Validation of Alternatives to Aliphatic Isocyanate Polyurethanes

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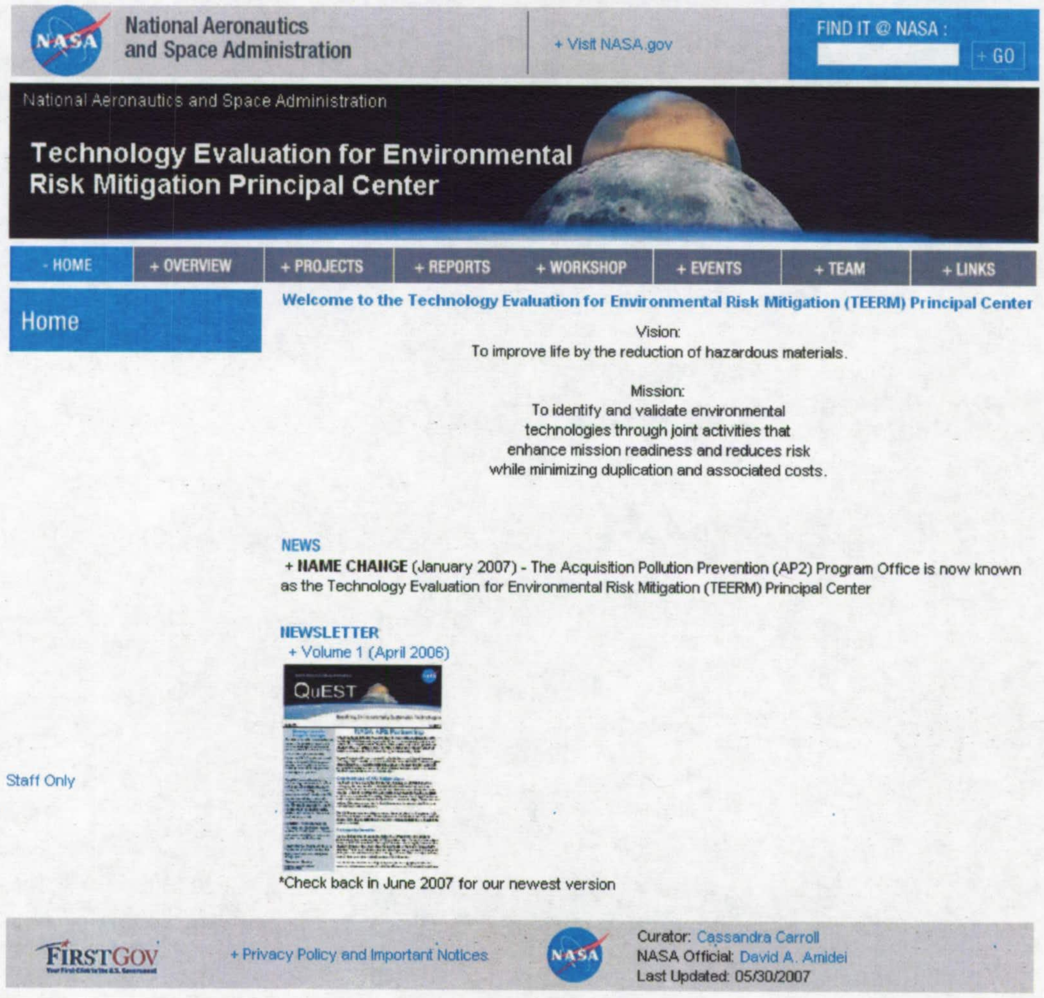
This project was sponsored and managed through the NASA Technology Evaluation for Environmental Risk Mitigation Principal Center (TEERM) office



Outline

- What is TEERM?
- Project description and coating requirements.
- Why replace aliphatic isocyanate polyurethanes?
- Overview of validation procedures.
- Project set-up
- Test requirements and results
- KSC 18-Month exposure pictures
- SSC Field Tests
- Conclusion

What is TEERM?

- The Technology Evaluation for Environmental Risk Mitigation Principal Center (TEERM) (formerly the Acquisition Pollution Prevention program) was established in 1998 by National Aeronautics and Space Administration (NASA) Headquarters and Kennedy Space Center, Florida. It is operated under NASA's Applied Technology Office. The TEERM identifies and validates sustainable pollution prevention technologies through joint activities that enhance NASA mission readiness and reduce risk while minimizing duplication and associated costs.
- TEERM projects commonly involve two or more NASA stakeholders in the planning and execution of laboratory or field testing of commercially available replacements for hazardous materials currently used by NASA.

Project Description and Coating Requirements

Project Description:

- Goal is to validate alternatives to polyurethanes that contain isocyanates
- Currently polyurethanes are used across NASA on structural and non-structural elements in both shuttle and non-shuttle programs
- Stennis Space Center has banned the use of any coating containing isocyanates and other Centers restrict their use

Alternative Coating Systems:

- Do not contain isocyanates
- Reviewed for:
  - Volatile Organic Compounds (VOCs)
  - Hazardous Air Pollutants (HAPs)
  - Other hazardous materials as regulated by the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Emergency Planning and Community Right-to-Know Act (EPCRA)

Why Replace Isocyanate Polyurethanes?

Isocyanates are classified as potential human carcinogens and are known to cause cancer in animals.
The Occupational Health & Safety Administration (OSHA) states that the effects of isocyanate exposure include:

- irritation of skin and mucous membranes
- chest tightness
- difficult breathing

Effects of overexposure:

- occupational asthma
- lung problems
- irritation of the eyes, nose, throat, and skin.

Overview of Validation Procedures

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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Submitted by
NASA Acquisition Pollution Prevention Office

This JTP was created from engineering, performance, and operational impact requirements defined by a consensus of NASA and Air Force Space Command (AFSPC) participants and contains the requirements and tests necessary to qualify coating alternatives for Aliphatic Isocyanate Polyurethane applications.

