Centro Para Prevenção da Poluição (C3P)
Engineering and Technical Services

Joint Test Protocol

C3P.Proj.CS.Port.001

For the Replacement of a Chromate and High-VOC Coating System in Aircraft Painting Process

November, 2004

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Reviewed by

NASA Acquisition Pollution Prevention Office (NASA AP2)

PREFACE

This report was prepared by the Centro Para Prevenção da Poluição (C3P) under the guidance of the NASA Acquisition Pollution Prevention Office. This report was prepared in accordance with the tenants of the *Joint Statement (JS) between NASA and the Portuguese Ministry of the Environment Regarding Cooperation in the Field of Environmental Pollution Prevention*, signed by the American Ambassador and the Ministério das Cidades, Ordenamento do Território e Ambiente Portugal, and the subsequent *Terms of Reference (TOR)*, signed by the NASA Director of Environmental Management, Portuguese President of the Institute of Environment, and the C3P Director General on September 18, 2002. The structure, format, and depth of technical content of the report was determined by a joint project team comprised of representatives from C3P, Instituto De Soldadure E Qualidade (Institute of Welding and Quality) (ISQ), International Trade Bridge, Inc. (ITB), Instituto de Engenharia Mecânica e Gestão Industrial (Institute of Mechanical Engineering and Industrial Management) (INEGI), TAP Air Portugal, and OGMA – Indústria Aeronáutica de Portugal, S.A.

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INTRODUCTION

The National Aeronautics and Space Administration (NASA) and the Portuguese Ministry of Urban Affairs, Spatial Planning and the Environment, in their concern for the quality of the natural environment have agreed jointly to explore ways to prevent environmental pollution.

John N. Palmer, U.S. Ambassador to Portugal on behalf of NASA, and Isaltino Afonso de Morais, Portuguese Minister of Environment, signed a joint statement regarding cooperation in the field of environmental pollution prevention (P2) on 18 September 2002 in Lisbon, Portugal.

The following outlines specific areas of P2 interests in the joint cooperation between NASA and the Portuguese Ministry of Environment:

- Integrating environmental, safety, and occupational health considerations in acquisition, manufacturing, and maintenance processes/procedures;
- Information sharing on integrating environment, safety, and occupational health considerations into life cycle analysis;
- Use of existing information networks for environmental purposes; Information sharing programs on United States and European regulations and their potential impact on manufacturing and maintenance processes and their impacts on operational capability/supportability; and
- Integrating safety and occupational health considerations into environmental programs.

The NASA AP2 Program Office, operated under the Spaceport Technology Directorate (YA) at Kennedy Space Center, Florida, will act as facilitator while the Center for Pollution Prevention (C3P), in Lisbon, Portugal, will establish the infrastructure and develop strategic plans.

The Center for Pollution Prevention Program (C3P) is a consortia made up of three principal elements: (1) International Trade Bridge, Inc. (ITB), serving as engineering and technical support to accomplish Program/Project/Study Management, Analysis, and Integration; (2) Instituto De Soldadura E Qualidade (Institute of Welding and Quality) (ISQ), to support identification of pervasive needs and technology across Portugal and the European Union (EU) through the 6th Framework Innovative Research Center and provide potential alternative material technology identification and demonstration/validation testing; and (3) Instituto de Engenharia Mecânica e Gestão Industrial (Institute of Mechanical Engineering and Industrial Management) (INEGI) is available to support C3P study requirements with laboratory facilities, equipment, and personnel responsible for research and development activities for environmental technology needs where existing technology is not available or for needs requiring re-formulation and qualification testing. The C3P Director General is General Castelo Branco (Ret.), who through government, academic, and small and

medium enterprise associations, provides program/project advocacy and needs and project participant identification.

The C3P Mission is to identify and validate pollution prevention technologies through joint activities that enhance environmental stewardship and reduce risk while minimizing duplication of effort and associated costs.

1. REPLACEMENT OF CHROMATE AND HIGH VOC COATING SYSTEM

A common coating system on aluminum substrates consists of a chromate conversion coating, a primer and a topcoat.

Hexavalent chromium as found in chemical conversion coatings and primers coats, as well as Volatile Organic Compounds (VOC) as found in paints, were identified as the target hazardous materials (HazMat) to be eliminated or reduced.

Chromate conversion coatings and primer coatings contain hexavalent chromium, a known human carcinogen that is strictly regulated. Within the United States (U.S.), the U. S. Environmental Protection Agency (EPA) limits air emissions and regulates solid waste disposal from operations using hexavalent chromium and the Occupational Safety and Health Administration (OSHA) regulates the amount of hexavalent chromium to which workers can be exposed. OSHA has proposed reducing the Permissible Exposure Limit (PEL) for hexavalent chromium from the current 50 micrograms per cubic meter (µg/m3) to less than 1 µg/m3. Such limits could increase costs of the pretreatment of aluminum and aluminum alloys.

