National Aeronautics and Space Administration (NASA)
Acquisition Pollution Prevention (AP2) Office

Joint Test Protocol

For Validation of Alternatives to Aliphatic Isocyanate Polyurethanes

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January 31, 2005

Distribution Statement "A" applies.
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Contract No. NAS10-03029
Task Nos. 1 and 6

Prepared by
International Trade Bridge (ITB), Inc.
Beavercreek, OH 45432

Submitted by
NASA Acquisition Pollution Prevention Office

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PREFACE

This report was prepared by International Trade Bridge, Inc. (ITB) through the National Aeronautics and Space Administration (NASA) Acquisition Pollution Prevention (AP2) Office under Contract Number NAS10-03029 Task Order Nos. 1 and 6. The structure, format, and depth of technical content of the report were determined by the NASA AP2 Office, Government contractors, and other Government technical representatives in response to the specific needs of this project.

The information contained in this report was leveraged from the Engineering and Technical Services for Joint Group on Acquisition Pollution Prevention (JG-APP) Pilot Projects Joint Test Protocols entitled *Joint Test Protocol (LM-P-1-1) for Validation of Alternatives to High Volatile Organic Compound (VOC) Topcoats and Primers*, dated June 16, 1997 (Revised November 19, 1998), which was prepared by Concurrent Technologies Corporation (CTC) through the National Defense Center for Environmental Excellence (NDCEE) under Contract Number DAAA21-93-C-0046 and *Joint Test Protocol (J-99-OC-014-P) for Low/No-VOC and Nonchromate Coating System for Support Equipment*, dated November 4, 1999, which was prepared by Science Applications International Corporation (SAIC) through the JG-PP under Contract Number F09603-95-D-0177 (Revised August 10, 2000 by NDCEE/CTC). Other information was leveraged from Logistics Environmental Office Pollution Prevention Project *Air Force Test Protocol ZHTV02W147 Low/No VOC Corrosion Preventive Coatings for ICBM Missile Support Equipment—Phase I*, dated July 25, 2003, which was prepared by HQ AFMC/LGPE under Contract Number GSA GS-23F-0216K.

We wish to acknowledge the invaluable contributions provided by all the organizations involved in the creation of this document.

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1. INTRODUCTION

Headquarters National Aeronautics and Space Administration (NASA) chartered the Acquisition Pollution Prevention (AP2) Office to coordinate agency activities affecting pollution prevention issues identified during system and component acquisition and sustainment processes. The primary objectives of the AP2 Office are to:

- Reduce or eliminate the use of hazardous materials (HazMats) or hazardous processes at manufacturing, remanufacturing, and sustainment locations.
- Avoid duplication of effort in actions required to reduce or eliminate HazMats through joint center cooperation and technology sharing.

NASA and Air Force Space Command (AFSPC) have similar missions and therefore similar facilities and structures in similar environments. Both are responsible for a number of facilities/structures with metallic structural and non-structural components in highly and moderately corrosive environments. Regardless of the corrosivity of the environment, all metals require periodic maintenance activity to guard against the insidious effects of corrosion and thus ensure that structures meet or exceed design or performance life. The standard practice for protecting metallic substrates in atmospheric environments is the application of an applied coating system. Applied coating systems work via a variety of methods (barrier, galvanic and/or inhibitor) and adhere to the substrate through a combination of chemical and physical bonds.

The most common topcoats used in coating systems are polyurethanes that contain isocyanates. Isocyanates are compounds containing the isocyanate group (-NCO). They react with compounds containing alcohol (hydroxyl) groups to produce polyurethane polymers, which are components of polyurethane foams, thermoplastic elastomers, spandex fibers, and the polyurethane paints used in NASA and AFSPC applications.

The Occupational Safety & Health Administration (OSHA) states that the effects of isocyanate exposure include irritation of skin and mucous membranes, chest tightness, and difficult breathing. Isocyanates are classified as potential human carcinogens and are known to cause cancer in animals. The main effects of overexposure are occupational asthma and other lung problems, as well as irritation of the eyes, nose, throat, and skin.

The primary objective of this effort is to demonstrate and validate alternatives to aliphatic isocyanate polyurethanes. Successful completion of this project will result in one or more isocyanate-free coatings qualified for use at AFSPC and NASA installations participating in this project.

Table 1-1 summarizes the target HazMats; processes and materials; applications, affected programs and candidate parts/substrates.

Table 1-1 Target HazMat Summary				
Target HazMat	**Current Process**	**Applications**	**Current Specifications**	**Candidate Parts/Substrates**
Isocyanates used in urethane coatings	Conventional spray and brush application	Any application where a high-gloss finish is required	NASA Approved Products (listed in Appendix B of NASA-STD-5008); AFSPC Approved Products	Carbon Steel

This Joint Test Protocol (JTP) contains the critical requirements and tests necessary to qualify alternatives for Aliphatic Isocyanate Polyurethane applications. These tests were derived from engineering, performance, and operational impact (supportability) requirements defined by a consensus of NASA and AFSPC participants.

The Field Test Plan (FTP) entitled *Field Evaluations Test Plan for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes*, prepared by ITB, defines the field evaluation and testing requirements for validating alternatives to aliphatic isocyanate polyurethanes and supplements this JTP. The field evaluations will be performed at Stennis Space Center, Mississippi, under the oversight of the Project Engineer. Additional field evaluations may be performed at other NASA centers or AFSPC facilities.

The Potential Alternatives Report (PAR) entitled *Potential Alternatives Report for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes*, prepared by ITB, provides technical analyses of identified alternatives to the current coatings, criteria used to select alternatives for further analysis, and a list of those alternatives recommended for testing.

The Cost Benefit Analysis (CBA) entitled *Cost Benefit Analysis for Alternatives to Aliphatic Isocyanate Polyurethanes*, prepared by ITB, provides financial analyses of identified alternatives to determine if implementation of the candidate alternatives is economically justified.

A Joint Test Report (JTR) will document the results of the testing as well as any test modifications made during the execution of the testing. The JTR will be made available as a reference for future pollution prevention endeavors by other NASA centers, the Department of Defense (DoD) and commercial users to minimize duplication of effort. Users of this JTP should check the project's JTR for additional test details or minor modifications that may have been necessary in the execution of the testing. The technical stakeholders will have agreed upon test procedures modifications documented in the JTR.

2. ENGINEERING, PERFORMANCE, AND TESTING REQUIREMENTS

A joint group led by the AP2 Office and consisting of technical representatives from NASA centers and Air Force Space Command (AFSPC) reached technical consensus on engineering, performance, and testing requirements for alternatives to Aliphatic Isocyanate Polyurethane coatings. The joint group defined critical tests with procedures, methodologies, and acceptance criteria to qualify alternatives against these technical requirements.

Once the JTP test criterion is approved, testing will be performed in a manner that will optimize the use of each test panel. For example, where practical, more than one type of test will be performed on the coated test panels. The number and types of tests performed on a given panel will be determined by the destructive nature of the tests in question.

All coating system candidates will be tested using approved NASA and AFSPC standard coating systems as experimental controls. Coating technicians will follow all manufacturer application instructions and will document all relevant conditions at the time of application.

> **Note:** Tests specified in this JTP may involve the use of hazardous materials, operations, and equipment. This JTP does not address all safety issues associated with its implementation. 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.

The objective of this project is to qualify the candidates under the specifications for the standard coating system. This project will compare coating performance of the proposed alternatives to existing coating systems or standards. The tests described in this JTP are in the following main categories: screening tests, common tests, and field evaluations. Tables 2-1, 2-2, and 2-3 summarize the test requirements for validating alternative coating candidates against existing approved aliphatic isocyanate polyurethane coating systems.

Table 2-1 lists screening tests. Screening tests are preliminary tests performed on the candidate coating systems. Candidate coatings that do not meet the requirements of the screening tests will be eliminated from further testing unless otherwise directed by the testing authority.

Table 2-2 lists the common tests required by participating installations, such as removability, reparability, 18-month Marine Environment, color and gloss retention, and LOX and Hypergol compatibility. Candidate coatings that do not meet the requirements of the common tests will be eliminated from further testing unless otherwise directed by the testing authority.

Table 2-3 lists field evaluations that are intended to compare the performance of candidate test coatings with current coatings when applied in an operational environment. The field evaluations will be performed in conjunction with laboratory tests. Coating evaluators will

complete a written evaluation and documentation checklist to organize and quantify the observations of coating system performance under actual operating conditions. These tests are further defined in the FTP.

These tables include acceptance criteria and the reference specifications, if any, used to conduct the tests. The proposed test and evaluation are based on the aggregate knowledge and experience of the assigned technical project personnel and prior testing where "None" appears under *Test Method References*.

Table 2-1 Screening Engineering, Performance, and Testing Requirements for Aliphatic Isocyanate Urethane Coatings				
Test	**JTP Section**	**Test Specimen**	**Acceptance Criteria**	**Test Methodology References**
Pot Life (Viscosity)	3.1.1.	Mixed Coating System	<u>Procedure A: High Solids Coatings</u> Viscosity of both test batches shall not exceed 60 seconds after 4 hours of continuous mixing in a closed container maintained at 75 ± 5°F (Batch 1) and 95 ± 5°F (Batch 2). The admixed materials must still be sprayable 4 hours after mixing. <u>Procedure B: Waterborne Coatings</u> Coating viscosity shall not exceed admix viscosity by more than 15 seconds after 4 hours, with no gelling of the admixed coating after 6 hours	ASTM D 1200
Ease of Application	3.1.2.	Coupon	Smooth coat, with acceptable appearance, no runs, bubbles or sags; Ability to cover the properly prepared/primed substrate with a single coat (one-coat hiding ability); Measure Dry Film Thickness.	SSPC-PA-2
Surface Appearance	3.1.3.	Coupon	No streaks, blistering, voids, air bubbles, cratering, lifting, blushing, or other surface defects/irregularities; No micro-cracks observable at 10X magnification	ASTM D 523; ASTM D 2244
Dry-To-Touch (Sanding)	3.1.4.	Coupon	No rolling or scribing during sanding, and "easy" sanding (as evaluated by technician)	None

Table 2-1 Screening Engineering, Performance, and Testing Requirements for Aliphatic Isocyanate Urethane Coatings

