to a selected target HazMat and process for a particular application.

A Joint Test Report (JTR) will document the data and results of the testing and will be made available as a reference for future pollution prevention efforts by other DOD and commercial users to minimize duplication of effort.

At the United Technologies Corporation–Pratt & Whitney (UTC-P&W) pilot site, chromium, as contained in a zinc chromate primer, was identified as the target HazMat to be eliminated or reduced. The identified process was manually dipping, spraying, or brushing of the primer onto parts. The identified application that the primer is used for is galvanic corrosion protection for internal aircraft engine components. The substrates protected are primarily aluminum. Table 1 summarizes the target HazMat, process and material, application, current specifications, affected programs, and candidate parts/substrates.

Table 1. Target HazMat Summary

Target HazMat	Current Process	Applications	Current Specifications	Affected Programs	Candidate Parts/ Substrates
Chromium, as contained in zinc chromate primer UTC-P&W: 170 lb/yr (94) SA-ALC: 178 lb/yr (94) NADEP/JAX: 4 gal/yr (94) OC-ALC: 5 lb/yr (95)	Manual dip, spray, or brush coating processes	Galvanic corrosion protection for internal engine components	AMS 3110 TT-P-1757 MIL-P-8585 MIL-P-7962 (used at OC-ALC)	Navy: J52, TF30 Air Force: F119, F100 (100, 200, 220, 220E, 229) NASA: *SSME Army: N/A	J52: Fuel Heater Assy., PN 506313, Aluminum alloy Fuel Control, PN 2188020, Aluminum alloy F100: Gearbox Housing, PN 4044761, Alloy C355.0-T6P (anodized) Lubr. Oil Tank Assy., PN 4043867-706, Alloy 6061-0 (heat treated and anodized) Block Grommet Clamp, PN 4073094, Alloy C355.0-T6P (anodized)

* NASA has a vested interest in the qualification of alternatives to the zinc chromate primer used in galvanic corrosion protection for inserts and fastener applications. However, in NASA's Space Shuttle Main Engine (SSME) project, this particular primer is not an issue. Therefore, while NASA has taken an active role in the technical decisions made in developing the JTP, it will not rely on the selected replacement primer for its SSME project

Baseline usage data for OC-ALC also reported 114 pounds of strontium chromate (MIL-P-23377 Type C) used in 1995 for various engine applications. Successful alternatives to zinc chromate primers should also prove successful for strontium chromate primers.

2.0. TESTING REQUIREMENTS

A joint group led by JG-APP and consisting of technical representatives from UTC-P&W, the affected DOD Program Managers, representatives of the Sustainment Community, and other government technical representatives identified and reached technical consensus on application, performance, and operational impact (supportability) requirements. These requirements were identified for zinc chromate primer for galvanic corrosion protection for internal aircraft engine components. This group then identified and defined critical tests with procedures, methodologies, and pass/fail criteria to qualify alternatives against these technical requirements.

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. Test Requirements

The Test Requirements in Table 2 are for validating alternatives to zinc chromate primer used for galvanic corrosion protection. (Note: the technical representatives determined that fatigue, component, and/or engine testing would not be included in the matrix since they were determined not necessary at this time.)

Table 2. Test Requirements

Requirement	JTP Section Reference and Test	Pass/Fail Criteria
Material Compatibility	3.1 Stress Corrosion Cracking Tests	
	3.1 (a) Titanium Alloy Test	Inspect visually or at low magnification: acceptable if no evidence of cracks or breaks in the interior (away from edge) of any test specimen
	3.1 (b) Aluminum Alloy Test	Inspect visually or at low magnification: acceptable if no evidence of cracks or breaks in the interior (away from edge) of any test specimen

Table 2. Test Requirements (continued)

Requirement	JTP Section Reference and Test	Pass/Fail Criteria
Material Compatibility, Continued	3.2 Hot Corrosion Test	Examine metallographically for intergranular attack, intergranular carbide oxidation, and general corrosion at 500x magnification: acceptable if no evidence of attack exceeding 0.0002 inches
Durability	3.3 Water Resistance/Adhesion Test	Inspect visually: acceptable if no peel away of coating from alloy
	3.4 Fuel/Engine Oil Resistance Test	Inspect visually: acceptable if no deterioration as compared to similar specimen not immersed and if there is no peel away of coating from alloy
Corrosion Resistance	3.5 Electrochemical Evaluation of Galvanic Protection Capability Test	None; documentation of protection and degradation mechanisms based on impedance analysis
	3.6 Salt Spray Tests	
	3.6.1 Adjacent Protection Tests 3.6.1 (a) Sheet Test 3.6.1 (b) Fitted Block Test	Inspect visually: acceptable if no signs of white corrosion
	3.6.2 Reparability Tests 3.6.2 (a) Sheet Test 3.6.2 (b) Fitted Block Test	Inspect visually: acceptable if no signs of white corrosion
	3.7 Salt Quench with Intermediate Heating Test	Inspect visually: acceptable if specimens coated with alternative shows less signs of white corrosion than zinc chromate primer