Project Set-up

Laboratory Testing

- Phase 1 Screening Tests.
- Phase 2 Tests including 18-Month Marine Exposure at KSC Beach Corrosion Test Site.

Field Testing at Stennis Space Center, Mississippi.

KSC Beach Atmospheric Corrosion Test Site

Phase 1 Testing Requirements

Test	*Test Methodology*	*AFSPC Requirement*	*NASA Requirement*
Pot Life (Viscosity)	ASTM D 1200	X	X
Ease of Application (including DFT)	SSPC-PA-2	X	X
Surface Appearance (including color and gloss)	ASTM D 523; ASTM D 2244	X	X
Dry-To-Touch (Sanding)	None	X	X
Accelerated Storage Stability	ASTM D 1849	X	X
Cure Time (MEK Solvent Rub)	ASTM D 4752	X	X
Solvent (Acetone) Rub	ASTM D 4752		X
Cleanability	MIL-PRF-83282 D; MIL-PRF-85285		X
X-Cut Adhesion by Wet Tape	ASTM D 3359; FED-STD-141	X	X
Tensile (Pull-off) Adhesion	ASTM D 4541	X	X
Knife Test	FED-STD-141	X	

Phase One Results

Test	Coating Systems									
	1	2	3	4	5	6	7	8	9	10
Pot Life (Heated)	B	C	B	B	B	B	B	C	B	B
Pot Life (Room Temp)	W	C	S	S	S	S	S	C	S	S
Ease of Application	S	C	S	S	S	S	S	C	W	S
Surface Appearance	S	C	S	S	S	S	S	C	S	S
Accelerated Storage	S	C	S	B	S	S	W	C	S	S
Cure Time	S	C	S	W	W	S	S	C	S	W
Cleanability	S	C	S	W	W	S	S	C	S	W
X-Cut Adhesion	W	C	W	W	S	W	S	C	S	W
Tensile Adhesion	W	C	W	W	W	S	S	C	B	W
Knife Test	W	C	S	S	S	S	S	C	S	W

C = Control

B = Better

S = Similar

W = Worse

Phase 2 Testing Requirements

Test	*Test Methodology*	*AFSPC Requirement*	*NASA Requirement*
Abrasion Resistance	ASTM D 4060		X
Mandrel Bend Flexibility	ASTM D 522	X	
Gravelometer	ASTM D 3170	X	
Fungus Resistance	ASTM D 3359; MIL-STD-810F		X
Accelerated Weathering	ASTM D 523; ASTM D 2244; ASTM G 155	X	X
Removability	ASTM G 155	X	X
Repairability	ASTM D 523; ASTM D 2244; ASTM D 3359	X	X
Cyclic Corrosion Resistance	GM 4465 P; GM 9540 P	X	X
18-Month Marine Environment	ASTM D 610; ASTM D 714; ASTM D 523	X	X
Hypergol Compatibility	KSC MTB-175-88; NASA-STD-6001	X	X
LOX Compatibility	ASTM D 2512; NASA-STD-6001		X