Paints contain VOC that have toxic properties to human health. In the European Union VOC emissions are regulated by EU Directive 1999/13/CE, March 11, 1999, that has the objective to reduce both the direct and indirect effects of the VOC emissions to the environment, as well as reduce the potential risks to human health in consequence of a series of procedures applicable to the industrial activities described in the Directive. The Directive was adopted in Portugal through law DL nº 242/2001, which imposes: elaboration of plans for solvent management concerning industrial sectors; elaboration of plans for solvent management; and definition of emission limit values.

Within Portugal, this project will achieve the goal of reducing or eliminating the use of hexavalent chromium and high VOC coatings in aluminum finishing by demonstrating and validating the performance of alternatives in the field.

The purpose of the Joint Test Protocol (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.

This JTP contains the technical requirements and tests necessary to qualify coating systems applied on aluminum and aluminum alloys in aircraft processing.

Table 1 summarizes the target HazMats, process/material, application, current specification, affected programs, and candidate substrates.

Table 1. Target HazMat Summary – TAP

Target HazMats	Process/ Material	Current Specification	Affected Programs	Candidate Substrates
Hexavalent Chrome	Chemical Conversion Coatings	AMS 3095	Airbus: A310, A320 family and A340 Boeing: B727, B737 Lockheed: L101	2024, 6061, 7075 Aluminum Alloys
Hexavalent Chrome	Primers			
VOC	Topcoats			

2. PERFORMANCE AND TESTING REQUIREMENTS

The project's joint technical team identified engineering, performance, and operational impact (supportability) requirements for hexavalent chromium found in chemical conversion coatings and primer coatings, and high VOC paints. The technical team then reached consensus on testing requirements, methodologies, and acceptance criteria for evaluating alternative coating systems technologies. Data obtained from these tests is intended as a guide for implementation for each user and is not intended to be used for qualifying or excluding any alternative. Users will select alternatives based on their respective business case.

The major requirements for which the tests in this JTP were chosen are the following:

- Corrosion resistance;
- Adhesion properties;
- Paint system adhesion.

Tests shall be conducted in a manner that will eliminate duplication and maximize use of each test specimen. Where possible, more than one test should be performed on each specimen. The number and type of tests that can be run on any one specimen will be determined by the destructiveness of the test.

> **NOTE:** Tests in this JTP may involve the use of hazardous materials, operations, and equipment. This JTP does not address all safety issues associated with its use. It is the responsibility of each user of this JTP to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.

A joint group consisting of technical representatives from C3P, TAP Portugal, OGMA, ISQ, INEGI, affected program managers, 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.

All potential alternatives must meet the performance requirements in order to qualify a coating system as valid. Alternatives must complete the screening phase of the JTP before entering into the field portion.

For all testing, alternatives will be applied and tested at stakeholder sites and not at vendor sites.

Table 2 contains the tests requirements on dry film of a coating system. This table summarizes each test, pass/fail criteria, and test method.

The tests identified in the table are further defined in Section 3 to include test description, rationale, and methodology. Also included, are any major or unique equipment requirements, as well as data reporting and analysis procedures. Test methodology includes the definition of test parameters, test specimens, number of trials per specimen, any experimental control specimens required, and acceptance criteria. The primary purpose of this JTP is to provide data to the joint user community, which it can use to select alternatives, for field testing and possible implementation. Decision criteria will vary by user, and it is likely that different users will choose different alternatives based on their business cases.