2.2 Test Flow Diagram

The relationships among the groups of tests identified in the Test Requirements are detailed below in Figure 1.

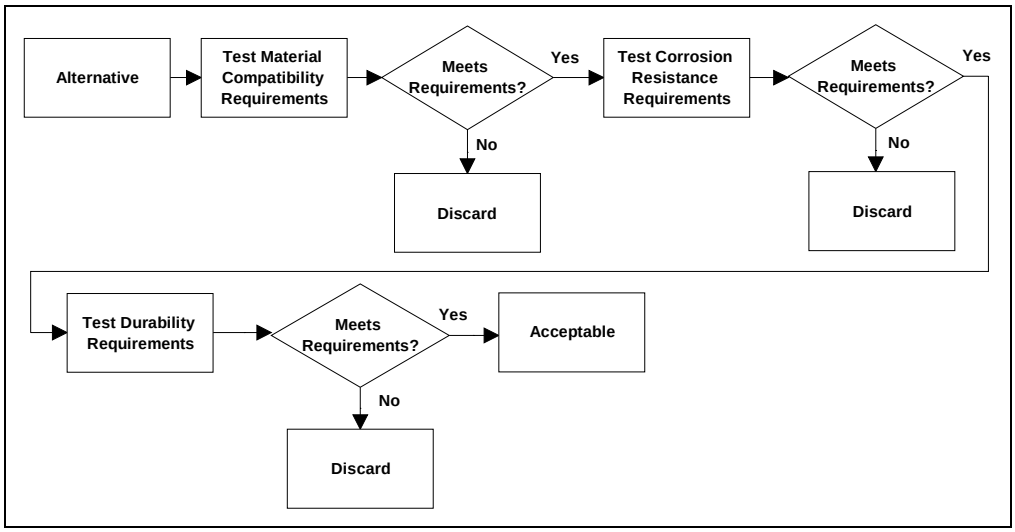

Figure 1. Test Flow Diagram

3.0. TEST DESCRIPTIONS

Tests identified in Table 2 are defined to include test procedures, test methodologies, any unique equipment and instrumentation, and data analysis, as needed. Test methodology includes the definition of test parameters, test specimens/substrates, test trials, and pass/fail criteria. Note: Specific testing and material requirements are referenced in Table 3 of Section 4 of this JTP.

Test specimens shall be coated by alternative materials based on vendor recommended procedures. As a reference for comparison within each test, specimens shall also be coated with zinc chromate primer.

Aluminum alloys C355.0-T6P and 6061-0 shall be mechanically deoxidized prior to testing with 3M Scotch Brite™ brand cleaning pads, product number 7447. The only exception is Section 3.6, where aluminum alloys C355.0-T6P and 6061-0 shall be anodized.

Actual execution of the tests may vary from that described in this JTP. Any deviations will be justified by the technical stakeholders and discussed in the project's JTR. Therefore, users of this document should check the JTR for modifications that may have been necessary in the execution of testing.

3.1. Stress Corrosion Cracking Tests

Test Procedure

3.1 (a) Titanium Alloy Test: Test specimens conforming to specified dimensions will be examined at 10x magnification prior to testing. Specimens exhibiting any significant surface imperfections at this magnification shall not be used. Clean specimens by immersing briefly in technical grade acetone followed by ultrasonic cleaning in reagent grade acetone for at least 15 minutes. After loading specimens by gently bending into specimen holder, gradually apply a stress of 60,000 psi, and apply 50 µl of 3% NaCl solution to the control specimen. Apply the designated alternative or zinc chromate to the test specimens. The solution, designated alternative, or the zinc chromate should be applied at the apex of the bent specimen and should cover approximately one inch of its length. Dry specimens at 180°F to 200°F. A solid residue should remain on the specimens. Place loaded specimen holder into a clean, air-circulating furnace at 900° F for 100 hours. Remove loaded specimen holder from furnace and allow to air cool to room temperature. Visually examine specimens for breaks or gross cracks.

