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

Field Evaluations Test Plan

For Validation of Alternatives to Aliphatic Isocyanate Polyurethanes

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January 31, 2005

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Contract No. NAS10-03029
Task Nos. 1 and 6

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Prepared by
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Submitted by
NASA Acquisition Pollution Prevention Office

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PREFACE

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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 plan is to be used in conjunction with NASA AP2 Office Joint Test Protocol entitled *Joint Test Protocol for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes*; *Potential Alternatives Report for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes*; and *Cost Benefit Analysis for Alternatives to Aliphatic Isocyanate Polyurethanes*, all of which were prepared by ITB, Inc.; and the Air Force Research Laboratory (AFRL) document entitled *DRAFT The Testing and Demonstration of Metal Wire Arc Sprayed Materials on Rocket Launch Facilities*, dated November 26, 2003, prepared by Science Applications International Corporation (SAIC).

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 Health & Safety 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 centers participating in this project.

Table 1-1 summarizes the target HazMats; processes and materials; applications; current specifications 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 Field Test Plan (FTP) defines the field evaluation and testing requirements for validating alternatives to aliphatic isocyanate polyurethanes and supplements the NASA AP2 Office Joint Test Protocol (JTP) entitled *Joint Test Protocol for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes*, prepared by ITB. 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 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 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 under the JTP and this FTP.

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 Air Force Space Command (AFSPC) and NASA centers 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.

The objective of this project is to qualify candidate alternatives to Aliphatic Isocyanate Polyurethane coatings under the specifications for the standard system. This project will compare coating performance of the proposed alternatives to existing coating systems or standards.

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 as specified in the Joint Test Protocol. Coating evaluators will complete a written evaluation and documentation checklist to organize and quantify the observations of coating system performance under actual operating conditions.

Table 2-1 lists field evaluations that are intended to compare the performance of candidate test coatings with current coatings when applied in an operational environment.

The table includes 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 Field Evaluation and Testing Requirements for Alternatives to Aliphatic Isocyanate Polyurethane Coatings			
Test	**Test Plan Section**	**Acceptance Criteria**	**Test Method References**
Ease of Application	3.2.1.	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.	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.	No rolling or scribing during sanding, and "easy" sanding (as evaluated by technician)	None

3. TEST DESCRIPTIONS

Test requirements identified in Table 2-1 are further defined in this section to include the test description, rationale, and test methodology. The *Test Methodology* lists the major parameters and acceptance (pass/fail) criteria. Any U*nique Equipment or Instrumentation* requirements and *Data Analysis and Reporting Criteria* are also included.

3.1. Surface Preparation and Coating Application

Each testing surface shall be a minimum of 3 ft × 3 ft. All coatings shall be applied under the direction of a NACE Certified Coatings Inspector. The coating of test areas will be documented using the "Coating System Evaluation and Inspection Report" (Appendix A) based on the Application Record Sheet in NASA-STD-5008, or an equivalent form.

If liquid coatings are being tested, test areas shall be allowed 24 hours of unaided drying time prior to dry film thickness measurements. If powder coatings are being tested, test areas shall be cured in accordance with manufacturer's recommendations prior to dry film thickness measurements. Coating process parameters, including application method and cure schedule, shall be documented at the facility that prepares the test areas using the "Coating System Field Evaluation and Inspection Report" (Appendix A), or an equivalent form.

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. 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. 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.

3.2. 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.

3.2.1. Ease of Application

<u>Test Description</u>

This procedure is used to determine how easily a coating system may be applied in actual field conditions. The evaluation is based on the aggregate knowledge and experience of the technician applying the coating. This test will also measure Dry Film Thickness (DFT) and report any pot life issues. DFT measurements shall be made nondestructively in accordance with SSPC-PA-2 (*Measurement of Dry Coating Thickness with Magnetic Gages*, revised 2004).