Table 2. Common Test Requirements on the Dry Film of the Coating System				
Property	**Test**	**Pass/Fail Criteria**	**Test Method**	**JTP Section**
Appearance	Gloss	90 units (min)	ISO 2813 60º meter	3.1.1.
	Initial Color	ΔE^*_{ab} max compared to reference color type	ISO 7724 AMS 3095 5.3	3.1.2.
Adhesion	Cross Hatch	Grade 0	ISO 2409 Tape: 3M 250	3.2.1.
	Impact (reverse)	No cracking or loss of adhesion	ISO 6272	3.2.2.
Flexibility	Conical Mandrel	No cracking, no peel, no damage	ISO 6860	3.3.1
	Cylindrical Mandrel	No cracking, no peel, no damage	ISO 1519	3.3.2.
Water Resistance	Blistering	D max. 2/S max. 1(microblistering)	ISO 4628 ½	3.4.1.
	Grade	Grade 1, max	ISO 2409	3.4.2.
	Penetration	No penetration to the substrate	ISO 1518	3.4.3.
Fluid Resistance	Fluid Resistance	No blisters; minor defect within 1.5 mm (1/16 inch) of scribe allowable No penetration to the substrate	ISO 1518	3.5.
Corrosion Resistance	Filiform	No filaments greater than 3 mm (1/8 inch)	EN 3665 1000 hours	3.6.1.
	Salt Spray	No spots or pits of 3mm (1/8 inch) in diameter	ISO 7253 3000 hours	3.6.2.
Artificial Weathering Resistance	Artificial Weathering	Gloss retention: 80% min of initial value Color retention: ΔE^*_{ab} 4 units max compared to initial value	ISO 2813 60º meter ISO 7724	3.7.
Cleaning Efficiency	Washability	Gloss retention: 95% min of initial value	ISO 2813 60º meter	3.8.
Strippability	Strippability	95% removal, min in 7 hours	AMS 3095 5.4	3.9.
Restoration	Restoration	Shall conform to pass/fail criteria of Table 2	AMS 3095 5.5	3.10.
Heat Stability	Heat Stability	No cracking, no peel, no damage Color change accepted	ISO 1519 ISO 3270	3.11.

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.
All tests described in this section are in accordance with specification AMS 3095 *"Paint, Gloss, Airline Exterior System"* from SEA International. This specification defines requirements for a high gloss paint system for use on civil aircraft.

The substrate types that will be used for these procedures are aluminum alloy 2024-T3 clad and 2024-T3 unclad. Tests are to be performed, except when otherwise cited below, on test specimens measuring 150 x 100 mm (6 x 4 inch) 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 0.8 mm (0.03 inch). The test panels should be prepared conforming to EN 2090 or AMS 4041 Aluminum alloy 2024-T3 clad, or EN 3997 or AMS 4037 Aluminum alloy 2024-T3 unclad.

The test panels must be detergent degreased removing the protective oil or grease either by vapor degreasing or solvent washing according to ISO 1514. Also the panels should be lightly abrade with fine grade Scotchbrite or equivalent and rinse with solvent, and then allow drying.

Other pre-treatment can be applied if specified by the manufacturer of the coating system in accordance the manufacturer's instructions.

The coatings should be prepared and applied on the test panels in accordance with the manufacturer's instructions, and must dry in a vertical altitude with free access of air for 7 days unless otherwise specified before testing.

3.1. Appearance Tests

3.1.1. Gloss Test

Test Description

The coating system shall be as uniform in appearance as practical. Use this test to determine the specular gloss of the coating using a reflectometer with 60º meter geometry, in accordance with ISO 2813 *"Paints and Varnishes – Determination of Specular Gloss of Non-Metallic Paint Films at 20º, 60º and 85º"*.
The test panels are placed in the gloss measure equipment and six readings are performed in different areas. The acceptance criteria are 90 units.

Test Methodology

Table 3. Test Methodology for Gloss Test	
Test Method	ISO 2813, 60º meter
Parameters	At 23±2ºC, 50±5% humidity
Type and Number of Panels	2024-T3 clad/Three (3)
Trials Per Panel	Six (6)
Acceptance Criteria	90 units (min)

Unique Equipment and Instrumentation

- Gloss measure apparatus

Data Analysis

- Report the different readings and calculate the average for each specimen.

3.1.2. Initial Color Test

Test Description

Use this test to measure and compare the color.
First measure X_{10}, Y_{10} and Z_{10} tristimulus values using a colorimeter according to the specification ISO 7724/2 for the test panels and the reference color standard. The calculate L^*, a^* and b^* for both the test panel and the reference color standard in accordance with specification ISO 7724/1 *"Paints and Varnishes – Colorimetry"*. And finally calculate ΔE^*_{ab} for the difference between the test panel and the reference color standard in accordance with specification ISO 7724/3.