If subtle cracking is not readily visible due to scale or to residual solution remaining after high temperature exposure, treat specimens by abrasive blasting with aluminum oxide grit (320 grit or finer). Prepare a fresh solution of five parts nitric acid, one part hydrofluoric acid, and one part sulfuric acid. Heat solution to 130° F to 150° F. Immerse the specimen in this solution until red fumes are

liberated but for no longer than 30 seconds. Immediately rinse the specimen in running water and air dry. Reexamine treated specimen visually for cracks. If necessary, low magnification (10x) may be used to assist in identification of cracks.

3.1 (b) For Aluminum Alloy Test: Load specimens into a two point or three-point specimen holder. The stress applied shall be 75% of the 0.2% offset yield strength. Inspect specimens visually or at 10x for cracking. Apply the zinc chromate and designated alternative to the convex side and middle area of the respective loaded specimens. The control specimen shall be left free of any material. Place loaded specimens into a clean oven at 425° F for 250 hours. After 250 hours, inspect specimens for cracks by visual observation. If necessary, low 10x magnification may be used to assist in the identification of cracks.

Test Methodology

	3.1 (a) Titanium Test	**3.1 (b) Aluminum Tests**
Parameters	50 µl of 3% NaCl, alternative material, or zinc chromate, applied as required; drying at 180° F to 200° F; heated at 900° F for 100 hours, 60,000 psi stress applied	Applied stress of 75% of the 0.2% offset yield strength; at least 50 µl of alternative material or zinc chromate, applied as required; specimens heated at 425° F for 250 hours
Test Specimens		
Substrates	Titanium alloy 8-1-1, annealed, sheet, strip, and plate	Aluminum alloy 7075-T6; annealed; sheet and plate
Size of each specimen	0.5" x 5.6", 0.050" thick	1" x 7", 0.050" thick
Trials		
Specimens per trial	1 specimen cleaned, 50 µl of 3% NaCl applied, uncoated, as a control 1 specimen cleaned, uncoated, as a control 2 specimens cleaned, coated per designated alternative material 2 specimens cleaned, coated with zinc chromate as a reference	3 specimens uncoated as a control; 3 specimens per designated alloy coated per designated alternative material; 3 specimens per each alloy coated per zinc chromate as a reference
Number of trials	1 trial per alternative	1 trial per alternative
Pass/Fail Criteria	Inspect visually or with low magnification: acceptable if no cracks or breaks in the interior (away from edge) of any test specimen	Inspect visually or with low magnification: acceptable if no cracks or breaks in the interior (away from edge) of any test specimen

Unique Equipment and Instrumentation

For Titanium Test:

- Specimen holder
- Air-circulating furnace capable of maintaining 900° F for 100 hours

For Aluminum Tests:

- Two-point or three-point bend specimen holder; Air-circulating oven capable of maintaining 450° F for 250 hours

Data Analysis

For Titanium Test and Aluminum Tests:

- Visually or low magnification inspect each test, reference, and control specimen. Acceptable if no cracks or breaks in the interior of any test specimen.

3.2. Hot Corrosion Test

Test Procedure

Mark one side of test specimens with the material specification and cleaner identification using a silver pencil or mechanical engraving tool to ensure identification after thermal exposure. Polish the side opposite specimen identification to a finish equivalent to that produced by 600 grit emory cloth. Arrange test and control specimens, polished side up, on a suitable sheet of high temperature alloy or in a container that will withstand test temperatures. Coat the surface of the test specimens with the designated alternative or zinc chromate primer. Leave the control specimens uncoated. Do not allow the designated alternative or zinc chromate primer to contact the control specimens. Dry the test specimens in a low temperature oven or other low heat source such as heat lamps.

Expose the specimens for a minimum of 8 hours and a maximum of 10 hours at the following temperatures:

Alloy	Temperature, °F
Aluminum alloy 2024-T3	750 ± 5
Aluminum alloy C355.0-T6P	750 ± 5
Aluminum alloy 6061-0	750 ± 5
Magnesium alloy AZ31B-0	750 ± 5
Steel alloy 4340	750 ± 5
Steel alloy Greek Ascoloy	1050 ± 5
Nickel alloy Hastelloy X	1600 ± 5
Nickel alloy Waspaloy	1600 ± 5
Cobalt alloy Haynes 188	1600 ± 5

After specimens have cooled, polish and examine metallographically at 500x magnification for intergranular attack, intergranular carbide oxidation, and general corrosion. Compare each test specimen to its respective control specimen.