Test	JTP Section	Test Specimen	Acceptance Criteria	Test Methodology References
Accelerated Storage Stability	3.1.5.	Mixed Coating System	No skinning, grains, or lumps of the coating; no pressure buildup, corrosion on the container, odor of spoilage or cloudy appearance of catalyst.	ASTM D 1849
Cure Time (MEK Solvent Rub)	3.1.6.	Coupon	No effect on surface or coating on the cloth (Resistance Rating 5)	ASTM D 4752
Solvent (Acetone) Rub	3.1.7.	Coupon	No effect on surface or coating on the cloth (Resistance Rating 5)	ASTM D 4752
Cleanability	3.1.8.	Coupon	Cleaning efficiency equal to or better than control coatings	MIL-PRF-83282D; MIL-PRF-85285
X-Cut Adhesion by Wet Tape	3.1.9.	Coupon	Candidate coating adhesion performs as well or better than control coatings and greater than or equal to 4a as specified in ASTM D 3359	ASTM D 3359; FED-STD-141
Tensile (Pull-off) Adhesion	3.1.10.	Coupon	Pull-off strength achieved at time of failure equal to or better than control coatings	ASTM D 4541
Knife Test	3.1.11.	Coupon	Candidate coating performs as well or better than control coatings	FED-STD-141

Table 2-2 Common Engineering, Performance, and Testing Requirements for Aliphatic Isocyanate Urethane Coatings				
Test	**JTP Section**	**Test Specimen**	**Acceptance Criteria**	**References**
Removability	3.2.1.	Coupon	Less than one minute to penetrate substrate; Tested during Repairability and Abrasion Resistance Tests; Measure DFT of remaining coating	ASTM G 155
Repairability	3.2.2.	Coupon	Ease of removal and replacement of damaged areas of the test coatings, color matching of aged versus new material; No streaks, blistering, voids, air bubbles, over-spray "halo", cratering, lifting, blushing, or other surface irregularities, No peel away of the repaired coating during the dry tape adhesion test	ASTM D 523; ASTM D 2244; ASTM D 3359
Abrasion Resistance	3.2.3.	Coupon	Coating removal (weight loss) less than or equal to control coating or less than 4 mm^2 exposed substrate	ASTM D 4060
Gravelometer	3.2.4.	Coupon	Rating should be equal to or better than control	ASTM D 3170
Fungus Resistance	3.2.5.	Coupon	Does not support fungal growth and meets adhesion requirements	ASTM D 3359; MIL-STD-810F
Accelerated Weathering	3.2.6.	Coupon	Color change performance < one unit (ΔE) @ 500 hour intervals	ASTM D 523; ASTM D 2244; ASTM G 155
Mandrel Bend Flexibility	3.2.7.	Coupon	No peeling or delamination from the substrate and no cracking greater than ¼-inch from the edges.	ASTM D 522
18-Month Marine Environment	3.2.8.	Coupon	Gloss change and panel condition of candidate coating rated equal to or better than control coatings	ASTM D 610; ASTM D 714; ASTM D 523

Table 2-2 Common Engineering, Performance, and Testing Requirements for Aliphatic Isocyanate Urethane Coatings				
Test	**JTP Section**	**Test Specimen**	**Acceptance Criteria**	**References**
Cyclic Corrosion Resistance	3.2.9.	Coupon	Candidate coating performs as well or better than the control coatings; No significant blistering, softening, or lifting of coating	GM 4465 P; GM 9540 P
Hypergol Compatibility	3.2.10.	Coupon	Slight to Moderate Reactivity Observed: When test data based on visual observations with the unaided eye reveal reactivity (but no ignition) and/or any changes in the visual characteristics, bulk characteristics, and/or surface characteristics of the test sample	KSC MTB-175-88; NASA-STD-6001
LOX Compatibility	3.2.11.	Coupon	Twenty samples must not react when impacted at 72 ft-lbs (98 J). If one sample out of 20 reacts, 40 additional samples must be tested without any reactions.	ASTM D 2512; NASA-STD-6001

Table 2-3 Field Evaluation and Testing Requirements for Aliphatic Isocyanate Urethane Coatings				
Test	**Field Test Plan Section**	**Test Specimen**	**Acceptance Criteria**	**References**
Ease of Application	3.2.1.	Field Test	Smooth coat, with acceptable appearance, no runs, bubbles or sags; Ability to cover the properly prepared/primed substrate with a single coat (one-coat hiding ability); Record Pot Life, DFT and associated issues	SSPC-PA-2
Surface Appearance	3.2.2.	Field Test	No streaks, blistering, voids, air bubbles, cratering, lifting, blushing, or other surface defects/irregularities; No micro-cracks observable at 10X magnification	ASTM D 523; ASTM D 2244
Dry-To-Touch (Sanding)	3.2.3.	Field Test	No rolling or scribing during sanding, and "easy" sanding (as evaluated by technician)	None

3. TEST DESCRIPTIONS

Test requirements identified in Tables 2-1 and 2-2 are further defined in this section to include the test description, rationale, and test methodology. The *Test Methodology* lists the major parameters, test coupon descriptions, number of test coupons, number of coupons per coating system, number of control coupons and acceptance (pass/fail) criteria. Any U*nique Equipment or Instrumentation* requirements and *Data Analysis and Reporting Criteria* are also included. In some cases no control coupons are required for a test, as the baseline coating performance is well documented.

Field Evaluation and Testing Requirements identified in Table 2-3 are further defined in the NASA AP2 Office document *Field Evaluations Test Plan for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes*, prepared by ITB.

The coating of coupons will be documented using the "Coating System Application Evaluation and Inspection Report" (Appendix A) based on the Application Record Sheet in NASA-STD-5008, or an equivalent form. For each test requiring coupons, a minimum of six (6) coupons shall be prepared; those with the best coating as determined by the technician shall be used in accordance with the number of coupons required as specified in the *Test Methodology*. Unless otherwise required by a specific test, all coupons will be prepared as follows:

Unless otherwise noted, test coupons will be four (4) inches wide by six (6) inches long and of suitable thickness. Metal coupons shall be prepared in accordance with NACE-STD-RP0281 [*Method for Conducting Coating (Paint) Panel Evaluation Testing in Atmospheric Exposures*, revised 2004]. Surface roughness shall be measured in accordance with NACE-STD-RP0287 (*Field Measurements of Surface Profile of Abrasive Blast Cleaned steel Surfaces Using a Replica Tape*, revised 2002) and recorded for informational purposes prior to application of the primer. All edges and corners shall be rounded prior to primer application to promote adhesion. The surface conditioning for steel test coupons will be in accordance with the Society of Protective Coating Standards SSPC-SP-1 (*Solvent Cleaning*, approved 1982) and -5 (*White Blast Cleaning*, approved 2000). Each test will be performed on identical test panels prepared with the candidate alternative coating systems and the NASA and AFSPC standard control coating(s) as the test controls.

If liquid coatings are being tested, test coupons shall be allowed 24 hours of unaided drying time prior to dry film thickness measurements. If powder coatings are being tested, test coupons shall be cured in accordance with manufacturer's recommendations prior to dry film thickness measurements. The dry film thickness measurements shall be made nondestructively in accordance with SSPC-PA-2 (*Measurement of Dry Coating Thickness with Magnetic Gages*, revised 2004). If liquid coatings are being tested for a destructive test, coupons shall be allowed to cure for an additional 14 days before they undergo any destructive testing to ensure full polymerization of the coating. Coating process parameters,

including application method and cure schedule, shall be documented by the facility that prepares the test coupons.

Each coating system will be prepared and applied according to instructions provided by the manufacturer. Coating systems should be applied by spraying, or, in the case of advanced film technology, by hand to the dry film thickness recommended by the coating manufacturer. Application should be conducted at a minimum temperature of 75 ± 5°F and 50 ± 10% relative humidity (RH), unless otherwise specified. The coating system may be applied in one or two coats if allowed by the manufacturer and provided that the manufacturer's instructions are carefully followed. Unless otherwise specified, test panels with organic topcoats should be held at 75 ± 5°F and 50 ± 10% RH prior to testing. If a topcoat is to be applied over the primer, the topcoat should be applied within 24 hours of primer application. In many cases, the topcoat will be applied before the primer is fully cured; however, the topcoat should never be applied sooner than specified by the manufacturer or before the primer is dry to the touch (dry-to-handle). Unless otherwise specified, the topcoat should be applied to the total dry film thickness recommended by the coating manufacturer.

Table 3-1 contains a listing of substrate types that will be used for testing and their test specimen code.

Table 3-1 Test Specimen Codes and Substrate Descriptions

Test Coupon Code	Substrate Description
A36	Carbon Steel 4 inch x 6 inch x 3/16 inch panels fabricated from ASTM A36 hot rolled carbon steel; primed, intermediate coated (if required), and topcoated with the candidate coating system. Coatings applied per the coating manufacturer specifications.
CCS	Composite Carbon Steel 4 inch x 6 inch x 3/16 inch panels with a 1 inch channel welded on front face fabricated from ASTM A36 hot rolled carbon steel; primed, intermediate coated (if required), and topcoated with the candidate coating system. Coatings applied per the coating manufacturer specifications.

3.1. Screening Tests for Alternatives to Aliphatic Isocyanate Urethane Coatings

Screening tests are preliminary tests performed on selected candidate coating systems. Candidate coating systems that do not meet the acceptance criteria of the screening tests will be eliminated from further testing. Coating systems that meet the requirements of the screening tests will be subjected to the additional tests listed in this JTP. Screening tests include pot life, ease of application, surface appearance, accelerated storage stability, dry-to-touch time, cure time, solvent rub, cleanability, and adhesion evaluations. The initial

screening of the coating candidates will compare the test candidates against the control coatings as described in each *Test Methodology*.

3.1.1. Pot Life (Viscosity)

Test Description

This procedure is used to determine the viscosity increase of a mixed multi-component liquid coating system over a specified time. This test will be separated into two procedures. Procedure A is for solvent-borne coatings and Procedure B is for waterborne coatings.

Procedure A—Solvent-Borne Coatings

Mix the coating components according to the manufacturer's directions.

Maintain a freshly mixed sample of the coating system in a closed container at $75^{o} \pm 5^{o}$F for four hours with continuous stirring. Measure and record the mixture's viscosity every 30 minutes in accordance with ASTM D 1200 (*Test Method for Viscosity by Ford Viscosity Cup,* approved 1994, reaffirmed 1999).

Maintain a second sample of the freshly mixed coating system in a closed container at $95^{o} \pm 5^{o}$F for four hours with continuous mixing. Measure/record the mixture viscosity every 15 minutes with a #4 Ford viscosity cup. The test may be terminated when the viscosity exceeds 60 seconds. The admixed materials must still be sprayable 4 hours after mixing.

The samples mixed for this test should be used in coupon coatings processes.

Procedure B—Waterborne Coatings

Mix coating per the manufacturers' recommendations, thin to manufacturers' designation for admixed coating.

Allow coating to sit covered under agitation at $75^{o} \pm 5^{o}$F for 4 hours. Ensure waterborne coatings are not agitated to foam.