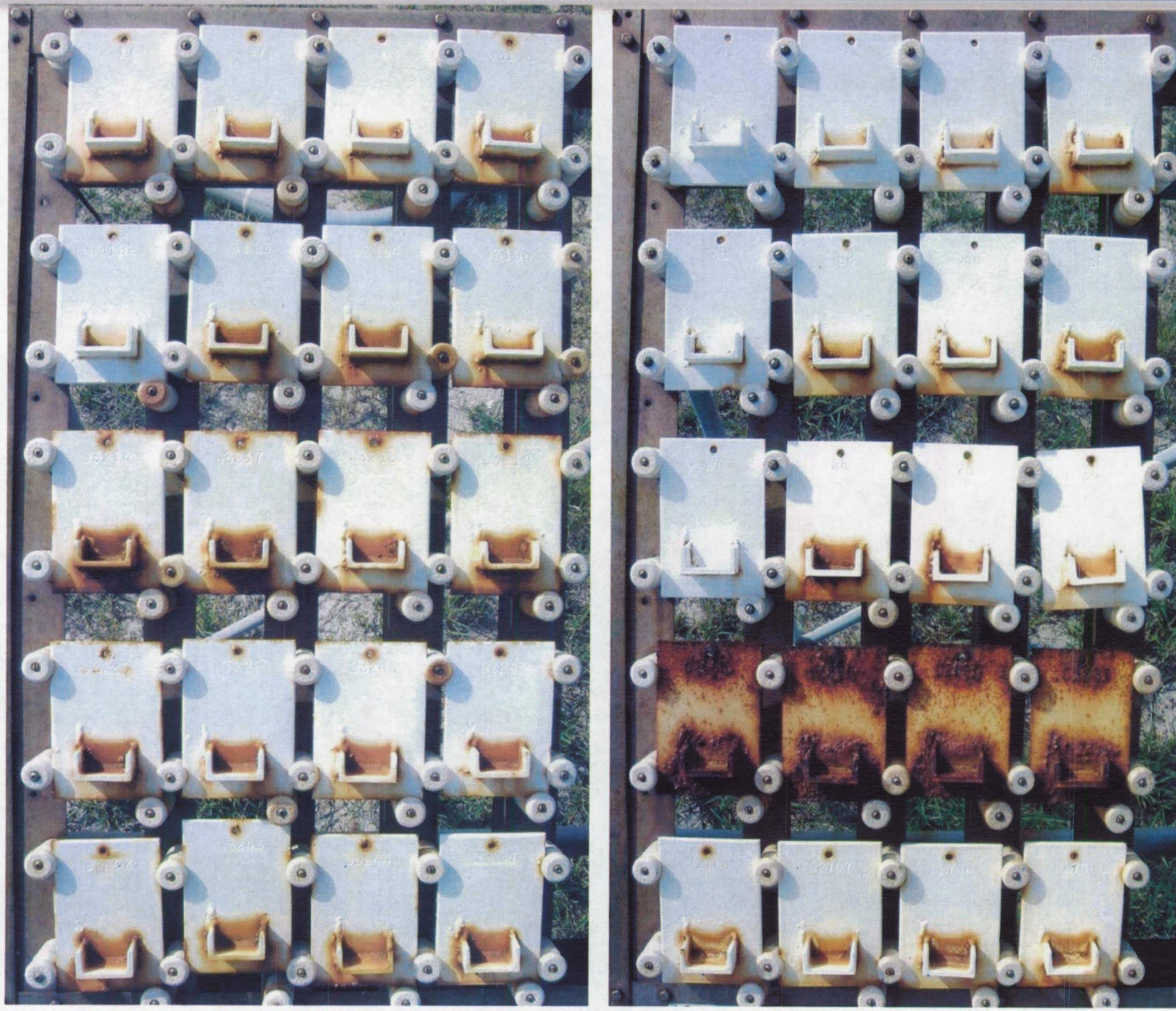
Phase Two Results

Test	Coating Systems									
	1	2	3	4	5	6	7	8	9	10
Abrasion		C	B			S	W	C	S	
Mandrel Bend		C	W			S	S	C	S	
Gravelometer		C	W			B	S	C	S	
Fungus Wet Cut Adhesion		C	W			S	S	C	W	
Accelerated Weathering (Gloss Retention)		C	S			S	S	C	S	
Accelerated Weathering (Color Change)		C	S			S	S	C	S	
Removability		C	S			S	S	C	S	
Repairability		C	S			S	S	C	W	
18 Month Marine Exp. (Gloss Retention)	B	C	S	W	B	B	B	C	S	B
18 Month Marine Exp. (Color Retention)	B	C	S	B	S	S	S	C	W	W
18 Month Marine Exp. (Blistering)	S	C	S	W	W	S	S	C	W	S
18 Month Marine Exp. (Visual Corrosion)	S	C	S	W	W	B	B	C	W	S
18 Month Marine Exp. (Creepage from Scribe)	S	C	S	S	S	S	S	C	W	S
Heat Adhesion	S	C	S	S	S	S	S	C		S
LOX Compatibility	S	C	S	S	S	S	S	C	S	S
Hypergol Reactivity	S	C	S	S	W	S	S	C	S	S
Cyclic Corrosion Testing	S	C	S	S	S	S	S	C	W	S

C = Control | B = Better | S = Similar | W = Worse | Eliminated

* System 9 is not an inorganic zinc coating system and was not tested for heat adhesion stability (required for zinc systems in NASA-STD-5008)