Test Methodology

Parameters	Thermal exposure at temperatures ranging from 750° F to 1600° F, depending on alloy
Test Specimens	
Substrates	Aluminum alloy 2024-T3; solution and heat treated; sheet and plate Aluminum alloy C355.0-T6P; solution and precipitation heat treated; casting Aluminum alloy 6061-0; annealed; sheet and plate Magnesium alloy AZ31B-0; annealed and recrystallized; sheet and plate Steel alloy 4340; sheet, strip, and plate Steel alloy Greek Ascoloy; annealed; corrosion and heat resistant; sheet, strip, and plate Nickel alloy Hastelloy X; solution heat treated; corrosion and heat resistant; sheet, strip, and plate Nickel alloy Waspaloy; consumable electrode or vacuum induction melted; annealed; corrosion and heat resistant; sheet, strip, and plate Cobalt alloy Haynes 188; solution heat treated; corrosion and heat resistant; sheet, strip, and plate
Size of each specimen	0.5” x 1”, 0.050” thick

Test Methodology (continued)

Trials	
Specimens per trial	1 specimen per alloy, uncoated, as controls 1 specimen per each alloy coated per designated alternative 1 specimen per each alloy coated per zinc chromate as a reference
Number of trials	1 trial, to include all alloys, per each alternative
Pass/Fail Criteria	Examine metallographically for intergranular attack, intergranular carbide oxidation, and general corrosion at 500x magnification: acceptable if no evidence of attack exceeding 0.0002 inches

Unique Equipment and Instrumentation

- Air-circulating furnace capable of maintaining 1,600° F for 10 hours

Data Analysis

- Examine each specimen metallographically for intergranular attack, intergranular carbide oxidation, and general corrosion at 500x magnification. Compare each test specimen to its respective control. Acceptable if no evidence of attack exceeding 0.0002 inches.

3.3. Water Resistance/Adhesion Test

Test Procedure

Test specimens shall be immersed for 4 days in distilled water at 120° F. After four days of immersion, each panel shall be removed from the water and wiped dry with a soft cloth. Immediately thereafter, using a stylus, two parallel scratches, down to metal, shall be made 1 inch apart on the portion of specimen previously immersed. One minute after removal from water, a 1 inch wide strip of masking tape shall be applied, adhesive side down, across the scratches. The tape shall immediately be pressed down, using two passes of a rubber-covered roller weighing 4.5 pounds. Immediately thereafter, the tape shall be removed in one abrupt motion and the panel examined for damage, such as removal of primer from the metal.

Test Methodology

Parameters	Immersion for 4 days at 120° F in distilled water
Test Specimens	
Substrates	Aluminum alloy C355.0-T6P; solution and precipitation heat treated; casting Aluminum alloy 6061-0; annealed; sheet and plate Magnesium alloy WE43A-T6; solution and precipitation heat treated; sand casting
Size of each specimen	3" x 6", 0.050" thick
Trials	
Specimens per trial	3 specimens per each alloy coated per designated alternative 3 specimens per each alloy coated per zinc chromate as reference
Number of trials	1 trial, to include all alloys, per each alternative
Pass/Fail Criteria	Inspect visually: acceptable if no peel away of coating from alloy

Unique Equipment and Instrumentation

- Masking tape, Code No. 250, 3M or equal, 1 inch wide
- 4.5 pound rubber-covered roller, approximately 3.5 inches in diameter by 1.75 inches in width, surface of which has a Shore "A" durometer hardness value within the range of 70 to 80

Data Analysis

- Inspect visually test specimens for damage. Acceptable if there is no peel away of coating from alloy.

3.4. Fuel/Engine Oil Resistance Test

Test Procedure

Test specimens (except for control specimens) shall be totally immersed in JP-5 fuel or synthetic-base aircraft turbine engine lubricating oil for four hours. The coating shall show no deterioration when compared with a control specimen not immersed in fuel or oil, 24 hours after removal from the fuel or oil.