Measure and record the coating viscosity with #4 Ford viscosity cup every 30 minutes in accordance with ASTM D 1200. Coating viscosity shall not exceed admix viscosity by more than 15 seconds after 4 hours, with no gelling of the admixed coating after 6 hours. If allowed by the coating manufacturer, the coating may be thinned with the appropriate amount of water if the viscosity is too high after 4 hours. The viscosity shall be reported in centistokes.

Rationale

All participants agreed the agitation history and temperature at which coating mixtures are maintained are important parameters in determining the pot life of the mixture. This test provides data to characterize the pot life envelope. Knowledge of initial viscosity and viscosity change, in relation to time and temperature is important for determining the effective time frame for coating application. Different coating systems will exhibit different viscosity properties making some systems easier to handle than others; however, applicators can usually modify operating procedures to accommodate the range of mixture characteristics.

Test Methodology

Table 3-2 Test Methodology for Pot Life (Viscosity) Test	
Parameters	Temperature, viscosity
Coupons Per Coating System	None
Control Coupons Required For Testing	None
Amount of Coating Per Test	One gallon of mixed coating per temperature condition
Acceptance Criteria	Procedure A – Solvent-Borne Coatings Viscosity of both test batches shall not exceed 60 seconds after 4 hours of continuous mixing in a closed container maintained at $75^{o} \pm 5^{o}$F (Batch 1) and $95^{o} \pm 5^{o}$F (Batch 2). The admixed materials must still be sprayable 4 hours after mixing. Procedure B – Waterborne Coatings Coating viscosity shall not exceed admix viscosity by more than 15 seconds after 4 hours, with no gelling of the admixed coating after 6 hours.

Unique Equipment or Instrumentation

- # 4 Ford cup - Figure 1 in ASTM D 1200
- Magnetic stirring unit, or equivalent, for one-gallon containers
- Environmental chamber for temperature control
- Timer

Data Analysis and Reporting

- Report viscosity measurements for every 30 minutes in centistokes and attach record to the "Coating System Application Evaluation and Inspection Report" (Appendix A), or an equivalent form.

3.1.2. Ease of Application

Test Description

This procedure is used to determine how easily a coating system may be applied.

Prepare the test coupons as described in Section 3, noting the appropriate coating application processes and equipment. This evaluation will be conducted while preparing "Control Coupons" for each coating described in this JTP. Accomplish tests at $75^{o} \pm 5°F$.

The Dry Film Thickness shall be measured in accordance with SSPC-PA-2 (*Measurement of Dry Coating Thickness with Magnetic Gages*, revised 2004).

Rationale

This screening test is conducted to identify and eliminate those candidate coating systems that are difficult to properly apply under normal maintenance operation conditions. All participants have agreed that *Ease of Application* is a performance requirement.

Test Methodology

Table 3-3 Test Methodology for Ease of Application Test	
Parameters	Coating Manufacturer preparation instructions; $75^{o} \pm 5°F$ and 50% ± 10% RH
Coupons Per Coating System	Not Applicable
Trials Per Test Coupon	One (1)
Control Coupons Required For Testing	Not Applicable
Acceptance Criteria	Smooth coat, with acceptable appearance, no runs, bubbles, or sags. Ability to cover the properly prepared/primed substrate with a single coat (one coat hiding ability). Measure Dry Film Thickness.

Unique Equipment and Instrumentation

- Magnetic Gage per SSPC-PA-2

Data Analysis and Reporting

- Report applicator evaluation of the coating application and Dry Film Thickness (DFT) in accordance with SSPC-PA-2 (*Measurement of Dry Coating Thickness with Magnetic*

Gages, revised 2004) on the "Coating System Application Evaluation and Inspection Report" (Appendix A), or an equivalent form.

3.1.3. Surface Appearance

Test Description

The purpose of this test is to evaluate and compare the surface appearance of the candidate and control coating systems.

Examine the surface of each coated test coupon for coating defects with unaided eye and with 10X magnification. Micro-cracks extending no more than ¼-inch from the panel edge are acceptable. A slight orange peel appearance is acceptable. Color and gloss measurements shall be conducted on each coated coupon per ASTM D 2244 (*Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates,* approved 1993, revised 2002) and ASTM D 523 (*Standard Test Method for Specular Gloss*, reaffirmed 1999), respectively, to document the specular gloss of the original finish of the control test coupons. The surface appearance of the topcoat is required to be evaluated only after the entire primer/topcoat system has been applied.

Rationale

This test is conducted to provide critical detailed evaluation of coating appearance and integrity. All participants agreed the surface appearance evaluation is a performance requirement.

Test Methodology

Table 3-4 Test Methodology for Surface Appearance Test	
Parameters	10X Magnification
Coupons Per Coating System	Not Applicable
Trials Per Test Coupon	One (1)
Control Coupons Required For Testing	Not Applicable
Acceptance Criteria	No streaks, blistering, voids, air bubbles, cratering, lifting, blushing, or other surface defects/irregularities. No micro-cracks observable at 10X magnification.

Unique Equipment or Instrumentation

- 10X optical magnifier
- Hunter Lab "Miniscan" Spectrophotometer (using CIE L*a*b* Color Measurement System) or equivalent

- Hunter Lab "Progloss" Meter or equivalent

Data Analysis and Reporting

- Measure and report observation on any coating defects, original color readings, and gloss readings on the "Coating System Application Evaluation and Inspection Report" (Appendix A), or an equivalent form.

3.1.4. Dry-To-Touch (Sanding)

Test Description

This procedure assists in determining the drying time (dry-to-touch) required for coating systems.

Coatings are applied to test coupons in accordance with manufacturers' directions/specifications and allowed to air dry for 24 ± 3 hours at the conditions outlined in Section 3. After 24 ± 3 hours, the coating is lightly abraded with very fine-grit nylon web pad to evaluate the ease of sanding.

Rationale

This test documents the time that a coating is "dry to the touch" so that the item can be handled without damaging the coating. All participants agreed it was important to know the drying time required before a succeeding coat may be applied.

Test Methodology

Table 3-5 Test Methodology for Dry-To-Touch (Sanding) Test	
Parameters	Coating cure time
Coupons Per Coating System	Three (3) A36
Trials Per Coupon	One (1)
Control Coupons Required For Testing	Three (3) A36
Acceptance Criteria	No rolling or scribing during sanding and "easy" sanding (as evaluated by technician).

Unique Equipment or Instrumentation

- Very fine grit nylon web abrasive pads (3M Co. Scotch Brite Type A, #6448 Light duty hand pad, or equivalent)

Data Analysis and Reporting

- Report technician evaluation of candidate coating on the "Coating System Application Evaluation and Inspection Report" (Appendix A), or an equivalent form.
- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon shall be taken after the test.

3.1.5. Accelerated Storage Stability

Test Description

This test evaluates any changes in consistency and certain other properties that may take place when liquid coatings are stored at a temperature above 32°F. This test simulates some of the effects of storage for 6 months to 1 year at 75° ± 3.5°F.

Obtain duplicate samples of the coating in the original unopened containers, preferably no larger than 1 quart. Open one of the containers and note any skinning, corrosion on the interior of the can, odors of putrefaction, rancidity, or souring. Store the samples, undisturbed for one-month at 125° ± 2°F. Bring the stored sample to 75° ± 3.5°F. Open the containers mix and apply the coatings to test coupons per ASTM D 1849 (*Standard Test Method for Package Stability of Paint*, approved 1995, reaffirmed 2003).

Rationale

The stability of a coating system while in extended storage is an important parameter in determining an acceptable coating for steel structures. This test simulates 6 months to a year of storage. All participants have agreed that storage stability of a coating is a performance requirement.

Test Methodology

Table 3-6 Test Methodology for Accelerated Storage Stability Test

Parameters	125° ± 2°F; Quart containers
Coupons Per Coating System	Three (3) A36
Trials Per Coupon	One (1)
Control Coupons Required For Testing	Three (3) A36
Acceptance Criteria	No skinning, grains, lumps, of the coating, pressure buildup, or corrosion on the container, odor of spoilage or cloudy appearance of any catalyst.

Unique Equipment or Instrumentation

- Heated storage room or container

Data Analysis and Reporting

On the "Coating System Screening Evaluation and Inspection Report" (Appendix B), or an equivalent form, report:

- Time of storage in days and the temperature of the storage
- Initial and final sample weights
- Any changes in the coating consistency or odors; any grains, lumps or streaks in the brushed film
- Rate the finish per paragraph 5.2.4 of ASTM D 1849

3.1.6. Cure Time (MEK Solvent Rub)

Test Description

This test determines how long an applied coating system requires to fully cure at room temperature up to a period of 14 days at 50% ±10% RH. Liquid primer/topcoat coating systems are required to be tested against this requirement.

Every two days, for a period of 14 days, perform twenty-five double-rubs (back and forth) on the coated panels with clean cheesecloth wetted with methyl ethyl ketone (MEK). Perform this test in accordance with ASTM D 4752 (*Standard Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub*, approved 1987, revised 2003). Each test should be conducted on a previously untested area of the coating. Visually examine the coating for substrate metal exposure. Pigment on the cheesecloth does not indicate failure.

Rationale

Although MEK use is being phase out, the participants deemed the MEK solvent rub test as the test of choice as it is more stringent than an acetone rub test. This test is a commonly accepted industrial criterion for determining coating cure and only small amounts of MEK is consumed. Inspecting at two-day intervals is required by participants to determine the actual cure time. All participants agreed the MEK rub test is a performance requirement.

Test Methodology

Table 3-7 Test Methodology for Cure Time (MEK Solvent Rub) Test

Parameters	MEK saturated terry cloth rag, 50 double rubs
Coupons Per Coating System	Three (3) A36
Trials Per Coupon	Three (3)*

Table 3-7 Test Methodology for Cure Time (MEK Solvent Rub) Test	
Control Coupons Required For Testing	Three (3) A36
Acceptance Criteria	No effect on surface or coating on the cloth (Resistance Rating 5)

*Perform succeeding trials on coupon areas that have not previously been rubbed.

Unique Equipment and Instrumentation

- None

Data Analysis and Reporting

On the "Coating System Screening Evaluation and Inspection Report" (Appendix B), or an equivalent form, report:

- Results of MEK rub test on candidate coating using rating system in ASTM D 4752, Table 1 (*Scale for Resistance Rating*)
- Dry Film Thickness of the coating
- Elapsed time between the application of the coating and the running of the tests
- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon shall be taken after the test.

3.1.7. Solvent (Acetone) Rub

Test Description

This test determines how long an applied coating system requires to fully cure at room temperature up to a period of 14 days at 50% ±10% RH. Liquid primer/topcoat coating systems are required to be tested against this requirement.

Every two days, for a period of 14 days, perform twenty-five double-rubs (back and forth) on the coated panels with clean cheesecloth wetted with acetone. Perform this test in accordance with ASTM D 4752 (*Standard Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub*, approved 1987, revised 2003), except use acetone instead of MEK. Each test should be conducted on a previously untested area of the coating. Visually examine the coating for substrate metal exposure. Pigment on the cheesecloth does not indicate failure.