Test Methodology

Table 4. Test Methodology for Initial Color Test	
Test Method	ISO 7724; AMS 3095 5.3
Parameters	At 23±2ºC, 50±5% humidity
Type and Number of Panels	2014-T3 clad/Three (3)
Trials Per Panel	One (1)
Acceptance Criteria	ΔE^*_{ab} max compared to reference color type

Unique Equipment and Instrumentation

- Tristimulus Colorimeter

Data Analysis

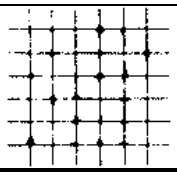
- Report the calculate value of $\Delta E^*_{ab.}$

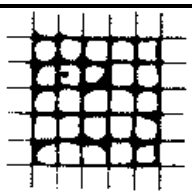
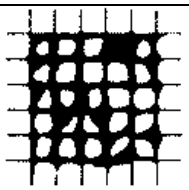
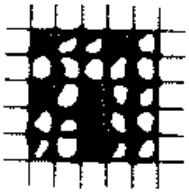
3.2. Adhesion Tests

3.2.1. Cross Hatch Test

Test Description

Use this test to determine coating resistance to substrate separation when the film is scribed with an "X" so that the substrate is exposed. The test panels must be smooth and without any deformation.
The test is performed at temperature of 23±2ºC (73±5ºF) and relative humidity of 50±5% in 3 different zones of the specimen with a distance between them and the borders of less than 5 mm. The specimens are submitted at least for 16 hours to a temperature of 23±2ºC (73±5ºF) and relative humidity of 50±5%. The specimens are evaluated for the coating particles detachment and are classified in accordance with Table 5.

Table 5. Tests Results Classification		
Grade	**Description**	**Square appearance** (6 cuts example)
0	The incisions edges are perfectly smooth, none of the coating material detached on the grids squares.	
1	Coating particles detached on the incisions intersections but doesn't affect more than 5% of the grid.	

2	Coating particles detached at incisions intersections edges between 5% and 15% of the grid.	
3	Coating particles detached on the incision edges and in several zones of the grids, affecting 15 to 35%.	
4	Coating particles detached on a big part of the incision edges affecting 35 to 65% of the grids.	
5	All that can not be classified as grade 4**.**	

Test Methodology

Table 6. Test Methodology for Cross Hatch Test	
Test Method	ISO 2409
Parameters	At 23±2ºC, 50±5% humidity
Type and Number of Panels	2024-T3 clad/Three (3)
Trials Per Panel	Three (3)
Acceptance Criteria	Grade 0

Unique Equipment and Instrumentation

- Cutting tool

Data Analysis

- The specimens are evaluated for loss of adhesion on the incisions edges.

3.2.2. Impact (Reverse) Test

Test Description

Use this test to determine the coating resistance to deformation caused by falling weight (in specific conditions). The test shall be conducted at a temperature 23±2ºC (73±5ºF) of and a relative humidity of 50±5%.
The falling weight equipment is mounted on a rigid surface. The specimen is placed on the equipment base and the weight (92 cm-kg/ 80 inch-lb) is dropped on the specimen. The intention is to analyze the coating and look for cracking and loss of adhesion. The test must be repeated at least in four different positions

(total of five weight drops).
The panel is then inspected for cracks where the impact occurred.

Test Methodology

Table 7. Test Methodology for Impact Test	
Test Method	ISO 6272
Parameters	At 23±2ºC, 50±5% humidity Weight: 92 cm-kg (80 inch-lb)
Type and Number of Panels	2024-T3 clad/Three (3)
Trials Per Panel	Five (5)
Acceptance Criteria	No cracking or loss of adhesion

Unique Equipment and Instrumentation

- Falling weight equipment

Data Analysis

- The coatings are analyzed looking for cracking and loss of adhesion. The coatings on the test panels are classified as satisfactory if no cracking or loss of adhesion appears at least in 4 positions.

3.3. Fexibility Tests

3.3.1. Conical Mandrel Test

Test Description

Coating flexibility is determined by use of a conical mandrel. The panel is placed, coated side away, over a conical mandrel and bent 180º during 2 to 3 sec. The panel is then inspected for cracks using a 10X magnification. Acceptance criteria in no cracking at the specified diameter (12 mm (0.5 inch) from 3 mm (0.12 inch) diameter end).

Test Methodology

Table 8. Test Methodology for Conical Mandrel Test	
Test Method	ISO 6860
Parameters	At 23±2ºC, 50±5% humidity Mandrel: 12mm (0.5inch) from 3mm (0.12 inch) diameter end, min
Type and Number of Panels	2024-T3 clad/Three (3)
Trials Per Panel	One (1)
Acceptance Criteria	No cracking, no peel, no damage

Unique Equipment and Instrumentation

- Conical Mandrel Test Apparatus

Data Analysis

- Inspect test panels for cracks. Report mandrel dimensions and distance from small end of mandrel to the farthest end of any crack. Compute percent elongation.