After visual inspection, specimens shall be cleaned with an alkaline cleaner, rinsed in clean, distilled water, and wiped dry with a soft cloth. Immediately thereafter, using a stylus, two parallel scratches, down to metal, shall be made 1 inch apart on the portion of specimen previously immersed. One minute after removal from water, a 1 inch wide strip of masking tape shall be applied, adhesive side down, across the scratches. The tape shall immediately be pressed down, using two passes of a rubber-covered roller weighing 4.5 pounds. Immediately

thereafter, the tape shall be removed in one abrupt motion and the panel examined for damage, such as removal of primer from the metal.

Test Methodology

Parameters	Total immersion, 4 hours, room temperature JP-5 fuel Synthetic-base aircraft turbine engine lubrication oil
Test Specimens	
Substrates	Aluminum alloy C355.0-T6P; solution and precipitation heat treated; casting Aluminum alloy 6061-0; annealed; sheet and plate Magnesium alloy WE43A-T6; solution and precipitation heat treated; sand casting
Size of each specimen	3" x 6", 0.050" thick
Trials	
Specimens per trial	1 specimen per alloy, uncoated, as controls 3 specimens per each alloy coated per designated alternative 3 specimens per each alloy coated per zinc chromate as reference
Number of trials	2 trials, one each for synthetic-base aircraft turbine engine lubrication oil and JP-5 fuel to include all alloys, per each alternative
Pass/Fail Criteria	Inspect visually: acceptable if no deterioration as compared to control specimen not immersed in fuel or oil and if there is no peel away of coating from alloy

Unique Equipment and Instrumentation

- Masking tape, Code No. 250, 3M or equal, 1 inch wide
- 4.5 pound rubber-covered roller, approximately 3.5 inches in diameter by 1.75 inches in width, surface of which has a Shore "A" durometer hardness value within the range of 70 to 80

Data Analysis

- Visually inspect specimens for no deterioration as compared to respective control specimen not immersed in fuel or oil. Also, visually inspect for no peel away of coating from the alloy after the tape test.

3.5. Electrochemical Evaluation of Galvanic Protection Capability Test

Test Procedure

Test specimens will be totally immersed in artificial sea water. The galvanic current of coated test specimens or uncoated controls versus stainless steel will be monitored at ambient temperature separately in controlled environments of an air blanket or a nitrogen blanket. Monitoring of specimens can range from 15 minutes to 48 hours. Impedance analysis will be performed to document the protection and degradation mechanisms of the zinc chromate primer and each alternative.

Test Methodology

Parameters	Artificial sea water, room temperature, controlled environments with air blanket or nitrogen blanket
Test Specimens	
Substrates	Aluminum alloy C355.0-T6P; solution and precipitation heat treated; casting Aluminum alloy 6061-0; annealed; sheet and plate Magnesium alloy WE43A-T6; solution and precipitation heat treated; sand casting Stainless steel alloy A286
Size of each specimen	Disks 0.625” in diameter, 0.1” thick
Trials	
Specimens per trial	1 specimen per alloy, uncoated, 1 stainless steel specimen, per each controlled environment, as controls 1 specimen per alloy coated per designated alternative, 1 stainless steel specimen, per each controlled environment 1 specimen per alloy coated per zinc chromate as reference, 1 stainless steel specimen, per each controlled environment
Number of trials	18 trials per alternative, to include both alloys, each alloy specimen tested individually with stainless steel
Pass/Fail Criteria	None, documentation of protection and degradation mechanisms based on impedance analysis for each test specimen.

Unique Equipment and Instrumentation

- High impedance potentiostat with AC impedance amplifier

Data Analysis

- Documentation of protection and degradation mechanisms based on impedance analysis for each test specimen. Compare specimens coated with alternative to reference specimens coated with zinc chromate primer.

3.6. Salt Spray Tests

3.6.1. Salt Spray – Adjacent Protection Tests

Test Procedure

3.6.1 (a) For Sheet Test: Coated test specimens shall be scribed with an "x" pattern by a carbide tool with scribes approximately 0.015–0.020 inches wide and 0.005 inches deep. Cover back and edges of specimens with vinyl tape. Suspend the specimens in the salt spray chamber between 15° and 30° from the vertical and preferably parallel to the principal direction of horizontal flow of salt fog through the chamber. The specimens shall not contact each other or any metallic material or any material capable of acting as a wick. Each specimen shall be placed so as to permit free settling of fog on all specimens. Salt solution from one specimen shall not drip on any other specimen.