Rationale

Acetone is used in place of MEK because it is judged that parts will encounter acetone more often than MEK. An MEK solvent rub test for primer/topcoat systems is specified in Section 3.1.6.

Test Methodology

Table 3-8 Test Methodology for Solvent (Acetone) Rub Test	
Parameters	Acetone saturated cheesecloth, 50 double rubs
Coupons Per Coating System	Three (3) A36
Trials Per Coupon	Three (3)*
Control Coupons Required For Testing	Three (3) A36
Acceptance Criteria	No effect on surface or coating on the cloth (Resistance Rating 5)

*Perform succeeding trials on coupon areas that have not previously been rubbed.

Unique Equipment and Instrumentation

- None

Data Analysis

On the "Coating System Screening Evaluation and Inspection Report" (Appendix B), or an equivalent form, report:

- Results of Acetone rub test on candidate coating using rating system in ASTM D 4752, Table 1 (*Scale for Resistance Rating*)
- Dry Film Thickness of the coating
- Elapsed time between the application of the coating and the running of the tests
- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon shall be taken after the test.

3.1.8. Cleanability

Test Description

This test evaluates the resistance of a topcoat to soil adhesion and staining.

Prepare an *artificial soil* by placing 50 ± 0.5 grams of carbon black and 500 ± 1 gram of hydraulic fluid [conforming to MIL-PRF-83282D (*Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft, Metric, NATO Code Number H-537*, issued 1986, revised 1997)] into a one quart jar. Homogenize using a high-shear mixer for 15 ± 1 minutes. Prepare a *standard formula* and record the composition.

Prepare a *standard formula cleaner*. Lightly clean the test coupon with a detergent. Rinse the coupon three times with deionized water. Dry the coupon for 18 hours at 120° ± 4°F.

Measure the lightness value ("A", the L-value for the unsoiled test coupon) with a colorimeter.

Hand-mix the prepared artificial soil. Using a soft bristle acid brush, coat the test coupon with the artificial soil. Remove excess soil by placing a folded absorbent tissue onto the surface and passing a 5-pound rubber roller over the tissue two times. Brush the soiled surface using ten one-directional strokes of a hog bristle brush. Bake the test coupon at 221° ± 4°F for 60 ± 1 minutes. Measure the lightness value ("B", the L-value for the soiled test coupon) with a colorimeter.

Dilute the standard cleaner formula by mixing one part by volume of cleaner with nine parts by volume of deionized water. Attach a cellulose sponge to the cleaning head of the wear tester. Place the soiled test coupon in the tester at a 45° angle. Saturate the sponge with cleaner and place onto the test coupon. After the sponge and soiled coupon have been in contact for 60 ± 5 seconds, clean the soiled coupon with 5 cycles of the wear tester. Immediately turn the coupon through a 90° angle and clean for an additional 5 cycles. Rinse the coupon with room temperature tap water and allow to dry. Measure the lightness value of the coupon ("C", the L-value for the cleaned panel) with a colorimeter.

Rationale

The procedure is contained in MIL-PRF-85285 (*Coating: Polyurethane, Aircraft and Support Equipment*, issued 1988, revised 2002). Participants agreed that cleanability is a performance requirement.

Test Methodology

Table 3-9 Test Methodology for Cleanability Test	
Parameters	Per MIL-PRF-83282D and MIL-PRF-85285
Coupons Per Coating System	Three (3) A36
Trials Per Coupon	One (1)
Control Coupons Required For Testing	Three (3) A36
Acceptance Criteria	Cleaning efficiency of candidate coating equal to or better than control coatings.

Unique Equipment or Instrumentation

- High shear mixer
- Mechanical grease worker
- Acid brush
- Rubber roller, 5-pounds
- Forced draft oven(s) capable of 120 ± 4°F and 221 ± 4°F

- Colorimeter, McBeth Model MC-10TOS or equivalent
- Wear Tester, Gardner Heavy Duty Wear Tester Cat. No. WG 6700 or equivalent
- Hog bristle brushes
- Cellulose sponge (3.5 inches by 2.75 inches)

Data Analysis

- Calculate the percentage cleaning efficiency by

  $$[(C - B) \div (A - B)] \times 100$$

  (Refer to *Test Description* for definitions of A, B, and C) and report on the "Coating System Screening Evaluation and Inspection Report" (Appendix B), or an equivalent form.
- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon shall be taken after the test.

3.1.9. X-Cut Adhesion by Wet Tape

Test Description

This test method establishes the adequacy of intercoat and surface adhesion of an organic coating immersed in water by applying pressure sensitive tape over a scribed area of the coating. Perform this test in accordance with ASTM D 3359 (*Standard Test Methods for Measuring Adhesion by Tape Test*, approved 1995, revised 2002), Test Method A.

Immerse each test panel in deionized water at room temperature for 24 hours in accordance with Method 6301.3 [*Adhesion (Wet) Tape Test*] of FED-STD-141 (*Paint, Varnish, Lacquer and Related Materials*, approved 1986, last revised 2001). Remove each panel from the water and wipe dry with a soft cloth. Within one minute of removing a panel from the water, scribe two parallel lines one inch apart and scribe an "X" between the parallel lines (**Note:** This is a modification of the scribing described in Method 6301.2 of FED-STD-141). Apply tape over the scribed area, smoothing it down by passing a 4.5-pound roller across the tape eight times. Quickly and smoothly pull the tape off the panel at a 45° angle to the surface. Visually examine the panel for blistering and loss of adhesion. Accomplish this test using only the top ½ of the test coupon. Retain the test coupon for further testing in Section 3.1.10. [*Tensile (Pull-Off) Adhesion*].

Evaluate the adhesion of each coating system to the substrate as specified in Test Method A of ASTM D 3359. Inspect the X-cut and parallel lines-cut for removal of the coating from the substrate or previous coatings and rate the adhesion in accordance with the 0-5 scale

outlined in ASTM D 3359, Method A, Paragraph 7, *Procedure*, with the *0-A* rating being *coating removal beyond the scribed area* and the *5-A* rating being *no peeling or removal*.

Rationale

The X-cut with parallel lines scribe procedure increases the severity of this test over a dry tape adhesion test using a single "X" scribe and provides quantitative data for the adhesion of a coating system to the underlying metal substrate. All participants have agreed that adhesion testing is a performance requirement.

Test Methodology

Table 3-10 Test Methodology for X-Cut Adhesion by Tape Test	
Parameters	ASTM D 3359 rating related to amount of coating removal
Coupons Per Coating System	Three (3) A36
Trials Per Coupon	One (1)
Control Coupons Required For Testing	Three (3) A36
Acceptance Criteria	Candidate coating performs as well or better than control coatings and rates greater than or equal to 4a as specified in ASTM D 3359

Unique Equipment or Instrumentation

- One-inch (25mm) wide semitransparent pressure-sensitive tape 3M Code 250 or equivalent
- 4.5-pound rubber-covered roller, approximately 3.5 inches diameter by one-inch wide.
- Cutting tool
- Cutting guide

Data Analysis and Reporting

On the “Coating System Screening Evaluation and Inspection Report” (Appendix B), or an equivalent form, report:

- Results of the test using the classification guide in ASTM D 3359, Test Method A, paragraph 7.7
- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon shall be taken after the test.

3.1.10. Tensile (Pull-Off) Adhesion

Test Description

This test evaluates the pull-off strength (commonly referred to as adhesion) of a coating. The test determines either the greatest perpendicular force (in tension) that a surface area can bear before a plug of material is detached, or whether the surface of the material remains intact at a prescribed force.

This test method uses a class of apparatus known as portable pull-off adhesion testers. They are capable of applying a concentric load and counter load to a single surface so that coatings can be tested even though only one side is accessible. Measurements are limited by the strength of adhesion bonds between the loading fixture and the specimen surface or the cohesive strengths of the adhesive, coating layers, and substrate.

Perform this test in accordance with ASTM D 4541 (*Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers*, approved 2002).

Rationale

Participants agreed that adhesion is a critical performance requirement.

Test Methodology

Table 3-11 Test Methodology for Pull-Off Adhesion Test	
Parameters	Per ASTM D 4541
Coupons Per Coating System	One (1) A36
Trials Per Coupon	Three (3)
Control Coupons Required For Testing	One (1) A36
Acceptance Criteria	Pull-off strength of candidate coating achieved at time of failure equal to or better than control coatings

Unique Equipment and Instrumentation

- Patti adhesion tester or equivalent

Data Analysis

- Record the strength at which adhesion fails on the "Coating System Screening Evaluation and Inspection Report" (Appendix B), or an equivalent form; there should be three (3) data points for each coupon
- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon and the dolly shall be taken after the test.

3.1.11. Knife Test

Test Description

This test evaluates coatings for brittleness, toughness, and tendency to ribbon by cutting a narrow ribbon of the coating with a serviceable knife that has a sharp blade.

Perform this test in accordance with FED-STD-141 (*Paint, Varnish, Lacquer and Related Materials: Methods of Inspection, Sampling and Testing*, approved 2001), Method 6304.2 (*Knife Test*). Hold the blade at a 30 degree angle from the panel while performing the incision.

Rationale

The purpose of this test is to determine the brittleness of a film. This test was identified by AFSPC and other stakeholders agreed that it is a performance requirement.

Test Methodology

Table 3-12 Test Methodology for Knife Test	
Parameters	Hold blade at 30 degree angle
Coupons Per Coating System	One (1) A36
Trials Per Coupon	Three (3)
Control Coupons Required For Testing	One (1) A36
Acceptance Criteria	Candidate coating performs as well as or better than control coatings

Unique Equipment or Instrumentation

- Sharp Knife

Data Analysis and Reporting

- Report how coating reacts to scribe on the "Coating System Screening Evaluation and Inspection Report" (Appendix B), or an equivalent form.
- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon shall be taken after the test.

3.2. Common Tests for Alternatives to Aliphatic Isocyanate Urethane Coatings

The engineering, performance, and testing requirements of candidate alternatives are listed in Table 2-2. Screening tests that are intended for use prior to common tests are described in Section 3.1.

3.2.1. Removability

Test Description

This test determines the relative ease of removing coating on a 2-inch diameter area on a test coupon using Aluminum Oxide blast media after artificial weathering.

The coupons used for this test shall be three (3) inches by six (6) inches to accommodate the weathering chamber. Coated test panels shall be weathered for 500 hours in accordance with ASTM G 155 (*Standard Practice for Operating Light Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials*, approved 2000), G 155 corresponding test cycle for G 26, Method A (continuous light with intermittent water spray), prior to testing for removability.