Rationale

This test is conducted to identify 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 3-1 Test Methodology for Ease of Application Test	
Parameters	Coating Manufacturer preparation instructions
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); Record Pot Life, DFT and any related issues

Unique Equipment and Instrumentation

- Per manufacturer's application instructions
- Magnetic gage per SSPC-PA-2

Data Analysis and Reporting

- Report applicator evaluation of the surface coating condition, Ease of Use, Pot Life, DFT and other issues using the "Coating System Evaluation and Inspection Report" (Appendix A), or an equivalent form.

3.2.2. Surface Appearance

Test Description

The purpose of this test is to evaluate and compare the surface appearance of the candidate coating systems after application in actual field conditions. Coating evaluators will complete a written evaluation and documentation checklist to organize and quantify

the observations of coating system performance under actual operating conditions 24 ± 3 hours following application and at one (1)-month, six (6)-month, and 12-month intervals.

Examine the surface of each coated area for coating defects with unaided eye and with 10X magnification. Color and gloss measurements shall be conducted on each coated area 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 test areas. The initial 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 initial and extended surface appearance evaluations are performance requirements.

Test Methodology

Table 3-2 Test Methodology for Surface Appearance Test	
Parameters	10X Magnification
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

- A certified coatings inspector will evaluate the coatings 24 ± 3 hours after application and at one (1) month, six (6) month and 12-month intervals using the "Coating System Evaluation and Inspection Report" (Appendix A), or an equivalent form. Measure and report observations on any coating defects, color readings, and gloss readings.

- One color photograph of the area coated with each candidate coating shall be taken before the test. One color photograph of each tested area shall be taken 24 ± 3 hours after application and at one (1) month, six (6) month and 12-month intervals.

3.2.3. Dry-To-Touch (Sanding)

Test Description

This procedure assists in determining the drying time (dry-to-touch) required for coating systems in an operational setting. All non-liquid coatings such as metal wire arc spray, powder coatings, and dry film technology are exempt from this requirement.

Coatings are applied in accordance with manufacturer's directions/specifications and allowed to air dry for 24 ± 3 hours. 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 3-3 Test Methodology for Dry-To-Touch (Sanding) Test

Parameters	Coating cure time
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 for test on candidate coating using the "Coating System Evaluation and Inspection Report" (Appendix A), or an equivalent form.

4. REFERENCE DOCUMENTS

The documents in Table 4-1 were referenced in the development of this JTP. In addition, this report was leveraged from NASA AP2 Office Joint Test Protocol entitled *Joint Test Protocol for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes*; *Potential Alternatives Report for Validation of Alternatives to Aliphatic Isocyanate Polyurethanes*; and *Cost Benefit Analysis for Alternatives to Aliphatic Isocyanate Polyurethanes*, all of which were prepared by ITB, Inc.; and the Air Force Research Laboratory (AFRL) document entitled *DRAFT The Testing and Demonstration of Metal Wire Arc Sprayed Materials on Rocket Launch Facilities*, dated November 26, 2003, prepared by Science Applications International Corporation (SAIC).

Table 4-1 Summarized Test and Evaluation Reference Listing

Reference Document	Title	Date	Field Evaluation Test	Test Plan Section
ASTM D 523	*Standard Test Method for Specular Gloss*	Reaffirmed 1999	Surface Appearance	3.2.2.
ASTM D 2244	*Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates*	Approved 1993, Revised 2002	Surface Appearance	3.2.2.
SSPC-PA-2	*Measurement of Dry Coating Thickness with Magnetic Gages*	Revised 2004	Ease of Application	3.2.1.

Appendix A

Coating System Evaluation and Inspection Report

COATING SYSTEM EVALUATION AND INSPECTION REPORT*

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

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

EASE OF USE—Technician Evaluation

POT LIFE—Technician Evaluation

REMARKS

6. POST CURE INSPECTION

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

DRY-TO-TOUCH (SANDING) EVALUATION

EVALUATION WITH UNAIDED EYE

EVALUATION WITH 10X MAGNIFICATION

GLOSS READING	COLOR READING

REMARKS

INSPECTOR'S SIGNATURE DATE

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