The salt solution shall be 5% by weight NaCl in water and shall have a pH range of 6.5 to 7.2 at temperature of 95° F. The exposure zone of the salt spray chamber shall be maintained at 95° F. Specimens shall be exposed for a minimum of 250 hours. Additionally, specimens shall be tested up to the time at which the zinc chromate primer reference specimen fails (if greater than 250 hours) or to a maximum of 1,000 hours. Specimens shall be carefully removed from the chamber and gently washed or dipped in clean running water not warmer than 100° F to remove salt deposits from their surface, and then immediately dried. Drying shall be accomplished with a stream of clean, compressed air. Examine specimens immediately by visually inspecting specimens for white corrosion.

3.6.1 (b) For Fitted Block Test: Coated test specimen shall be drilled through and a stainless steel or nickel bolt and nut shall be attached through the hole. Scratches shall be scribed in the aluminum block underneath the heads of the bolt and nut with a carbide tool approximately 0.015–0.020 inches wide and 0.005 inches deep. This is to simulate a galvanic cell typical of field damage. Remaining procedure follows that for the above sheet test.

Test Methodology

	3.6.1 (a) Sheet Test	3.6.1 (b) Fitted Block Test
Parameters	5% by weight NaCl solution, 95° F, test to a minimum of 250 hours; additionally test up to the time at which the zinc chromate primer reference specimen fails (if > 250 hours) or to a maximum of 1,000 hours	5% by weight NaCl solution, 95° F, test to a minimum of 250 hours; additionally test up to the time at which the zinc chromate primer reference specimen fails (if > 250 hours) or to a maximum of 1,000 hours
Test Specimens		
Substrates	Anodized aluminum alloy C355.0-T6P; solution and precipitation heat treated; casting Anodized aluminum alloy 6061-0; annealed; sheet and plate Magnesium alloy WE43A-T6; solution and precipitation heat treated; sand casting	Anodized aluminum alloy C355.0-T6P; solution and precipitation heat treated; casting Anodized aluminum alloy 6061-0; annealed; sheet and plate Magnesium alloy WE43A-T6; solution and precipitation heat treated; sand casting
Size of each specimen	3” x 6”, 0.050” thick	2” x 2” x 1” block
Trials		
Specimens per trial	3 specimens per alloy coated per designated alternative 3 specimens per alloy coated per zinc chromate as a reference	3 specimens per alloy coated per designated alternative 3 specimens per alloy coated per zinc chromate as a reference
Number of trials	1 trial, to include all alloys, per alternative	1 trial, to include all alloys, per alternative
Pass/Fail Criteria	Inspect visually: acceptable if no signs of white corrosion after 250 hours	Inspect visually: acceptable if no signs of white corrosion after 250 hours

Unique Equipment and Instrumentation

- Salt spray chamber

Data Analysis

- Inspect test specimens visually. Compare test specimens coated with alternative material to reference specimens coated with zinc chromate primer. Acceptable if there are no signs of white corrosion after 250 hours.
- Additionally, specimens will be tested to the time at which the zinc chromate primer reference specimens failed if greater that 250 hours. By visual inspection, compare test specimens coated with alternative material and reference specimens coated with zinc chromate primer at this point of failure. These comparisons do not however impact acceptance criteria.

3.6.2. Salt Spray – Reparability Tests

Test Procedure

3.6.2 (a) For Sheet Test: Uncoated anodized test specimens shall be scribed with an "x" pattern by a carbide tool with scribes approximately 0.015–0.020 inches wide and 0.005 inches deep. Repair scribes with application of alternative material or zinc chromate reference into cracks. Remaining procedure follows sheet test in Section 3.6.1.

3.6.2 (b) For Fitted Block Test: Uncoated anodized test specimen shall be drilled through and a stainless steel or nickel bolt and nut shall be attached through the hole. Scratches shall be scribed in the aluminum block underneath the heads of the bolt and nut with a carbide tool approximately 0.015–0.020 inches wide and 0.005 inches deep. Repair scribes with application of alternative material or zinc chromate reference into cracks. This is to simulate a galvanic cell typical of field damage. Remaining procedure follows sheet test in Section 3.6.1.