Only half of the coupon will have the coating removed. The weathered panels shall be placed on a rack and tilted to a 60° angle to the horizontal. Adjust the system air pressure to 90 psi. Use only Aluminum Oxide blast media for this test. Media flow must be set in accordance with the media manufacturer's specifications. Direct the abrasive blast jet at the same area for 1 minute. Record the dry film thickness of the coating remaining in the abrasive blast area. Identical removal procedures shall be used for both the candidate and control coating systems.

Rationale

Coating systems must typically be removed after prescribed periods of use. Evaluation of relative removal ease for candidate alternate coating systems after aging is necessary for predicting the effectiveness of field maintenance operations.

Test Methodology

Table 3-13 Test Methodology for Removability Test

Parameters	Aluminum Oxide blast material; Blast pressure 90 psi
Coupons Per Coating System	Three (3) A36; 3x6 inch panels
Trials Per Coupon	One (1)
Control Coupons Required For Testing	Three (3) A36; 3x6 inch panels
Acceptance Criteria	Less than one minute to penetrate to substrate; Measure DFT of remaining coating

Note: The initial gloss, color, and dry film thickness of each panel will be recorded on the "Coating System Screening Evaluation and Inspection Report" (Appendix B), or an equivalent form, during application.

Unique Equipment or Instrumentation

- Sand Blast Cabinet
- Magnetic gage per SSPC-PA-2

Data Analysis and Reporting

On the "Coating System Common Evaluation and Inspection Report" (Appendix C), or an equivalent form, report:

- Dwell time to substrate
- Measure and report Dry Film Thickness (DFT) in accordance with SSPC-PA-2 (*Measurement of Dry Coating Thickness with Magnetic Gages*, revised 2004)
- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon shall be taken after the test.

3.2.2. Repairability

Test Description

This test determines the relative ease of replacing and blending-in coatings that have been removed or otherwise damaged. The dry tape adhesion test provides a procedure for establishing acceptability of intercoat and surface adhesion of an organic coating by applying pressure-sensitive adhesive tape over a scribed area of the coating, then removing that tape.

The coupons used for this test shall be three (3) inches by six (6) inches to accommodate the weathering chamber. Three procedures will be required for accomplishing this task; (A) Repair the baseline control coating with a baseline coating, (B) Repair the baseline control coating with each of the alternative coatings, and (C) Repair each alternative coating with the alternative coating. Only one set of coupons with the baseline coating repaired with the baseline coating is required for comparison. Test panels from which coatings have been removed (Section 3.2.1., *Removability*) shall be used for this evaluation.

Replace the removed coating in accordance with the coating manufacturer's repair instructions. Examine the surface of each test panel to evaluate the appearance of the repair. The repaired area must be free of voids, air bubbles or other significant defects. The repaired area shall be inspected for coating quality and match to the original, aged coating on the top half of the test coupon using ASTM D 523. Conduct a dry tape adhesion test on the repaired areas after the prescribed cure times of test coating on the repaired area to ensure the coating adherence. Perform this test in accordance with Method A of ASTM D 3359 (*Standard Test*

Methods for Measuring Adhesion by Tape Test, approved 1995, revised 2002), except use a 4.5 lb. roller instead of finger pressure for smoothing down the tape. In performing this test, scribe two "X" incisions through the coating so that the smaller angle of each "X" is 30°-45°, making sure that the coating has been scribed all the way to the substrate. The scribe must have a 45-degree bevel, and each line of each "X" should be approximately 1.5 inches long. Immediately place a piece of tape over the intersection of each "X" and smooth down by passing a 4.5 lb. roller over it eight times. Remove the tape rapidly at approximately an 180° angle. Inspect the incision area for peel away.

Rationale

This test provides data to evaluate how effectively coatings can be replace/repaired in field maintenance environments. All participants have agreed that coating reparability is a performance requirement.

Test Methodology

Table 3-14 Test Methodology for Repairability Test	
Parameters	Coating Manufacturer's instructions for coating repair
Coupons Per Coating System	Three (3) A36 with the baseline coating; 3x6 inch panels Three (3) A36 with the alternative coating; 3x6 inch panels
Trials Per Coupon	One (1)
Control Coupons Required For Testing	Three (3) A36 total for comparison; 3x6 inch panels
Acceptance Criteria	Ease of replacement of damaged areas of the test coatings, color matching of aged versus new material; No streaks, blistering, voids, air bubbles, over-spray "halo," cratering, lifting, blushing, or other surface irregularities; No peel away of the repaired coating during the dry tape adhesion test

Unique Equipment or Instrumentation

- 10X optical magnifier
- Hunter Lab "Miniscan" Spectrophotometer (using CIE L*a*b* Color Measurement System) or equivalent per ASTM D 2244 (*Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates,* approved 1993, revised 2002)
- Hunter Lab "Progloss" Meter or equivalent

- 1 inch masking tape, 3M Company Type 250 or equivalent
- 4.5 pound roller
- Carbide tip scribe

Data Analysis and Reporting

On the "Coating System Common Evaluation and Inspection Report" (Appendix C), or an equivalent form, report:

- Technician evaluation of coating quality and match to the original, aged coating on the top half of the test coupon.
- Coating color measurements of aged area and repaired area per ASTM D 523 (*Standard Test Method for Specular Gloss*, reaffirmed 1999).
- The adhesion rating as specified in ASTM D 3359, Method A, Section 7
- One color photograph of a coupon coated with each candidate primer or primer/topcoat system shall be taken after recoating is completed. One color photograph of each tested coupon shall be taken after the tape test is completed.

3.2.3. Abrasion Resistance

Test Description

This procedure measures the resistance of coatings to wear from abrasion.

Tests shall be conducted in accordance with ASTM D 4060 (*Standard Test Method for Abrasion Resistance of Organic Coating by the Taber Abraser*, revised 2001). Weigh the test coupon prior to testing and post testing.

Rationale

This test documents the abrasion protection (wear resistance) provided by the coating for the substrate.

Test Methodology

Table 3-15 Test Methodology for Abrasion Resistance Test	
Parameters	Per ASTM D 4060
Coupons Per Coating System	Three (3) A36
Trials Per Coupon	One (1)
Control Coupons Required For Testing	Three (3) A36
Acceptance Criteria	Candidate coating removal (weight loss) less than or equal to control coatings or less than 4 mm^2 exposed substrate

Unique Equipment or Instrumentation

- Per ASTM D 4060

Data Analysis and Reporting

- Report coating weight and area loss data for the candidate and control coating system per ASTM D 4060 on the "Coating System Common Evaluation and Inspection Report" (Appendix C), or an equivalent form.
- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon shall be taken after the test.

3.2.4. Gravelometer

Test Description

This procedure is for testing and evaluating the resistance of surface coatings to chipping by gravel impact. The test is designed to reproduce the effect of gravel or other media striking exposed paint or coated surfaces.

The coupons used for this test shall be six (6) inches by twelve (12) inches. Tests shall be conducted in accordance with ASTM D 3170 (*Standard Test Method for Chipping Resistance of Coatings*, approved 1973, revised 2003). Rate the coating per visual standard.

The test consists of projecting standardized road gravel by means of a controlled air blast onto a suitable test panel. The testing apparatus is called a gravelometer, designed to contain road gravel, a test panel holder, and a gravel projecting mechanism. All testing will be conducted under ambient temperature conditions as specified in Paragraph 5.4.3 of ASTM D 3170. After the gravel impact, tape is applied to remove any loose paint chips remaining on the panel, and the degree of chipping is determined by visual comparison.

Rationale

This test documents the chip protection provided by the coating for the substrate. Structures, particularly those near launch sites, are often subjected to flying debris.

Test Methodology

Table 3-16 Test Methodology for Gravelometer Test	
Parameters	1 pint standardized gravel; per ASTM D 3170
Coupons Per Coating System	Three (3) A36; 6x12 inch panels

Table 3-16 Test Methodology for Gravelometer Test	
Trials Per Coupon	One (1)
Control Coupons Required For Testing	Three (3) A36; 6x12 inch panels
Acceptance Criteria	Candidate coating performs as well as or better than control coatings

Unique Equipment or Instrumentation

- Gravelometer per ASTM D 3170

Data Analysis and Reporting

- Report Visual Rating on the "Coating System Common Evaluation and Inspection Report" (Appendix C), or an equivalent form.
- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon shall be taken after the test.

3.2.5. Fungus Resistance

Test Description

This test will be performed to measure the extent to which a coating will support fungal growth and how the fungal growth affects the adhesion of the topcoat.

Prepare subcultures of Aspergillus niger, Aspergillus flavus, Aspergillus versicolor, and Penicillium fungiculosum on an appropriate medium such as potato dextrose agar. Culture Chaetomium globosum on strips of filter paper overlaid on the surface of a mineral salts agar that consists of agar and a *mineral salts solution* with the following composition:

Table 3-17 Mineral Salts Solution Composition	
	Quantity
Potassium dihydrogen orthophosphate	0.7 gram
Potassium monohydrogen orthophosphate	0.7 gram
Magnesium sulfate heptahydrate	0.7 gram
Ammonium nitrate	1.0 gram
Sodium chloride	0.005 gram
Ferrous sulfate heptahydrate	0.002 gram
Zinc sulfate monohydrate	0.002 gram
Distilled water	1000 milliliters

Incubate subcultures at 86 ± 2.5°F for 14 to 21 days.

Prepare a spore suspension by pouring 10 milliliters of an aqueous solution containing 0.05 grams per liter of a nontoxic wetting agent (e.g., sodium dioctyl sulfosuccinate or sodium lauryl sulfate) onto each agar culture, and then pouring the mixture into an Erlenmeyer flask that contains 45 milliliters of water and 50 to 75 glass beads that have a five (5) millimeter diameter. Shake the flask. Filter the mixture with glass wool to remove the large mycelial fragments and clumps of agar. Resuspend the spores three additional times, filtering each time. After the final rinsing, suspend the spores in the mineral salts solution (composition previously described), so that the solution has 1,000,000 ± 200,000 spores per milliliter as determined with a counting chamber. Verify the viability of each spore suspension by incubating an inoculated potato dextrose agar plate at 75° - 88°F for 7 to 10 days and checking for fungal growth. If fungal growth does not occur, the fungal suspensions must be prepared again.

Prepare the final mixed spore suspension by combining equal volumes of each fungal suspension. Prepare an environmental chamber that has 95 ± 5% humidity at 86 ± 2°F, with an air velocity between 98 and 335 feet per minute (0.5 and 1.7 meters per second). Place the test coupons and cotton strips (used for a control) in the environmental chamber for at least 4 hours immediately prior to inoculation. Inoculate the coupons with the final mixed spore suspension by spraying a mist of the suspension with an atomizer or nebulizer. After 7 days of inoculation, the cotton strips should be at least 90 percent covered with fungal growth; if not, repeat the entire test. After a total of 84 days, remove the test coupons. Evaluate the topcoat adhesion in accordance with Section 3.1.9 (*X-Cut Adhesion by Wet Tape*) of this JTP. Visually inspect for fungal growth.