3.3.2. Cylindrical Mandrel

Test Description

Coating flexibility is determined by use of a cylindrical mandrel at low temperature [-55ºC±2ºC (-65ºF±4ºF)]. The panel is placed, coated side away, over a cylindrical mandrel (which is placed on an adjustable temperature chamber for 2 hours) and bent 180º during 1 to 2 sec. The panel is then inspected for cracks using a 10X magnification. Acceptance criteria is no cracking at the specified diameter [100 mm (4 inches)].

Test Methodology

Table 9. Test Methodology for Cylindrical Mandrel Test

Test Method	ISO 1519
Parameters	At -55ºC±2ºC Mandrel: 100mm (4 inches)
Type and Number of Panels	2024-T3 clad/Three (3)
Trials Per Panel	One (1)
Acceptance Criteria	No cracking, no peel, no damage

Unique Equipment and Instrumentation

- Cylindrical Mandrel Test Apparatus
- Adjustable Temperature Chamber

Data Analysis

- Report mandrel dimensions and the damages presented on the test panels.

3.4. Water Resistance

3.4.1. Blistering Test

Test Description

The coating system shall be as uniform in appearance as practical. The coating shall be evaluated by the intensity, quantity and size of defects. Immerse the test panels, in accordance with Method 1 of ISO 2812-1 *"Resistance to Liquids Part 1 – General Methods"*, in a container with water for 14 days at a temperature of 23±2ºC (73±5ºF). After exposure the specimens shall be evaluated by the degree of blistering of paint coatings in accordance with Picture 1 of specification ISO 4628 ½ *"Evaluation of Degradation of Paint Coatings – Designation of intensity, quantity and size of common types of defect"*.

Test Methodology

Table 10. Test Methodology for Blistering Test	
Test Method	ISO 4628 ½
Parameters	Immersion on water in accordance with ISO 2812-1 (method 1, 14 days at 23ºC±2ºC)
Type and Number of Panels	2024-T3 clad/Three (3)
Trials Per Panel	One (1)
Acceptance Criteria	D max. 2/S max. 1 (i.e. microblistering)

Unique Equipment and Instrumentation

- None

Data Analysis

- Report the numerical rating of the density of blistering.

3.4.2. Grade Test

Test Description

Use this test to determine coating resistance to substrate separation when the film is scribed with an "X" so that the substrate is exposed [See Cross Hatch Adhesion Test (Section 3.2.1.)]. Immerse the test panels, in accordance with Method 1 of ISO 2812-1, in a container with water for 14 days at a temperature of 23±2ºC (73±5ºF). After exposure the specimens are evaluated for the coating particles detachment and are classified in accordance with Table 5.

Test Methodology

Table 11. Test Methodology for Grade Test (Cross Hatch Test)	
Test Method	ISO 2409
Parameters	Immersion on water in accordance with ISO 2812-1 (method 1, 14 days at 23ºC±2ºC)
Type and Number of Panels	2024-T3 clad/Three (3)
Trials Per Panel	Three (3)
Acceptance Criteria	Grade 1, max

Unique Equipment and Instrumentation

- Same as Cross Hatch Adhesion Test (Section 3.2.1.).

Data Analysis

- Same as Cross Hatch Adhesion Test (Section 3.2.1.).

3.4.3. Penetration Test

Test Description

Use this test to determine, under defined conditions, the resistance of a coating system to penetration by scratching with a hemispherical tipped needle.
Immerse the test panels, in accordance with Method 1 of ISO 2812-1, in a container with water for 14 days at a temperature of 23±2ºC (73±5ºF). After exposure the test is conducted.
The scratch apparatus consists essentially of a horizontally sliding test panel holder, driven by a constant speed motor beneath the point of a scratching needle, which s perpendicular to the test panel. The needle must have a hard hemispherical tip of 1 mm diameter.
Fix the needle in the chuck so that, when in position on the test panel, the needle will be perpendicular to the panel holder. Clamp the test panel, with the coating under test uppermost, to the panel holder of the apparatus, with the longer side of the panel parallel to the direction in which the scratch will be made. Place the weights [1200 g (2.6 lb)] on the holder above the needle. Allow the scratch to be made on the coating (not less than 60 mm in length); the penetration of the needle is to the substrate.
Examine the scratch on the test panels to see if the coating has been penetrated to the extent specified.

Test Methodology

Table 12. Test Methodology for Penetration Test	
Test Method	ISO 1518
Parameters	Immersion in water in accordance with ISO 2812-1 (method 1, 14 days at 23ºC±2ºC) Use 1200 g (2.6 lb) needle weight
Type and Number of Panels	2024-T3 clad/Three (3)
Trials Per Panel	Three (3)
Acceptance Criteria	No penetration to the substrate

Unique Equipment and Instrumentation

- Scratch Apparatus (in accordance with Figure 1 of ISO 1518 *"Scratch Test"*)

Data Analysis

- Report the penetration to the substrate.