Test Methodology

	3.6.2 (a) Sheet Test	3.6.2 (b) Fitted Block Test
Parameters	5% by weight NaCl solution, 95° F, test to a minimum of 250 hours; additionally test up to the time at which the zinc chromate primer reference specimen fails (if > 250 hours) or to a maximum of 1,000 hours	5% by weight NaCl solution, 95° F, test to a minimum of 250 hours; additionally test up to the time at which the zinc chromate primer reference specimen fails (if > 250 hours) or to a maximum of 1,000 hours
Test Specimens		
Substrates	Anodized aluminum alloy C355.0-T6P; solution and precipitation heat treated; casting Anodized aluminum alloy 6061-0; annealed; sheet and plate Magnesium alloy WE43A-T6; solution and precipitation heat treated; sand casting	Anodized aluminum alloy C355.0-T6P; solution and precipitation heat treated; casting Anodized aluminum alloy 6061-0; annealed; sheet and plate Magnesium alloy WE43A-T6; solution and precipitation heat treated; sand casting
Size of each specimen	3” x 6”, 0.050” thick	2” x 2” x 1” block
Trials		
Specimens per trial	3 specimens per alloy repaired per designated alternative 3 specimens per alloy repaired per zinc chromate as a reference	3 specimens per alloy repaired per designated alternative 3 specimens per alloy repaired per zinc chromate as a reference
Number of trials	1 trial, to include all alloys, per alternative	1 trial, to include all alloys, per alternative
Pass/Fail Criteria	Inspect visually: acceptable if no signs of white corrosion after 250 hours	Inspect visually: acceptable if no signs of white corrosion after 250 hours

Unique Equipment and Instrumentation

- Salt spray chamber

Data Analysis

- Inspect test specimens visually. Compare test specimens coated with alternative material to reference specimens coated with zinc chromate primer. Acceptable if there are no signs of white corrosion after 250 hours.
- Additionally, specimens will be tested to the time at which the zinc chromate primer reference specimens failed if greater that 250 hours. By visual inspection, compare test specimens coated with alternative material and reference specimens coated with zinc chromate primer at this point of failure. These comparisons do not, however, impact acceptance criteria.

3.7. Salt Quench with Intermediate Heating Test

Test Procedure

Heat test specimens to 300° F. Spray specimens with artificial sea water and place in closed container for one week. Remove specimens from container and heat to 450° F and maintain for 20 hours. Re-heat test specimens to 300° F. Spray specimens with artificial sea water and place in closed container for one week. Remove test specimens and examine for signs of white corrosion.

Test Methodology

Parameters	Preheating to 300° F, artificial sea water, closed container for 1 week, immediate heating at 450° F for 20 hours, and re-heating to 300° F, artificial sea water, closed container for 1 week
Test Specimens	
Substrates	Aluminum alloy C355.0-T6P; solution and precipitation heat treated; casting Aluminum alloy 6061-0; annealed; sheet and plate Magnesium alloy WE43A-T6; solution and precipitation heat treated; sand casting
Size of each specimen	3” x 6”, 0.050” thick
Trials	
Specimens per trial	3 specimens per alloy coated per designated alternative 3 specimens per alloy coated per zinc chromate as a reference
Number of trials	1 trial, to include all alloys, per alternative
Pass/Fail Criteria	Inspect visually: acceptable if specimens coated with alternative shows less signs of white corrosion than zinc chromate primer

Unique Equipment and Instrumentation

- Air-circulating oven capable of maintaining 450° F for 20 hours

Data Analysis

- Inspect test specimens visually. Compare test specimens coated with alternative material to reference specimens coated with zinc chromate primer. Acceptable if specimens coated with the alternative shows less signs of white corrosion than zinc chromate primer.

4.0. REFERENCE DOCUMENTS

The following documents in Table 3 were referenced in the development of the JTP.

Table 3. Reference Documents

JTP Requirement	JTP Section Cross-Reference	Reference Document	Title	Date	Applicable Section(s) of Reference Document
Synthetic-Base Aircraft Turbine Engine Lubrication Oil	3.4	MIL-L-7808K	Lubrication Oil, Aircraft Turbine Engine, Synthetic Base	20 Jul 94	All
Water Resistance/ Adhesion Test	3.3	TT-P-1757A	Primer Coating, Zinc Chromate, Low-Moisture-Sensitivity	21 Aug 84	4.5.10
Anodizing	3.6	AMS 2470J	Anodic Treatment of Aluminum Alloys, Chromic Acid Process	1 Nov 95	All
Fuel/ Engine Oil Resistance Test	3.4	AMS 3110G	Primer - Zinc Chromate	Revised 1 Jan 92	3.2.2.4
Aluminum Alloy 6061-0; Annealed; Sheet and Plate	3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7	AMS 4025J	Aluminum Alloy, Sheet and Plate, 1.0 Mg 0.60 Si 0.28 Cu 0.20 Cr, Annealed	1 Jul 94	All
Aluminum Alloy 2024-T3; Solution and Heat Treated; Sheet and Plate	3.2	AMS 4037M	Aluminum Alloy, Sheet and Plate, 4.4 Cu 1.5 Mg 0.60 Mn, Solution Heat Treated	1 Jan 93	All
Aluminum Alloy C355.0-T6P; Solution and Precipitation Heat Treated; Casting	3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7	AMS 4215F	Aluminum Alloy, Castings, 5.0 Si 1.2 Cu 0.50 Mg, Solution and Precipitation Heat Treated	1 Dec 94	All
Magnesium Alloy AZ31B-0; Annealed and Recrystallized; Sheet and Plate	3.2	AMS 4375J	Sheet and Plate, Magnesium Alloy, 3.0 Al 1.0 Zn 0.20 Mn, Annealed and Recrystallized	1 Oct 91	All