18-Month Beach Exposure Pictures



System 1

System 2
Control

System 3
Passed
Phase 1

System 4

System 5

System 6
Passed
Phase 1

System 7
Passed
Phase 1

System 8
Control

System 9
Passed
Phase 1

System 10

18-Month Beach Exposure Pictures

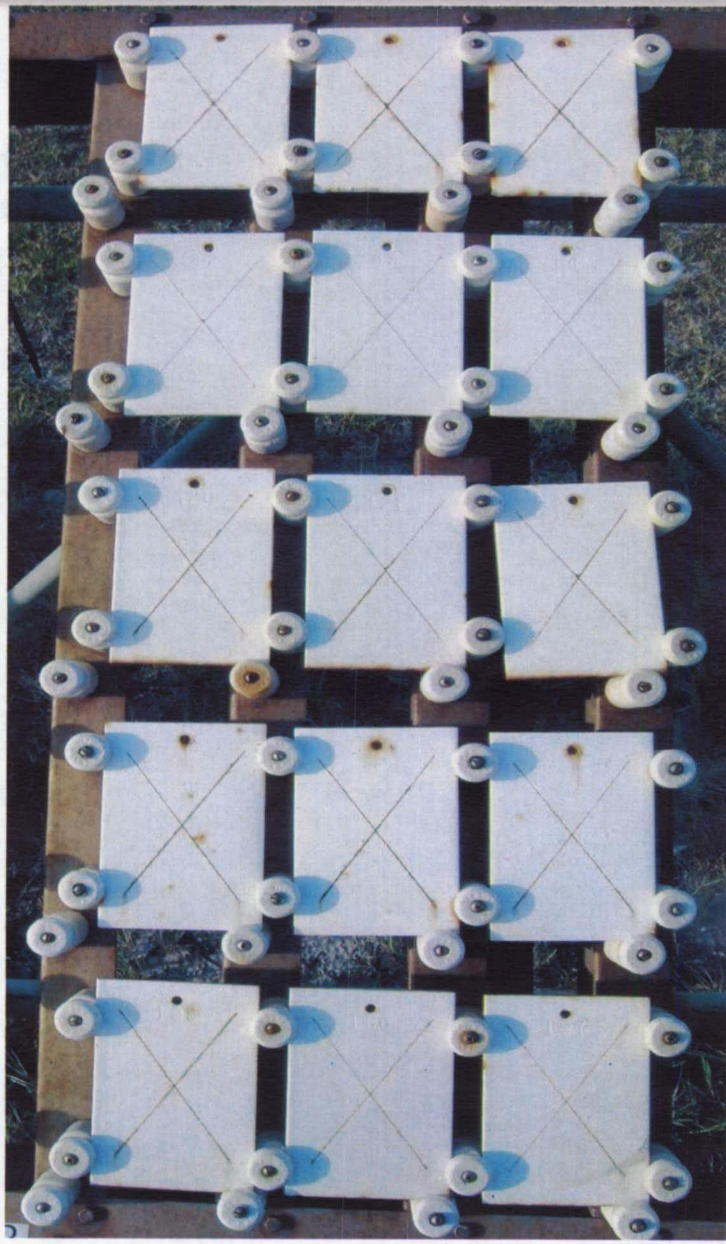
System 1

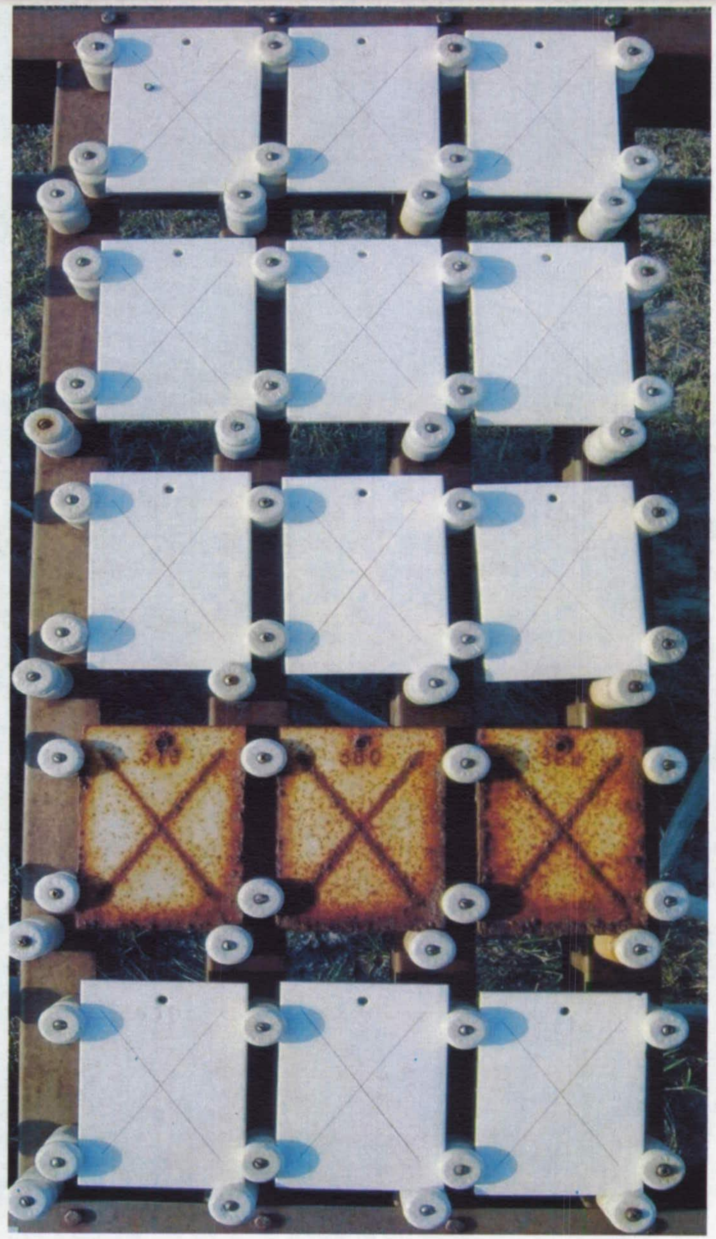