3.5. Fluid Resistance Test

Test Description

Use this test to determine the resistance of a coating system to exposure to fluids. The test panels must be scribed to metal substrate immediately before immersion. Immerse the test panels, in accordance with Method 1 of ISO 2812-1, in a container with Hydraulic fluid *Skydrol LD4*, *Hyjet IV-A* or equivalent, for 30 days at a temperature of 23±2ºC (73±5ºF). After exposure conduct the scratch test [See Penetration Test (Section 3.4.2.)].
Examine the scratch on the test panels to see if the coating has been penetrated to the extent specified.

Test Methodology

Table 13. Test Methodology for Fluids Resistance Test	
Test Method	ISO 1518
Parameters	Immersion on Hydraulic Fluid (*Skydrol LD4*, *Hyjet IV-A* or equivalent) in accordance with ISO 2812-1 (method 1, 30 days at 23ºC±2ºC). Use 1200 g (2.6 lb) needle weight.
Type and Number of Panels	2024-T3 clad/Three (3)
Trials Per Panel	Three (3)
Acceptance Criteria	No blisters; minor defect within 1.5 mm (1/16 inch) of scribe allowable No penetration to the substrate

Unique Equipment and Instrumentation

- Same as Penetration Test (Section 3.4.2.).

Data Analysis

- Same as Penetration Test (Section 3.4.2.).

3.6. Corrosion Resistance

3.6.1. Filiform Corrosion Test

Test Description

Test panels will be scribed with two grooves (See Figure 1) so that the substrate is exposed.

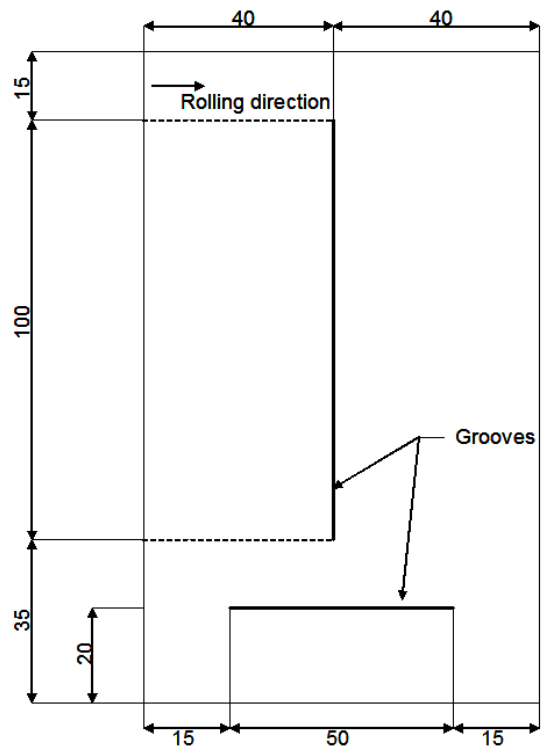


Figure 1. Grooves dimensions (mm).

The panels will then be placed horizontally with the paint film downwards in the container containing 20±2ml of Hydrochloric acid/liter of volume. The distance between test panels and liquid level shall be 100±10mm, and the distance between test panels shall be 20 mm minimum. The container shall remain closed for 60±5min at a temperature of 23±2ºC (73±5ºF). After removal from the container the test panels shall stand out in open air for 15 to 30 min. Then the panels are placed in a test cabinet at a temperature of 40±2ºC (104±5ºF) and 82±3% relative

humidity for 1000 hours in an approximately vertical position.
After exposure, test panels shall be flushed with warm water and then again with alcohol, and placed in a desiccator until evaluation of filiform growth. No filaments should be greater than 3 mm (1/8 inch).

Test Methodology

Table 14. Test Methodology for Filiform Test	
Test Method	EN 3665, 1000 hours
Parameters	20ml HCl/l volume for 60 min, 40°C, and 82% humidity for 1000 hours
Type and Number of Panels	2024-T3 clad, 2024-T3 unclad/Three (3)
Trials Per Panel	One (1)
Acceptance Criteria	No filaments greater than 3 mm (1/8 inch)

Unique Equipment and Instrumentation

- Humidity cabinet.
- Container with cover, resistant to Hydrochloric acid.

Data Analysis

- Record filiform corrosion on unscribed area and creepage from scribe.

3.6.2. Salt Spray Test

Test Description

Use this test to determine coating resistance to corrosion over a specified period of time in a controlled corrosive environment. Test specimens are placed in the salt spray chamber at a 15° to 25° angle from the vertical. Specimens are placed to permit free settling of fog on all specimens, but preventing salt solution from one specimen from dripping onto any other specimen.