Rationale

This test was identified as a performance requirement. This fungus resistance test is performed in accordance with Method 508.5 (*Fungus)* of MIL-STD-810F (*Department of Defense Test Method Standard for Environmental Considerations and Laboratory Tests*, issued 2000, last changed 2003). Method 508.5 of MIL-STD-810F recommends that the minimum test duration is 28 days, but suggests a longer test duration of 84 days to allow for fungal germination, breakdown of carbon molecules, and degradation of the material being tested. The longer test duration was selected for this test procedure.

Test Methodology

Table 3-18 Test Methodology for Fungus Resistance Test	
Parameters	Five (5) types of fungus/84 days at 95 ± 5% RH/ 86 ± 2°F
Coupons Per Coating System	Fifteen (15) A36—Three (3) for each of the 5 types of fungus
Trials Per Coupon	One (1)
Control Coupons Required For Testing	Fifteen (15) A36—Three (3) for each of the 5 types of fungus

Table 3-18 Test Methodology for Fungus Resistance Test	
Acceptance Criteria	Adhesion per Section 3.1.9 of this JTP; Does not support fungal growth

Unique Equipment and Instrumentation

- Environmental chamber capable of maintaining 86 ± 2°F and 95 ± 5% humidity
- 125-W Heating coil
- Psychrometer
- Counting chamber
- Atomizer or nebulizer
- Unique equipment and instrumentation required for the wet tape adhesion test (Section 3.1.9 of this JTP).

Data Analysis

On the "Coating System Common Evaluation and Inspection Report" (Appendix C), or an equivalent form, report:

- Test item identification, the presence/absence of fungal growth at a seven-day check and at the end of the test, the location of the fungi, and a narrative description of growth. Include a determination of the effect of fungi on performance.
- Results of the Adhesion testing using the classification guide in ASTM D 3359, Test Method A, paragraph 7.7.
- One color photograph of a coupon coated with each candidate primer/topcoat system and of a coupon coated with the baseline primer/topcoat system shall be taken before the test. One color photograph of each tested coupon shall be taken after the test.

3.2.6. Accelerated Weathering

Test Description

This accelerated test evaluates the degree of coating color and gloss degradation when exposed to simulated outdoor weathering.

The coupons used for this test shall be three (3) inches by six (6) inches to accommodate the weathering chamber. The initial gloss and color measurements of each panel will be recorded on the "Coating System Screening Evaluation and Inspection Report" (Appendix B), or an equivalent form, during application. Test coupons are exposed to UV, through a borosilicate inner and outer filter to simulate sunlight, and intermittent moisture to failure for 2000 hours in accordance with ASTM G 155 (*Standard Practice for Operating Light Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials*, approved 1996), G 155 corresponding test cycle for G 26, Method A (continuous light with intermittent water spray). Measure at 500-hour intervals to failure. Failure should

be defined as a delta E (ΔE) change. At the conclusion of testing, measure color and gloss changes on each coated coupon per ASTM D 2244 (*Test method for Calculation of Color Differences from Instrumentally Measured Color Coordinates*, approved 1993, revised 2002) and ASTM D 523 (*Standard Test Method for Specular Gloss*, reaffirmed 1999), respectively.

Rationale

Steel structures must withstand daily outdoor exposure to sunlight and wet/dry cycles. This procedure will document coating resistance to accelerated outdoor weather exposure conditions. All of the participants agreed accelerated weathering is a performance requirement.

Test Methodology

Table 3-19 Test Methodology for Accelerated Weathering Test	
Parameters	140 ± 5°F; 50 ± 5% RH; Borosilicate glass inner and outer filter; One cycle: 102 minutes of light only and 18 minutes of light and water spray; Spectral irradiance levels 0.35 W/m^2 incident at 340 nm; Measure every 500 hours (250 cycles) to failure up to 2000 hours
Coupons Per Coating System	Three (3) A36; 3x6 inch panels
Trials Per Coupon	One (1)
Control Coupons Required For Testing	Three (3) A36; 3x6 inch panels
Acceptance Criteria	Color change performance < one unit (ΔE) @ 500 hr intervals

Unique Equipment or Instrumentation

- Xenon light/moisture environmental exposure chamber per ASTM G 155, with a borosilicate glass inner and outer filter
- Hunter Lab "Miniscan" Spectrophotometer (using CIE L*a*b* Color Measurement System) or equivalent
- Hunter Lab "Progloss" Meter or equivalent

Data Analysis and Reporting

- On the “Coating System Common Evaluation and Inspection Report” (Appendix C), or an equivalent form, report color/gloss change data for test coatings at 500 hour intervals until failure.

- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon shall be taken after the test.

3.2.7. Mandrel Bend Flexibility

Test Description

This test evaluates coating flexibility and adhesion to substrate limits when the test coupon is bent around a ¼-inch fixed diameter mandrel.

The bend test shall be conducted in accordance with the version of ASTM D 522 (*Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings*, approved 1993, revised 2001), Test Method B for Ambient Temperature.

Rationale

This method will determine whether the coatings will provide the necessary flexibility when compared to other more conventional coatings. All participants have agreed that the mandrel bend test is a performance requirement for the coatings.

Test Methodology

Table 3-20 Test Methodology for Mandrel Bend Flexibility Test	
Parameters	¼-inch diameter mandrel at ambient temperature
Coupons Per Coating System	Three (3) A36
Trials Per Coupon	One (1)
Control Coupons Required For Testing	Three (3) A36
Acceptance Criteria	No peeling or delamination from the substrate and no cracking greater than ¼-inch from the edges.

Unique Equipment or Instrumentation

- Mandrel bend apparatus (¼-inch diameter mandrel)

Data Analysis and Reporting

On the "Coating System Common Evaluation and Inspection Report" (Appendix C), or an equivalent form, report:
- Pass/fail on the ¼ inch mandrel test
- Material characteristics of the alternatives after this test is performed

- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon shall be taken after the test

3.2.8. 18-Month Marine Environment

Test Description

This test evaluates the performance of the test and control coatings after an 18-month outdoor exposure in a marine environment.

The 4 inch x 6 inch composite panels shall be used for this test. Coat all surfaces of the test panels with the prescribed coating. Install the test panels at the Kennedy Space Center (KSC) outdoor exposure rack 100 feet from the ocean high tide line. Follow all KSC test rack procedures for fasteners, exposure angle, and inspection interval. At the conclusion of the test, rate the test coupon condition per ASTM D 610 (*Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces*, approved 1995, revised 2001). Use the numerical grade scale in ASTM D 610, Table 1, *Scale and Description of Rust Grades*, where 0 indicates 100% surface rusting and 10 indicating less than 0.01% surface rusting. At the conclusion of the test, rate the test coupon condition per ASTM D 714 (*Standard Test Method for Evaluating Degree of Blistering of Paints,* approved 1987, revised 2002); use the reference standards in section 3. Also at the conclusion of testing, measure gloss changes on each coated coupon per ASTM D 523 (*Standard Test Method for Specular Gloss*, reaffirmed 1999).

Rationale

This test documents the actual exposure of the coatings to UV radiation, as well as different cycles of salt spray exposure. NASA requires this test for validation of alternative coating systems.

Test Methodology

Table 3-21 Test Methodology for 18-Month Marine Environment Test	
Parameters	100 feet from the ocean high tide in Florida
Coupons Per Coating System	Three (3) CCS
Trials Per Coupon	One
Control Coupons Required For Testing	Three (3) CCS
Acceptance Criteria	Gloss change and panel condition (per ASTM D 610 and ASTM D 714) of candidate coating rated equal to or better than control coatings

Unique Equipment or Instrumentation

- Outdoor test rack located 100 feet from ocean high tide line
- BYK Gardener Micro Tri-Gloss Glossmeter or equivalent

Data Analysis and Reporting

On the "Coating System Common Evaluation and Inspection Report" (Appendix C), or an equivalent form, report:

- Corrosion rating per ASTM D 610, Table 1
- Blister rating per ASTM D 714, Section 3
- Gloss measurements per ASTM D 523
- One color photograph of a coupon coated with each candidate coating and of a coupon coated with the baseline coating shall be taken before the test. One color photograph of each tested coupon shall be taken after the test.

3.2.9. Cyclic Corrosion Resistance

Test Description

These tests evaluate the ability of coating systems to prevent corrosion when exposed to a simulated neutral pH corrosive environment.

Tests shall be conducted on all coupons in accordance with General Motors (GM) 9540 P (*Accelerated Corrosion Test*, approved December 1997). Coupons will be evaluated at the conclusion of a week of testing or 5 cycles.

One test cycle is as follows:

Step 1. Expose the coupon to salt water solution (0.9% sodium chloride, 0.1% calcium chloride and 0.025% bicarbonate of soda) spray for one minute.

Step 2. Allow the coupon ambient atmospheric exposure for 89 minutes.

Step 3. Expose the coupon to salt water solution (0.9% sodium chloride, 0.1% calcium chloride and 0.025% bicarbonate of soda) spray for one minute.

Step 4. Allow the coupon ambient atmospheric exposure for 89 minutes.

Step 5. Expose the coupon to salt water solution (0.9% sodium chloride, 0.1% calcium chloride and 0.025% bicarbonate of soda) spray for one minute.

Step 6. Allow the coupon ambient atmospheric exposure for 89 minutes.

Step 7. Expose the coupon to salt water solution (0.9% sodium chloride, 0.1% calcium chloride and 0.025% bicarbonate of soda) spray for one minute.

Step 8. Allow the coupon ambient atmospheric exposure for 209 minutes.

Step 9. Expose the coupon to high humidity exposure [in accordance with GM 4465 P (*Water Fog Humidity Test*, revised 1995) at 120 ± 3°F and 1-2 ml/hr collection rate].

Step 10. Dry off exposure at 140 ± 3°F and < 30% RH.

Repeat for the appropriate number of cycles.

Rationale

The GM Accelerated Corrosion Test provides an acceptable correlation between accelerated laboratory corrosion tests and actual corrosion experienced in the field. Data from these tests will be compared with the filiform test data obtained in Section 3.2.7. to determine whether or not a correlation exists between the two test results.

