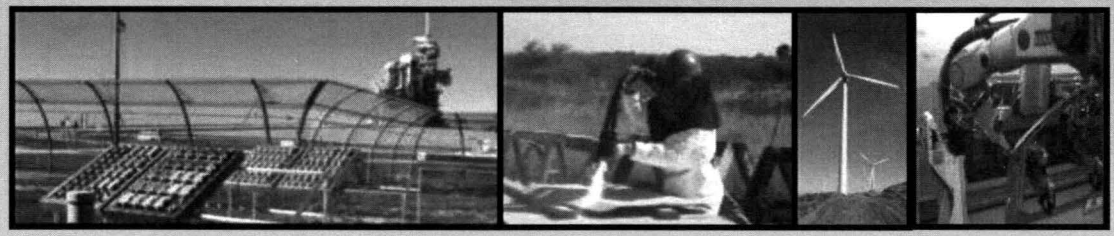
Environmentally-preferable Launch Coatings Project Overview



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Summary

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- NASA-STD-5008B
- Previous Work
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2. Experimental Procedure

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- Surface Appearance
- Heat Adhesion
- Atmospheric Exposure

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Project Team Members

1. **NASA**
   - Ground Systems Development and Operations Program
   - NASA TEERM Principal Center
   - NASA Corrosion Technology Laboratory
   - Kennedy Space Center, Stennis Space Center, White Sands Test Facility, and Wallops Flight Facility
2. **U.S. Air Force**
   - Air Force Space Command
   - Space and Missile Command
   - Coatings Technology and Integration Office (CTIO)

Background

1. **Corrosion is expensive**
   - Financial
   - Asset Downtime
   - Worker Safety
   - Environmental Risks
2. **Launch Facility Locations**
   - Typically in coastal areas
   - Extreme launch environments
3. **Coating Systems**
   - Work via a variety of methods (barrier, galvanic, and/or inhibitor)
   - Adhere to substrate through a combination of chemical and physical bonds

Specification NASA-STD-5008B *Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities, and Ground Support Equipment*

- Governs maintenance at John F. Kennedy Space Center and other NASA Centers.
- Establishes practices for the protective coating of ground support equipment and related facilities.
- Zones of Exposure are established to define coating system requirements for specific environments.
  - ***Zone 4a.*** Surfaces not located in the launch environment, but located in a neutral pH corrosive marine industrial environment or other chloride-containing environments.
  - ***Zone 4b.*** Surfaces located in neutral pH exterior environments in any geographical area.
  - ***Zone 4c.*** Surfaces located in indoor environments that are not air-conditioned.

Previous Work

- **This project builds off of previous efforts by NASA and others**
  - Isocyanate-free Coatings for Structural Steel Project
  - Low VOC Coatings and Depainting Field Testing Phase 2 Project
  - Launch Coatings Phase 3 Project
  - Eastern Range Coatings Support Project
  - Coatings Demonstration/Validation at Vandenberg Air Force Base Project
- **This is a continuous process**
  - Changing regulations
  - Emerging technologies

Environmental, Safety, and Occupational Health Regulations

- Air Emissions per the Clean Air Act (CAA) and National Emissions Standards for Hazardous Air Pollutants (NESHAPs)
- Solid/Hazardous Waste Generation per the Resource Conservation and Recovery Act (RCRA)
- Reporting requirements per Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA)
- Hazardous Substances per Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)
- OSHA Standards per 29 CFR 1910 (General Industry), 29 CFR 1915 (Shipyard Employment), and 29 CFR 1926 (Construction Industry) and OSHA Directive CPL 03-00-017