The salt (NaCl) solution is verified to have a concentration of 50±5g/l, with a pH between 6.5 and 7.2, and a temperature of 35±2°C (95±5ºF). No scribe is required. Expose specimens for 3000 hours. After exposure, the specimens are cleaned in running water, not warmer than 38°C (100ºF) 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

Table 15. Test Methodology for Salt Spray Test	
Test Method	ISO 7253, 3000 hours
Parameters	50±5 g/l NaCl solution/3000 hours
Type and Number of Panels	2024-T3 clad, 2024-T3 unclad/Three (3)
Trials Per Panel	One (1)
Acceptance Criteria	No spots or pits of 3 mm (1/8 inch) in diameter

Unique Equipment and Instrumentation

- Salt Spray (Fog) Test Cabinet

Data Analysis

- The specimens are evaluated for surface corrosion spots or pits on a daily basis and at the end of the test period.

3.7. Artificial Weathering Test

Test Description

Artificial aging of test panels using UV light and water condensation or spraying is conduct in order to originate a certain alteration degree in a property after radiating exposure, in accordance with specification ISO 11507 *"Exposure of Coatings to Artificial Weathering – Exposure to Fluorescent UV and Water"*. The properties of the exposed specimens are compared with the properties of the unexposed specimens, which are prepared with the same coating materials.
Use this test to determine the difference between the gloss and initial color properties of the exposed specimens and the unexposed specimens [See Gloss Test (Section 3.1.1.) and Initial Color Test (Section 3.1.2.)].

Test Methodology

Table 16. Test Methodology for Artificial Weathering Test		
	Gloss Test	**Initial Color**
Test Method	ISO 2813, 60º meter	ISO 7724
Parameters	In accordance with ISO 11507, 1000 hours, UVB 313, light 4 hours, humidity 4 hours	In accordance with ISO 11507, 1000 hours, UVB 313, light 4 hours, humidity 4 hours
Type and Number of Panels	2024-T3 clad/Three (3)	2024-T3 clad/Three (3)
Trials Per Panel	Six (6)	One (1)
Acceptance Criteria	Gloss retention: 80% min of initial value	Color retention: ΔE^*_{ab} 4 units max compared to initial value

Unique Equipment and Instrumentation

- Same as Gloss Test (Section 3.1.1.).
- Same as Initial Color Test (Section 3.1.2.).

Data Analysis

- Same as Gloss Test (Section 3.1.1.).
- Same as Initial Color Test (Section 3.1.2.).

3.8. Washability Test

Test Description

Use this test to determine the gloss of the coating using a reflectometer with 60º meter geometry after cleaning the test panels in accordance with MIL-PRF-85285 *"Coating, Polyurethane, High Solids"*. The test panels are placed in the gloss measure equipment and six readings are performed in different areas. The gloss retention must be 95% min of initial value.

Test Methodology

Table 17. Test Methodology for Washability Test (Gloss Test)

Test Method	ISO 2813, 60º meter
Parameters	Cleanability test in accordance with MIL-PRF-85285
Type and Number of Panels	2024-T3 clad/Three (3)
Trials Per Panel	Six (6)
Acceptance Criteria	Gloss retention: 95% min of initial value

Unique Equipment and Instrumentation

- Same as Gloss Test (Section 3.1.1.).

Data Analysis

- Same as Gloss Test (Section 3.1.1.).

3.9. Strippability Test

Test Description

Use this test to determine the ability to remove the coating system. The specimens must be aged for 96 hours at 70±2ºC (158±5ºF). Evenly apply an environmental acceptable paint remover by means of brush. The paint remover shall be free of halogenated solvents, chromates, phenol and cresols. Determine the time required to degrade the adhesion of the coating to a condition that permits its removal with polyethylene scraper. Then remove the degraded material and clean remaining

paint film in accordance with manufacture's instructions. Examine the panel substrate for effectiveness of removal.

Test Methodology

Table 18. Test Methodology for Strippability Test	
Test Method	AMS 3095, 5.4
Parameters	96 hours at 70±2ºC
Type and Number of Panels	2024-T3 clad/Three (3) Panels size: 300x300 mm (12x12 inches)
Trials Per Panel	One (1)
Acceptance Criteria	95% removal, min in 7 hours

Unique Equipment and Instrumentation

- None

Data Analysis

- Report the effectiveness of coating removal.