Test Methodology

Table 3-22 Test Methodology for Cyclic Corrosion Resistance Test	
Parameters	Exposure conditions include: • Electrolyte solution: 0.9% sodium chloride, 0.1% calcium chloride and 0.025% bicarbonate of soda • PH: between 6.0 and 8.0 **Note:** One test cycle is equal to 24 hours, One phase is equal to 8 test cycles, Test shall encompass 60 cycles or 12 weeks
Coupons Per Coating System	Three (3) A36
Trials Per Coupon	One (1)
Control Coupons Required For Testing	Three (3) A36
Acceptance Criteria	Candidate coating performs as well or better than control coatings; No significant blistering, softening, or lifting of coating

Unique Equipment or Instrumentation

- Programmable salt spray (fog) chamber

Data Analysis and Reporting

- Report coating condition and corrosion data for candidate coating system and the control coating system(s) on the "Coating System Common Evaluation and Inspection Form" (Appendix C), or an equivalent form.
- Photograph a selected test panel for each substrate prior to test initiation to use as a reference photo, group photographs in the test chamber at the end of each 5-cycle period (or each week), and selected photographs at the terminus of the test to capture the results of the test

3.2.10. Hypergol Compatibility

Test Description

This procedure evaluates the effects on coatings from casual exposure to hypergolic fluids [nitrogen tetroxide (N_2O_4), hydrazine (N_2H_4), and monomethylhydrazine (MMH)]. This procedure provides the method to determine if a fluid could react exothermally or spontaneously ignite on contact with a material.

This test will be performed in accordance with NASA KSC MTB-175-88 (*Procedure for Casual Exposure of Materials to Hypergolic Fluids*, dated September 12, 1994), Test Method 7.1, *Reactivity Test Method*. The materials to be tested shall be identified on the "Material Identification Form" (Appendix D) based on KSC Report MTB-175-88 Figure 1, or an equivalent form. The results of the tests shall be recorded on the "Chemical Analysis Laboratory Compatibility Report," KSC Form 3-539NS (Appendix E), or an equivalent form.

The alternative coatings shall be applied in a thickness equivalent to normal use on aluminum foil (measuring 4 inches by 4 inches) and cured, if necessary, in accordance with the manufacturer's instructions.

Rationale

This test is specified in NASA-STD-6001 and was identified as a testing requirement. Materials intended for use in space vehicles, specified test facilities, and specified ground support equipment (GSE) must meet the requirements of this document.

Test Methodology

Table 3-23 Test Methodology for Hypergol Compatibility Test	
Parameters	Per NASA KSC MTB-175-88; nitrogen tetroxide (N_2O_4), hydrazine (N_2H_4), and monomethylhydrazine (MMH)
Coupons Per Coating System	One (1) 4x4 inch aluminum foil coupon
Trials Per Coupon	One (1)
Control Coupons Required For Testing	None

Table 3-23 Test Methodology for Hypergol Compatibility Test	
Acceptance Criteria	Slight to Moderate Reactivity Observed: When test data based on visual observations with the unaided eye reveal reactivity (but no ignition) and/or any changes in the visual characteristics, bulk characteristics, and/or surface characteristics of the test sample.

Unique Equipment and Instrumentation

- None

Data Analysis

- Complete the "Material Identification Form" (Appendix D), or an equivalent form.
- Complete the "Chemical Analysis Laboratory Compatibility Report" (Appendix E), or an equivalent form.

3.2.11. LOX Compatibility

Test Description

The purpose of this test is to determine if materials in oxygen environments react when mechanically impacted. A reaction from mechanical impact can be determined by an audible report, an electronically or visually detected flash, or obvious charring of the sample, sample cup, or striker pin.

Perform this test in accordance with NASA-STD-6001 (*Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion,* issued 1998). Specifically reference Test Method 13A, *Mechanical Impact for Materials in Ambient Pressure LOX*. The test system should be identical to that described in ASTM D 2512 [*Compatibility of Materials with Liquid Oxygen (Impact Sensitivity Threshold* and *Pass-Fail Techniques*), approved 1982].

Rationale

This test is specified in NASA-STD-6001 and was identified as a testing requirement. Materials intended for use in space vehicles, specified test facilities, and specified ground support equipment (GSE) must meet the requirements of this document.

Test Methodology

Table 3-24 Test Methodology for LOX Compatibility Test	
Parameters	Per NASA-STD-6001; The thickness of the sample must be the worst-case thickness. Test conditions (pressure and temperature) are the ambient pressure of the test facility and the boiling point of LOX at that pressure.
Coupons Per Coating System	Twenty (20)*
Trials Per Coupon	One (1)
Control Coupons Required For Testing	None
Acceptance Criteria	Twenty samples must not react when impacted at 72 ft-lbs (98 J). If one sample out of 20 reacts, 40 additional samples must be tested without any reactions.

*Minimum required

Unique Equipment and Instrumentation

- ABMA-Type Impact Tester

Data Analysis

- The test report must include sample identification, configuration, test conditions, number of reactions, and observations from the test. Proper reporting of the test observations, especially of unusual behavior, is critical.

3.3. Summary of Field Engineering, Performance, and Testing Requirements for Alternatives to Aliphatic Isocyanate Urethane Coatings

Field evaluations demonstrate comparative field performance of candidate coating systems when applied on operating structures. The field evaluations will be performed in conjunction with the laboratory tests. Field Evaluation and Testing Requirements are further defined in the NASA AP2 Office document, *Field Evaluations Test Plan for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes*, prepared by ITB.

4. REFERENCE DOCUMENTS

The documents in Table 4-1 were referenced in the development of this JTP. In addition, this report was leveraged from the Engineering and Technical Services for Joint Group on Acquisition Pollution Prevention (JG-APP) Pilot Projects Joint Test Protocols entitled *Joint Test Protocol (LM-P-1-1) for Validation of Alternatives to High Volatile Organic Compound (VOC) Topcoats and Primers*, dated June 16, 1997 (Revised November 19, 1998), which was prepared by Concurrent Technologies Corporation (CTC) through the National Defense Center for Environmental Excellence (NDCEE) under Contract Number DAAA21-93-C-0046 and *Joint Test Protocol (J-99-OC-014-P) for Low/No-VOC and Nonchromate Coating System for Support Equipment*, dated November 4, 1999, which was prepared by Science Applications International Corporation (SAIC) through the JG-PP under Contract Number F09603-95-D-0177 (Revised August 10, 2000 by NDCEE/CTC). Other information was leveraged from Logistics Environmental Office Pollution Prevention Project *Air Force Test Protocol ZHTV02W147 Low/No VOC Corrosion Preventive Coatings for ICBM Missile Support Equipment—Phase I*, dated July 25, 2003, which was prepared by HQ AFMC/LGPE under Contract Number GSA GS-23F-0216K.

Table 4-1 Summarized Test and Evaluation Reference Listing

Reference Document	Title	Date	Applicable Section(s) of Reference Document	JTP Test	JTP Section
ASTM D 522	*Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings*	Approved 1993, Revised 2001	Test Method B	Mandrel Bend Flexibility	3.2.7.
ASTM D 523	*Standard Test Method for Specular Gloss*	Reaffirmed 1999	n/a	Surface Appearance; Repairability; Accelerated Weathering; 18-Month Marine Environment	3.1.3.; 3.2.2.; 3.2.6.; 3.2.8.
ASTM D 610	*Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces*	Approved 1995, Revised 2001	n/a	18-Month Marine Environment	3.2.8.

Table 4-1 Summarized Test and Evaluation Reference Listing					
Reference Document	**Title**	**Date**	**Applicable Section(s) of Reference Document**	**JTP Test**	**JTP Section**
ASTM D 714	*Standard Test Method for Evaluating Degree of Blistering of Paints*	Approved 1987; Revised 2001	n/a	18-Month Marine Environment	3.2.8.
ASTM D 1200	*Test Method for Viscosity by Ford Viscosity Cup*	Approved 1994, Reaffirmed 1999	Figure 1	Pot Life (Viscosity)	3.1.1.
ASTM D 1849	*Standard Test Method for Package Stability of Paint*	Approved 1995, Reaffirmed 2003	Paragraph 5.2.4	Accelerated Storage Stability	3.1.5.
ASTM D 2244	*Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates*	Approved 1993, Revised 2002	n/a	Surface Appearance; Repairability; Accelerated Weathering	3.1.3.; 3.2.2.; 3.2.6.
ASTM D 2512	*Compatibility of Materials with Liquid Oxygen (Impact Sensitivity Threshold* and *Pass-Fail Techniques*)	Approved 1982	n/a	LOX Compatibility	3.2.11.
ASTM D 3170	*Standard Test Method for Chipping Resistance of Coatings*	Approved 2003	Ambient Temperature	Gravelometer	3.2.4.
ASTM D 3359	*Standard Test Methods for Measuring Adhesion by Tape Test*	Approved 1995, Revised 2002	Test Method A	X-Cut Adhesion; Repairability; Fungus Resistance	3.1.9; 3.2.2; 3.2.5

Table 4-1 Summarized Test and Evaluation Reference Listing					
Reference Document	**Title**	**Date**	**Applicable Section(s) of Reference Document**	**JTP Test**	**JTP Section**
ASTM D 4060	*Standard Test Method for Abrasion Resistance of Organic Coating by the Taber Abraser*	Revised 2001	n/a	Abrasion Resistance	3.2.3.
ASTM D 4541	*Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers*	Approved 2002	n/a	Tensile (Pull-off) Adhesion	3.1.10
ASTM D 4752	*Standard Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub*	Approved 1987; Last Revised 2003	Table 1	Cure Time (MEK Solvent Rub); Solvent (Acetone) Rub	3.1.6.; 3.1.7.
ASTM G 155	*Standard Practice for Operating Light Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials*	Approved 1996	Test Method 1	Removability; Accelerated Weathering	3.2.1.; 3.2.6.
FED-STD-141	*Paint, Varnish, Lacquer and Related Materials*	Approved 1986, Revised 2001	Method 6301.3; Method 6304.2	X-Cut Adhesion; Knife Test	3.1.9.; 3.1.11.
General Motors (GM) 4465 P	*Water Fog Humidity Test*	Revised 1995	n/a	Cyclic Corrosion Resistance	3.2.9.

Table 4-1 Summarized Test and Evaluation Reference Listing					
Reference Document	**Title**	**Date**	**Applicable Section(s) of Reference Document**	**JTP Test**	**JTP Section**
General Motors (GM) 9540 P	*Accelerated Corrosion Test*	Approved December 1997	n/a	Cyclic Corrosion Resistance	3.2.9.
KSC Report MTB-175-88	*Procedure For Casual Exposure Of Materials To Hypergolic Fluids*	September 12, 1994	Test Method 7.1	Hypergol Compatibility	3.2.10.
MIL-PRF-83282D	*Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft, Metric, NATO Code Number H-537*	Issued 1986, Revised 1997	n/a	Cleanability	3.1.8.
MIL-PRF-85285	*Coating: Polyurethane, Aircraft and Support Equipment*	Issued 1988, Revised 2002	n/a	Cleanability	3.1.8.
MIL-STD-810F	*DoD Test Method Standard for Environmental Engineering Considerations and Laboratory Tests*	Issued 2000, Last Changed 2003	Method 508.5	Fungus Resistance	3.2.5.
NACE-STD-RP0281	*Method for Conducting Coating (Paint) Panel Evaluation Testing In Atmospheric Exposures*	Revised 2004	n/a	Test Descriptions	3.