Phase 1 Performance Requirements

Test	*Acceptance Criteria*	*Test References*
Pot Life	Equal to or better than control coating based upon Applicator Evaluation.	None
Ease of Application	Based on Applicator Evaluation: 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); Dry Film Thickness Measurements.	SSPC-PA-2
Surface Appearance	Based on Applicator Evaluation: No streaks, blistering, voids, air bubbles, cratering, lifting, blushing, or other surface defects/irregularities.	ASTM D 523; ASTM D 2244
Atmospheric Exposure	Gloss/color change and panel condition of candidate coating rated equal to or better than control coatings.	ASTM D 610; ASTM D 714; ASTM D 523; NASA-STD-5008B
Heat Adhesion	No loss of adhesion after heating.	ASTM D 4541; NASA-STD-5008B

Phase 2 Performance Requirements

Test	*Acceptance Criteria*	*Test References*
Hypergol Compatibility	Slight to Moderate Reactivity Observed	KSC MTB-175-88; NASA-STD-6001
LOX Compatibility	Twenty samples must not react when impacted at 72 ft-lbs or 98 J. If one sample out of 20 reacts, 40 additional samples must be tested without any reactions.	ASTM D 2512; NASA-STD-6001
Cure Time (MEK Solvent Rub)	Coating will be tested every 2 days for a total of 14 days; No effect on surface or coating on the cloth (Resistance Rating 5).	ASTM D 4752
Removability	Less than one minute to penetrate substrate.	ASTM G 155
Reparability	Ease of removal and replacement of damaged areas of the test coatings, color matching of aged versus new material; Acceptable surface appearance, No peel away of the repaired coating during the dry tape adhesion test.	ASTM D 523; ASTM D 2244; ASTM D 3359
Mandrel Bend Flexibility	No peeling or delamination from the substrate and no cracking greater than ¼-inch from the edges.	ASTM D 522

Potential Alternative Evaluation

1. **Commercially Availability**
2. **Technical Feasibility**
3. **Volatile Organic Compound (VOC) Content < 200 g/L**
4. **Hazardous Air Pollutants (HAPs) Content**
5. **Other Hazardous Constituents**
6. **Isocyanates**
7. **Heavy Metals**
   - Lead
   - Chromium
   - Cadmium
   - Zinc

Potential Alternative Evaluation

Table 7 Excalibur OZWBP-In-710/EXWBP 700G/Aqua-Thane Coatings

Manufacturer:	Excalibur Paints 1116 E. Scott Ave. Wichita Falls, TX 76303	Tel: 904.767.9912 www.excaliburpaint.com

Material Description: OZWBP-In-710 is a self-curing water-based potassium silicate zinc primer for use in heavy-duty protective systems that offers superior abrasion, chemical and corrosion resistance. It is designed to protect steel galvanically and also prevent undercutting type corrosion. EXWBP 700G epoxy primer or intermediate coat is formulated to meet stringent VOC regulation yet provide excellent resistance to corrosive chemicals, staining, and abrasion. Aqua-Thane (patent pending) is a high performance 2-component water-borne acrylic polyurethane that meets or exceeds the properties of conventional solvent-borne polyurethanes.

	VOCs	HAPs	EPCRA/TRI	CERCLA	RCRA	Other Information
Primer OZWBP-In-710 Water-borne IOZ Dust Primer	35 g/L	Ethylene Glycol	Ethylene Glycol	Ethylene Glycol	N/A	• OZWBP-In-710 Primer: Recommended DFT = 3.0 mils; Color is Gray with Flat sheen • EXWBP Intermediate: Recommended DFT = 2.0-3.0 mils; Colors are Red Oxide and Gray with Flat sheen • Aqua-Thane Topcoat: Recommended WFT = 6.0-7.0 mils/DFT = 3.0-4.0 mils; Various colors are available with High Gloss and Satin sheen
Intermediate EXWBP 700G Epoxy Primer	40 g/L	N/A	N/A	N/A	N/A	
Topcoat Aqua-Thane	42 g/L	N/A	N/A	N/A	N/A	

Recommended Surface Prep: Remove all oil, grease and other contaminants by washing with solvent or surface cleaner/degreaser in accordance with SSPC-SP-1. Allow to dry prior to painting. For optimum performance: Abrasive blast to a near white finish in accordance with SSPC-SP-10 and obtain a 1.5-3.0 mil blast profile.