System 2
Control

System 3
Passed
Phase 1

System 4

System 5





System 6
Passed
Phase 1

System 7
Passed
Phase 1

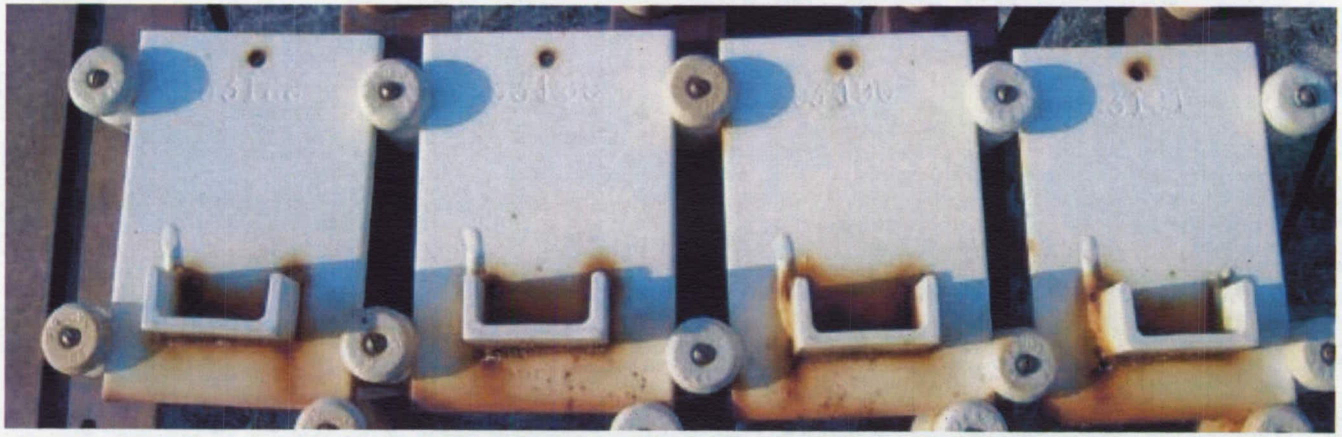
System 8
Control

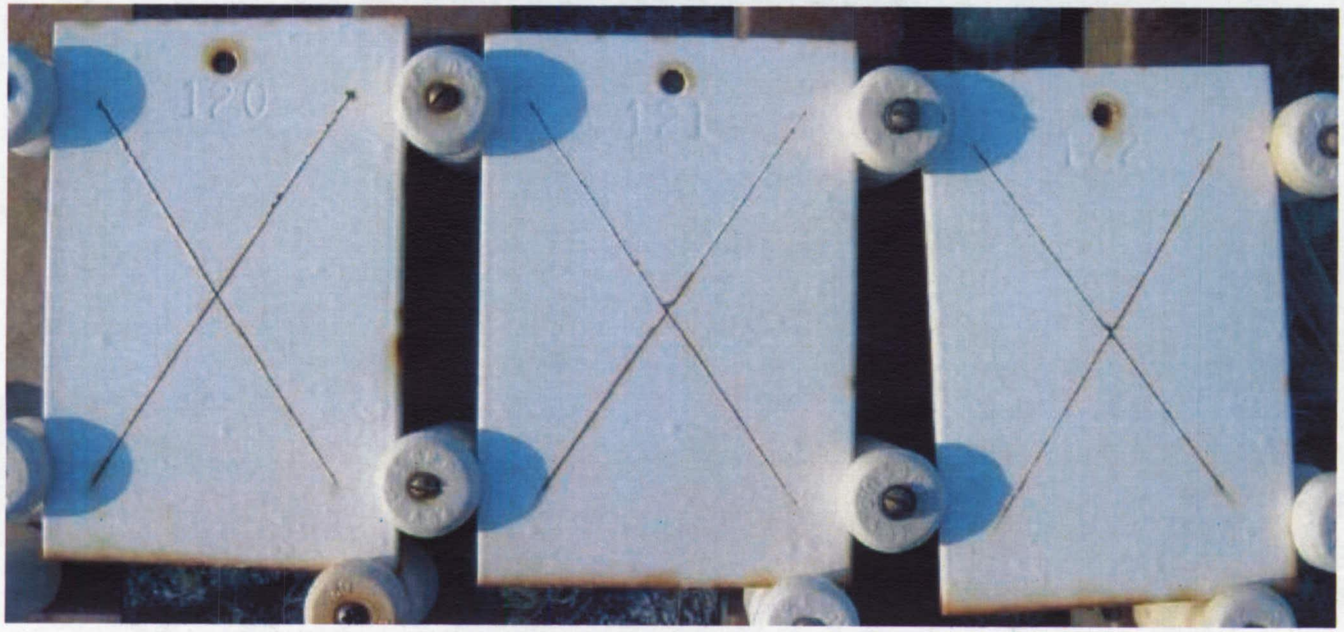
System 9
Passed
Phase 1

System 10

18-Month Beach Exposure Pictures

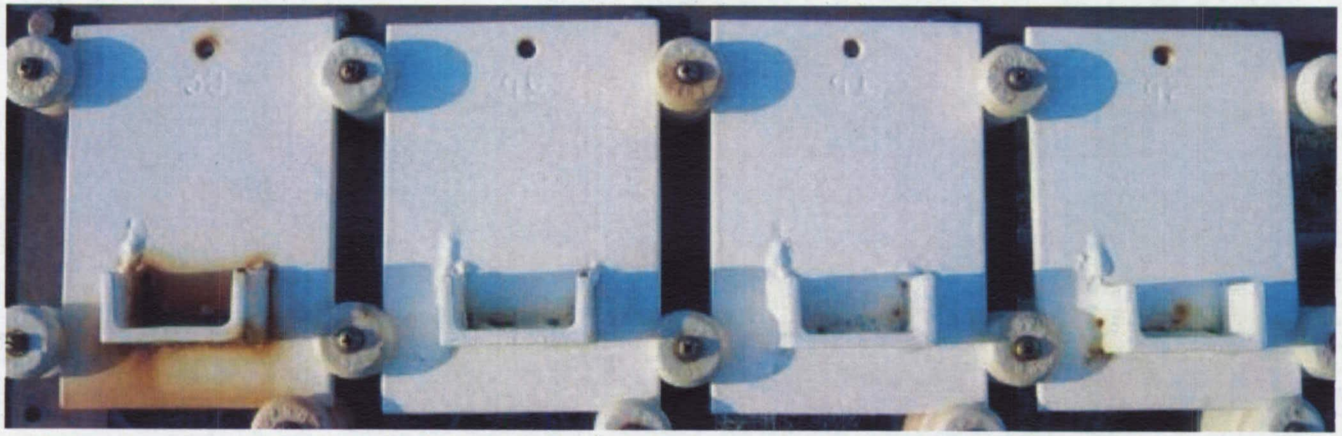
System 3:

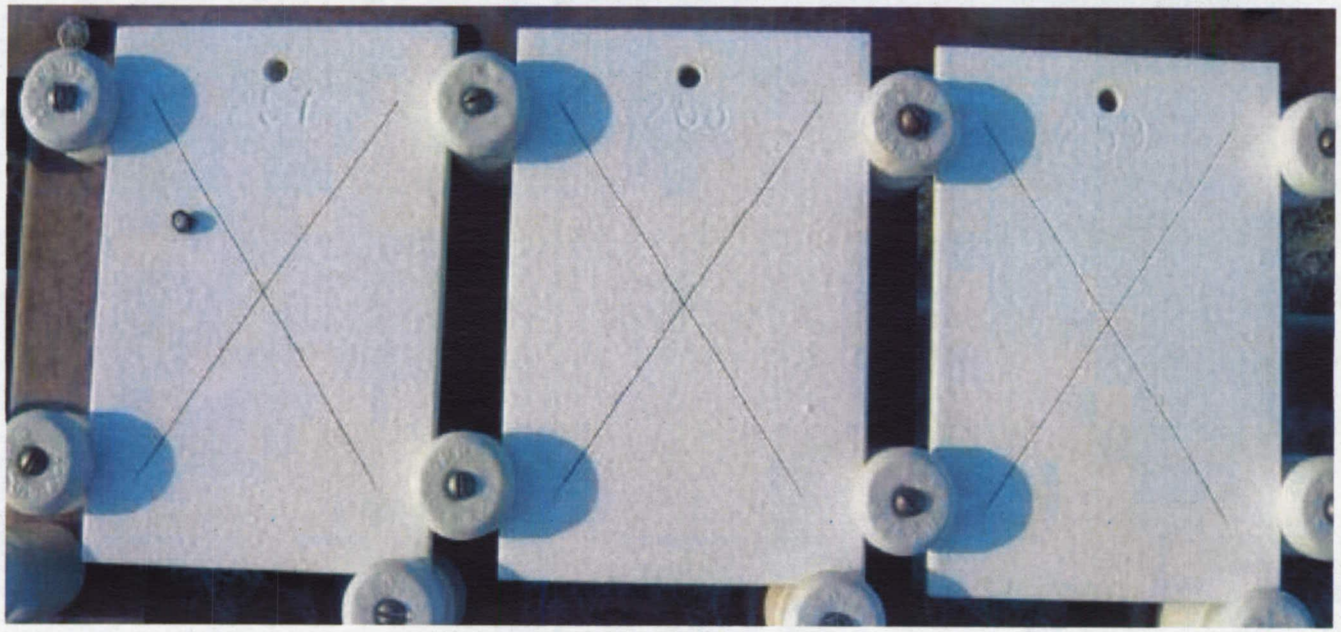




18-Month Beach Exposure Pictures

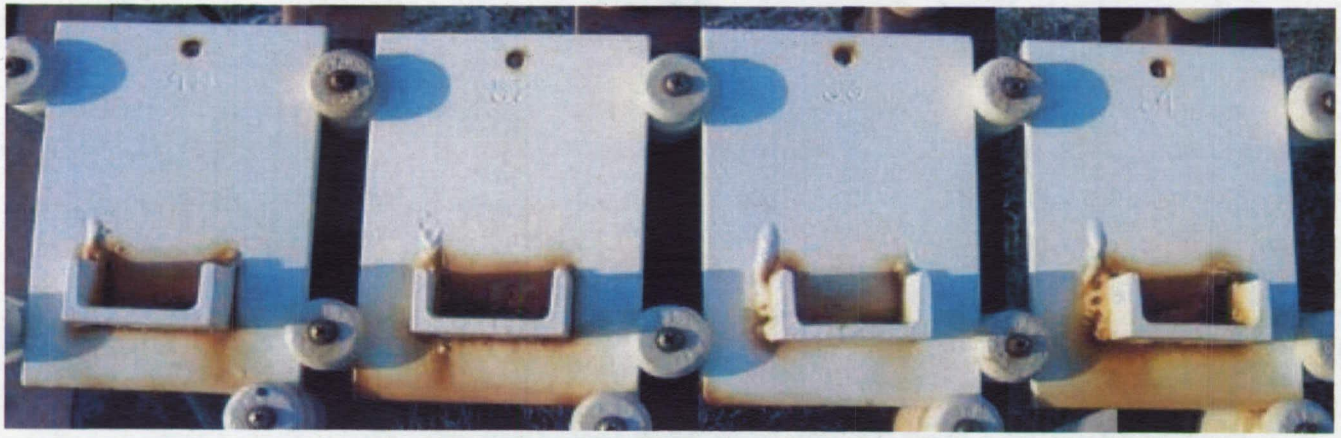
System 6:

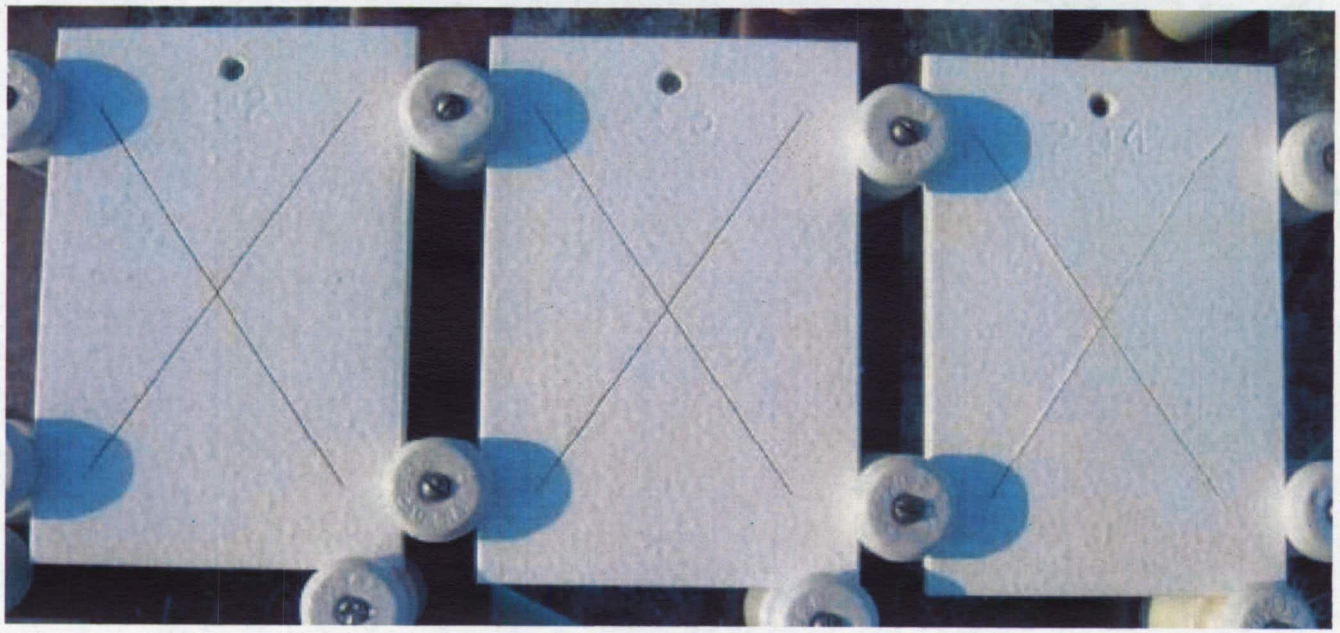




18-Month Beach Exposure Pictures

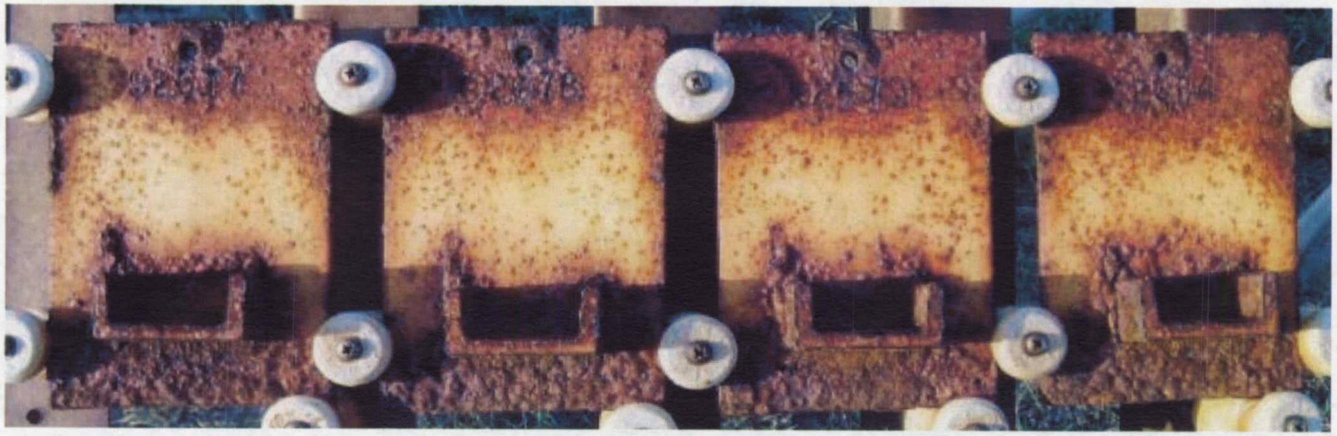
System 7:

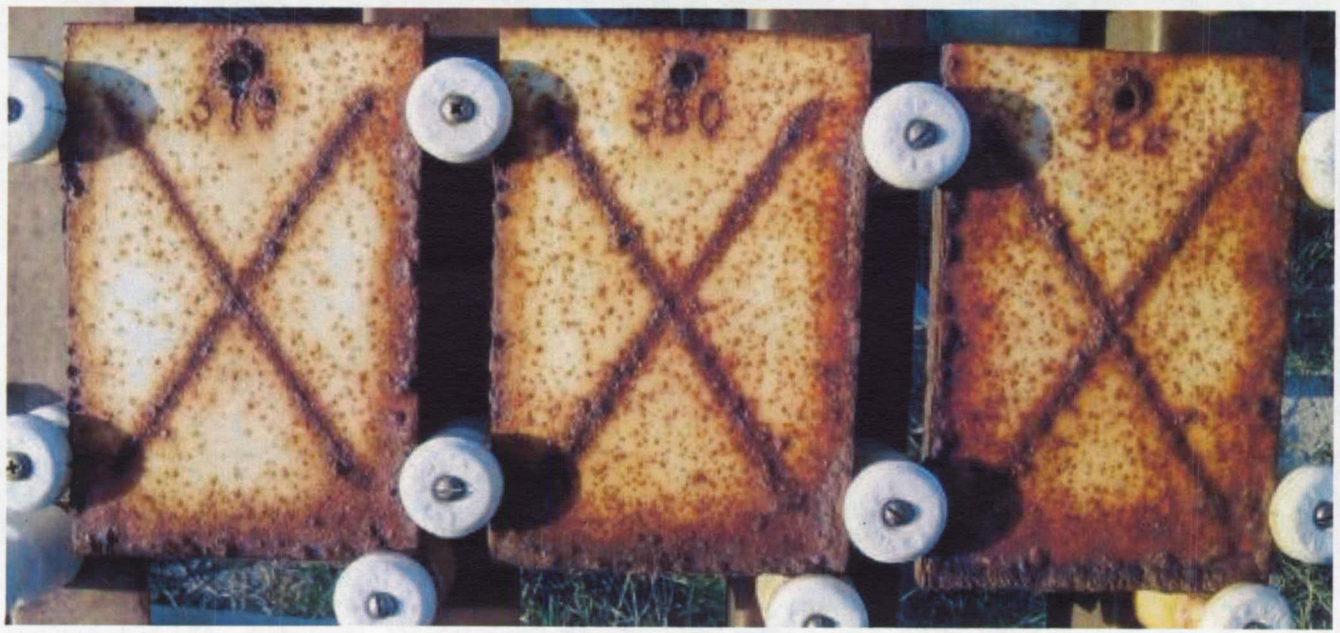




18-Month Beach Exposure Pictures

System 9:



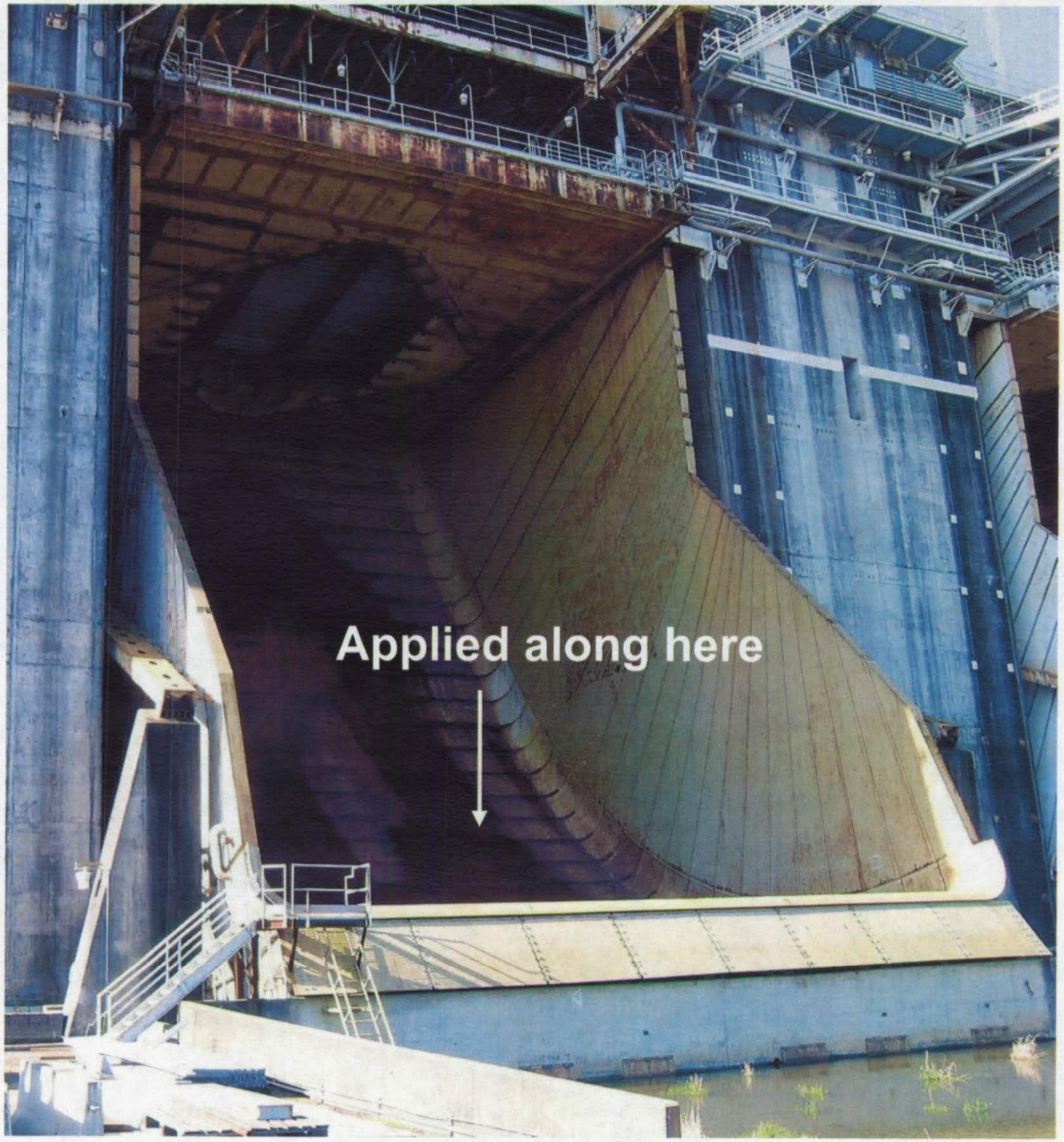


SSC Field Tests

Test	*Test Methodology*	*AF Requirement*	*NASA Requirement*
Ease of Application (including DFT)	SSPC-PA-2	X	X
Surface Appearance (including color retention and gloss)	ASTM D 523; ASTM D 2244	X	X
Dry-To-Touch (Sanding)	None	X	X

- All ten coating systems were applied to the Flame Bucket of an Engine Test Stand at Stennis Space Center, MS
- Applied August 2005 (just weeks before Hurricane Katrina)
- Surface Prep was Sponge Media
- Examined at application, 6-months and 12-months

SSC Field Tests



SSC Field Tests

SSC Field Test Results

Test	Coating Systems									
	1	2	3	4	5	6	7	8	9	10
Ease of Application	S	C	S	S	S	S	S	C	S	B
Surface Appearance (gloss)	B	C	S	W	S	S	W	C	B	S
Surface Appearance (color)	S	C	S	S	S	W	S	C	W	W
Dry-to-Touch	S	C	S	S	S	S	S	C	S	S
12-Month Corrosion Performance	S	C	S	S	S	S	S	C	W	S

C = Control

B = Better

S = Similar

W = Worse

Phase Two Conclusions

- **System 3** performed similar to the control coatings in the field exposure tests, but performed poorly in the Mandrel Bend, Gravelometer, and X-cut Adhesion tests. Failure in these tests generally suggest a coating to be more brittle and not flexible.

- **System 6** showed performance characteristics similar to or better than the control coatings, except for the field color retention at SSC.

- **System 7** provided better corrosion protection in the field exposures but did not perform as well in the abrasion test and gloss retention on the SSC field exposure test, although it performed well at the KSC beach atmospheric test.

- **System 9** performed well during Phase I testing, but did not fare well in Phase II. The corrosive atmospheric testing caused severe corrosion of the underlying substrate. System 9 was the only coating system in the test that did not contain a sacrificial protecting primer, such as an inorganic zinc primer.

Thank you

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All available project documents can be found at the TEERM website.

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14. ABSTRACT

The National Aeronautics and Space Administration (NASA) Headquarters 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 objective of this effort is to demonstrate and validate alternatives to aliphatic isocyanate polyurethane coatings. Successful completion of this project will result in one or more isocyanate-free coating systems qualified for use at Air Force Space Command (AFSPC) and NASA centers participating in this study.

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

15. SUBJECT TERMS

Coatings, aliphatic isocyanate polyurethanes,Volatile Organic Compounds

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