Table 4-1 Summarized Test and Evaluation Reference Listing					
Reference Document	**Title**	**Date**	**Applicable Section(s) of Reference Document**	**JTP Test**	**JTP Section**
NACE-STD-RP0287	*Field Measurements of Surface Profile of Abrasive Blast Cleaned Steel Surfaces Using a Replica Tape*	Revised 2002	n/a	Test Descriptions	3.
NASA-STD-6001	*Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion*	Issued 1998	Test Method 7.1; Test Method 13A	Hypergol Compatibility; LOX Compatibility	3.2.10.; 3.2.11.
SSPC-PA-2	*Measurement of Dry Coating Thickness with Magnetic Gages*	Revised 2004	n/a	Test Descriptions; Ease of Application; Ease of Application	3.; 3.1.2.; 3.2.1.
SSPC-SP-1	*Solvent Cleaning*	Approved 1982	n/a	Test Descriptions	3.
SSPC-SP-5	*White Blast Cleaning*	Revised 2000	n/a	Test Descriptions	3.

n/a = Not Applicable

Appendix A

Coating System Application Evaluation and Inspection Report

COATING SYSTEM APPLICATION EVALUATION AND INSPECTION REPORT*

DATE	PROJECT REF. NO.	PAGE OF
PROJECT NAME	LOCATION	
INSPECTION ORGANIZATION	INSPECTOR	
PRODUCT MANUFACTURER / NAME	COUPON	

1. DESCRIPTION OF ITEMS AND /OR AREAS

2. DESCRIPTION OF WORK PERFORMED / REMARKS

3. ENVIRONMENTAL CONDITIONS

TIME	:	:	:	:	:	:
AIR TEMP °F						
RELATIVE HUMIDITY	%	%	%	%	%	%

REMARKS

4. PRE-WORK SURFACE CONDITIONS / SURFACE PREPARATION

5. COATING APPLICATION

METHOD OF APPLICATION	START TIME STOP TIME
	APPROXIMATE SQ. FT. COATED
EQUIPMENT DESCRIPTION	GALS COATING APPLIED
	WET FILM THICKNESS (AVG) MILS

POT LIFE (VISCOSITY)—Technician Evaluation and attach records of viscosity readings

EASE OF APPLICATION—Technician Evaluation

REMARKS

SAMPLE

6. POST CURE INSPECTION

DRY FILM THICKNESS (AVG) MILS (See Attached Documentation)

SURFACE APPEARANCE WITH UNAIDED EYE—Technician Evaluation

SURFACE APPEARANCE WITH 10X MAGNIFICATION—Technician Evaluation

GLOSS READING (per ASTM D 523)	COLOR READING (per ASTM D 2244)

REMARKS

7. DRY TO TOUCH SANDING—Technician Evaluation

INSPECTOR'S SIGNATURE DATE

*Based on Application Record Sheet in NASA-STD-5008

Appendix B

Coating System Screening Evaluation and Inspection Report

COATING SYSTEM SCREENING EVALUATION AND INSPECTION REPORT

DATE	PROJECT REF. NO.	PAGE OF
PROJECT NAME	LOCATION	
INSPECTION ORGANIZATION	INSPECTOR	
PRODUCT MANUFACTURER / NAME	COUPON	

1. ACCELERATED STORAGE STABILITY	
TIME OF STORAGE	TEMPERATURE OF STORAGE
INITIAL SAMPLE WEIGHT	FINAL SAMPLE WEIGHT
TECHNICIAN EVALUATION—Any changes in coating consistency or odors; any grains, lumps or streaks in brushed film	
FINISH RATING (per ASTM D 1849)	
REMARKS	

2. CURE TIME (MEK SOLVENT RUB)	
APPLICATION TIME	TIME ELAPSED BETWEEN APPLICATION AND TESTING
TESTING TIME	
DRY FILM THICKNESS (AVG)	MILS (See Attached Documentation)
RESISTANCE RATING (per ASTM D 4752)	
REMARKS	

3. SOLVENT (ACETONE) RUB	
APPLICATION TIME	TIME ELAPSED BETWEEN APPLICATION AND TESTING
TESTING TIME	
DRY FILM THICKNESS (AVG)	MILS (See Attached Documentation)
RESISTANCE RATING (per ASTM D 4752)	
REMARKS	

4. CLEANABILITY	
A =	CALCULATED PERCENTAGE CLEANING EFFICIENCY
B =	$[(C - B) \div (A - B)] \times 100] =$ %
C =	
REMARKS	

5. X-CUT ADHESION BY WET TAPE	
ADHESION RATING (per ASTM D 3359)	
REMARKS	

6. TENSILE (PULL-OFF) ADHESION		
PULL-OFF STRENGTH AT TIME OF FAILURE (per ASTM D 4541)	1.	PSI
	2.	PSI
	3.	PSI
REMARKS		

7. KNIFE TEST—Technician Evaluation
INSPECTOR'S SIGNATURE DATE

SAMPLE

Appendix C

Coating System Common Evaluation and Inspection Report

COATING SYSTEM COMMON EVALUATION AND INSPECTION REPORT

DATE	PROJECT REF. NO.	PAGE OF
PROJECT NAME	LOCATION	
INSPECTION ORGANIZATION	INSPECTOR	
PRODUCT MANUFACTURER / NAME	COUPON	

1. REMOVABILITY

DWELL TIME TO SUBSTRATE	DFT REMAINING IN BLAST AREA (AVG)

REMARKS

2. REPAIRABILITY

SURFACE APPEARANCE—Technician Evaluation

COLOR READING (per ASTM D 523) Weathered	COLOR READING (per ASTM D 523) Repaired

ADHESION RATING (per ASTM D 3359)

REMARKS

3 ABRASION (per ASTM D 4060)

WEIGHT PRIOR TESTING	AREA LOSS
WEIGHT POST TESTING	

REMARKS

4. GRAVELOMETER

RATING (per ASTM D 3170)

REMARKS

SAMPLE

5. FUNGUS RESISTANCE

GROWTH AT 7 DAYS—Technician Evaluation (Location, Description, Length)

GROWTH AT 84 DAYS—Technician Evaluation (Location, Description, Length)

X-CUT ADHESION (per ASTM D 3359)

REMARKS

6. ACCELERATED WEATHERING

	500 hours	1000 hours	1500 hours	2000 hours
COLOR READING (per ASTM D 2244)				
GLOSS READING (per ASTM D 523)				

REMARKS

COATING SYSTEM COMMON EVALUATION AND INSPECTION REPORT

DATE	PROJECT REF. NO.	PAGE OF
PROJECT NAME	LOCATION	
INSPECTION ORGANIZATION	INSPECTOR	
PRODUCT MANUFACTURER / NAME	COUPON	

7. MANDREL BEND FLEXIBILITY

PASS/FAIL

MATERIAL CHARACTERISTICS

REMARKS

8. 18-MONTH MARINE ENVIRONMENT

CORROSION RATING (per ASTM D 610)

BLISTER RATING (per ASTM D 714)

GLOSS READING (per ASTM D 523)

REMARKS

9. CYCLIC CORROSION RESISTANCE—Technician Evaluation

10. HYPERGOL COMPATIBILITY—See Attachments

REMARKS

11. LOX COMPATIBILITY—See Attachments

REMARKS

INSPECTOR'S SIGNATURE DATE

SAMPLE

Appendix D

Coating System Common Hypergol Compatibility Material Identification Form

COATING SYSTEM COMMON HYPERGOL COMPATIBILITY MATERIAL IDENTIFICATION FORM
TEST MATERIAL:
MANUFACTURER DESIGNATION
COMPOSITION
SPECIFICATION
MATERIAL CODE
GENERIC ID
APPLICATION
USE TEMPERATURE (MIN)
USE TEMPERATURE (MAX)
HYPERGOLIC FLUID EXPOSURE TIME (FIELD USE)
MANUFACTURER
NAME
ADDRESS 1
ADDRESS 2
CITY
STATE
COUNTRY
SUPPLIER
NAME
ADDRESS 1
ADDRESS 2
CITY
STATE
COUNTRY
REMARKS
INSPECTOR'S SIGNATURE DATE

SAMPLE

KSC Report MTB-175-88 Figure 1

Appendix E

Chemical Analysis Laboratory Compatibility Report

CHEMICAL ANALYSIS LABORATORY COMPATIBILITY REPORT		DATE	LAB WORK ORDER NO.
REQUESTING ORGANIZATION	REQUESTOR	TELEPHONE NO.	REFERENCE NO.
VEHICLE	SYSTEM		REFERENCE DOCUMENT

MATERIAL NAME OR MFGR'S ID

CHEMICAL CLASS OF MATERIAL

GENERIC NAME OF MATERIAL

SPECIAL INSTRUCTIONS

SAMPLE

TEST CONDITIONS

Test 1 Sample per: _____
Test Name: _____
Test Fluid: _____

TEST DATA

Test Sample Description: _____
Material Quantity (gms): _____ Container Volume (ml): _____
Media Volume (ml): _____ Media Exposure Time (Hrs): _____

OBSERVATIONS
Burn _____ Temp. Change _____
Smoke _____ Soluble _____
Froth _____ Fracture _____
Bubble _____ Swell _____
Char _____
Remarks: _____
_____

VISUAL CHARACTERISTICS	Pre-Test	Post-Test
Color	_____	_____
Opaque	_____	_____
Translucent	_____	_____
Transparent	_____	_____

Remarks: _____
_____
_____

BULK CHARACTERISTICS	Pre-Test	Post-Test
Shape	_____	_____
Flexible	_____	_____
Rigid	_____	_____
Soft	_____	_____
Hard	_____	_____
Friable	_____	_____
Powder	_____	_____

Remarks: _____
_____

SURFACE CHARACTERISTICS	Pre-Test	Post-Test
Smooth	_____	_____
Rough	_____	_____
Wrinkled	_____	_____
Pitted	_____	_____
Woven	_____	_____
Matted	_____	_____
Tacky	_____	_____

Remarks: _____
_____

OTHER OBSERVATIONS

CONCLUSIONS

- ☐ NO SIGNIFICAT REACTIVITY OBSERVED
- ☐ SLIGHT TO MODERATE REACTIVITY OBSERVED
- ☐ SAMPLE SHOWS INDICATIONS OF GROSS INCOMPATIBILITY

ANALYST:	DATE:	APPROVAL:

KSC FORM 3-539NS