3.10. Restoration Test

Test Description

Use this test to determine the ability to restore the coating system after removal. After the test panels have been stripped and cleaned in accordance with the Strippability Test (See Section 3.9.) restore the system on the panels in accordance with the manufacture's instructions and repeat all the performance tests.

Test Methodology

Table 19. Test Methodology for Restoration Test	
Test Method	AMS 3095, 5.5
Parameters	
Type and Number of Panels	All/All
Trials Per Panel	One (1)
Acceptance Criteria	Shall conform to pass/fail criteria of Table 2

3.11. Heat Stability Test

Test Description

Coating flexibility is determined by use of a cylindrical mandrel at a temperature of 150±2ºC (302±5ºF). The specimen is placed, coated side away, over a cylindrical mandrel [25 mm mandrel (1 inch)], which is placed on a adjustable temperature chamber for 100 hours, and bent 180º during 1 to 2 sec. The panel is then inspected for cracks using a 10X magnification. Acceptance criteria is no peeling, no cracking or damage after bend test 180º around 25 mm (1 inch) mandrel.

Test Methodology

Table 20. Test Methodology for Heat Stability Test

Test Method	ISO 1519; ISO 3270
Parameters	At 150ºC±2ºC for 100 hours Mandrel: 25mm (1 inch)
Type and Number of Panels	2024-T3 clad/Three (3)
Trials Per Panel	One (1)
Acceptance Criteria	No cracking, no peel, no damage Color change accepted

Unique Equipment and Instrumentation

- Cylindrical Mandrel Test Apparatus (Same as Cylindrical Mandrel Test – Section 3.3.2.)
- Adjustable Temperature Chamber (Same as Cylindrical Mandrel Test – Section 3.3.2.)

Data Analysis

- Report mandrel dimensions and the damages presented on the test panels. (Same as Cylindrical Mandrel Test – Section 3.3.2.).

4. REFERENCE DOCUMENTS

The following documents in Table 21 were referenced in the development of the JTP.

Table 21. Reference Documents

Reference Document	Title	Date	Applicable Section(s) of Reference Document	JTP Property	JTP Section Cross-Reference
AMS 3095	Paint, Gloss, Airline Exterior System	2001	All	All	All
ISO 1512	Paint and Varnishes - Sampling	2002	All	All	All
ISO 1514	Standard Panels for Testing	2004	All	All	All
ISO 1518	Scratch Test	1992	All	Water, Fluid Resistance	3.4.3., 3.5.
ISO 1519	Bend Test (Cylindrical Mandrel)	2003	All	Flexibility, Heat Stability	3.3.2., 3.11.
ISO 2409	Cross Cut Test	1995	All	Adhesion, Water Resistance	3.2.1., 3.4.2.
ISO 2812-1	Resistance to Liquids, Part 1 – General Methods	1999	Method 1	Water, Fluid Resistance	3.4.1., 3.4.2., 3.4.3., 3.5.
ISO 2813	Specular Gloss of Non-Metallic Paint Films at 20 Degrees, 60 Degrees and 85 Degrees	2001	All	Appearance, Artificial Weathering, Cleaning Efficiency	3.1.1., 3.7., 3.8.
ISO 3270	Paints and Varnishes and their Raw Materials – Temperatures and Humidities for Conditioning and Testing	1995	All	Appearance, Adhesion, Flexibility, Heat Stability	3.1.1., 3.1.2., 3.2.1., 3.2.2., 3.3.1., 3.11.
ISO 4628 1/2	Evaluation of Degradation of Paint Coatings – Designation of Intensity, Quantity and Size of Common Types of Defect	1982	All	Water Resistance	3.4.1.
ISO 6272	Falling Weight Test	1996	All	Adhesion	3.2.2.
ISO 6860	Bend Test (Conical Mandrel)	1997	All	Flexibility	3.3.1.
ISO 7253	Resistance to Neutral Salt Spray	1999	All	Corrosion Resistance	3.6.2.

Table 21. Reference Documents					
Reference Document	**Title**	**Date**	**Applicable Section(s) of Reference Document**	**JTP Property**	**JTP Section Cross-Reference**
ISO 7724	Paints and Varnishes - Colorimetry	1984	All	Appearance, Artificial Weathering	3.1.2., 3.7.
ISO 11507	Exposure of Coatings to Artificial Weathering – Exposure to Fluorescent UV and Water	1999	All	Artificial Weathering	3.7.
EN 3665	Paint and Varnishes – Filiform Corrosion Test	1997	All	Corrosion Resistance	3.6.1.
MIL-PRF-85285	Coating: Polyurethane, High Solids	1990	Cleanability Test	Cleaning Efficiency	3.8.