Table 3. Reference Documents (continued)

JTP Requirement	JTP Section Cross-Reference	Reference Document	Title	Date	Applicable Section(s) of Reference Document
Titanium Alloy 8-1-1; Annealed; Sheet, Strip, and Plate	3.1	AMS 4916F	Titanium Alloy Sheet, Strip, and Plate, 8 Al 1 Mo 1 V, Duplex Annealed	1 Apr 94	All
Steel Alloy Greek Ascoloy; Annealed; Corrosion and Heat Resistant; Sheet, Strip, and Plate	3.2	AMS 5508E	Steel, Corrosion and Heat Resistant, Sheet, Strip, and Plate, 13 Cr 2.0 Ni 3.0 W, Annealed	1 Jan 93	All
Nickel Alloy Hastelloy X, Solution Heat Treated; Corrosion and Heat Resistant; Sheet, Strip, and Plate	3.2	AMS 5536L	Nickel Alloy, Corrosion and heat Resistant, Sheet, Strip, and Plate, 47.5 Ni 22 CR 1.5 Co 9.0 Mo 0.6 W 18.5 Fe, Solution Heat Treated	1 Jul 93	All
Nickel Alloy Waspaloy; Consumable Electrode or Vacuum Induction Melted; Annealed; Corrosion and Heat Resistant; Sheet, Strip, and Plate	3.2	AMS 5544G	Nickel Alloy, Corrosion and Heat Resistant, Sheet, Strip, and Plate, 57 Ni 19.5 Cr 13.5 Co 4.2 Mo 3.0 Ti 1.4 Al 0.05 Zr 0.006 B, Consumable Electrode or Vacuum Induction Melted, Annealed	1 Apr 94	All
Cobalt Alloy Haynes 188; Solution Heat Treated; Corrosion and Heat Resistant; Sheet, Strip, and Plate	3.2	AMS 5608D	Cobalt Alloy, Corrosion and Heat Resistant, Sheet, Strip, and Plate, 40 Co 22 Cr 22 Ni 14.5 W 0.07 La, Solution Heat Treated	1 Dec 95	All
Steel Alloy 4340; Sheet, Strip, and Plate	3.2	AMS 6359F	Steel Sheet, Strip, and Plate, 0.80 Cr 1.8 Ni 0.25 Mo (0.38° - 0.43° C)	1 Apr 94	All
Salt Spray Testing	3.6	ASTM B 117-90	Standard Test Method of Salt Spray (Fog) Testing	30 Mar 90	All

Table 3. Reference Documents (continued)

JTP Requirement	JTP Section Cross-Reference	Reference Document	Title	Date	Applicable Section(s) of Reference Document
Stress Corrosion Cracking Test for Aluminum Alloy	3.1	ASTM G 39-90	Standard Practice for Preparation and Use of Bent-Beam Stress-Corrosion Test Specimens	30 Mar 90	All
Hot Corrosion Test	3.2	PWA 36604, Appendix A	Hot Corrosion Testing of Standard Gas Turbine Engine Alloys		All
Stress Corrosion Cracking Test for Titanium Alloy	3.1	UTC-P&W MCL E-205	Stress-Corrosion of Titanium Alloys	Revised 11 Nov 91	All
Magnesium alloy WE43A-T6; Solution and Precipitation Heat Treated; Sand Casting	3.1, 3.3, 3.4, 3.5, 3.6, 3.7	AMS 4427	Magnesium Alloy Sand Castings 4.0 Y 2.3 Nd 0.7 Zr Solution and Precipitation Heat Treated	1 Jul 92	All