Other Application Notes: Primer: Stir Part A component thoroughly making sure no pigment remains on the bottom of container and color is uniform; Add Part B (Zinc Dust) to Part A while agitating; No thinning necessary. Intermediate: Stir each component thoroughly making sure no pigment remains on bottom of container and color is uniform; Mix 4 Part A Base to 1 Part B Activator. Topcoat: Stir each component thoroughly, Mix Part A with Part B; Thin up to 15% with water for an even flow; Allow a sweat-in period of 30 minutes prior to spraying.

Advantages:	• Low VOC content • No isocyanates • Does not contain chrome, cadmium, or lead • Can be applied by brush, roller, or spray • Easy clean-up with soap and/or water	**Disadvantages:**	• Primer contains zinc • Three (3) coat system

Recommended For Testing: Yes No	**Comments: This coating system was selected for testing.**

Round 1 Selection of Alternatives

- **Identified 21 commercially available potential alternatives**
- **Project stakeholders reviewed information and discussed advantages and disadvantages to down-select those to include in testing**
- **Selected 10 alternative coating systems:**
  - Four (4) zinc-free and isocyanate-free systems
  - Three (3) isocyanate-free systems (contain zinc)
  - Two (2) zinc-free systems (contain isocyanates)
  - One (1) isocyanate-free and reduced zinc content system

Round 1 Testing Summary

- **Completed test panel preparation**
- **Completed the following tests:**
  - Pot Life
  - Ease of Application
  - Surface Appearance
  - Heat Adhesion Testing
- **Atmospheric Exposure Testing currently underway**
- **Determining which alternatives are showing acceptable performance and will be subjected to Phase 2 Tests**

Test Panel Preparation

- 4 inches x 6 inches x 3/16 inches
- ASTM A 36 (*Standard Specification for Carbon Structural Steel*) hot rolled carbon steel
- Composite panels have 1" channel welded on the front face
- Panels were abrasive blasted to a white metal per SSPC-SP-5 (*White Blast Cleaning*) to remove any mill scale and weld slag
- Anchor profile created by the abrasive blasting was measured ranging from 2.5 to 3.0 mils (1 mil = 0.001 inches)

Test Panel Preparation

Preparation of Test Panels and Quality Control Check

Pot Life Testing

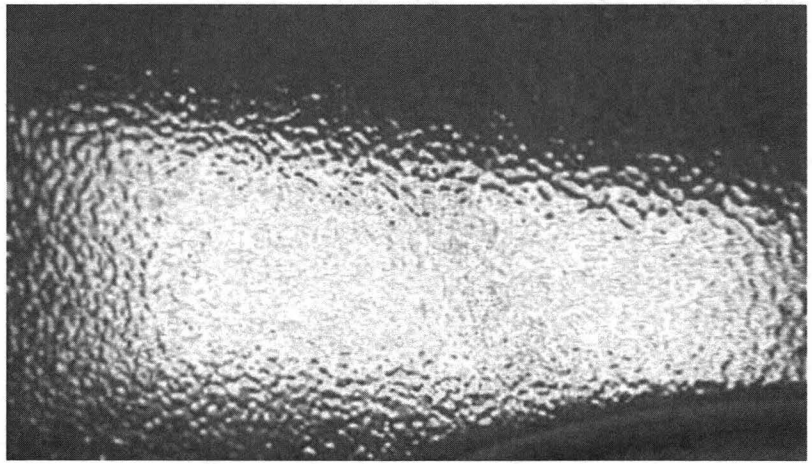
- This test provides data to characterize the pot life envelope.
- Pot life is a concern for project participants because it can affect the time available to maintenance personnel to apply the coating.
- If too short, it can cause an unacceptable coating resulting in poor performance.
- Evaluation completed during the test panel preparation and based on the Applicator's evaluation.

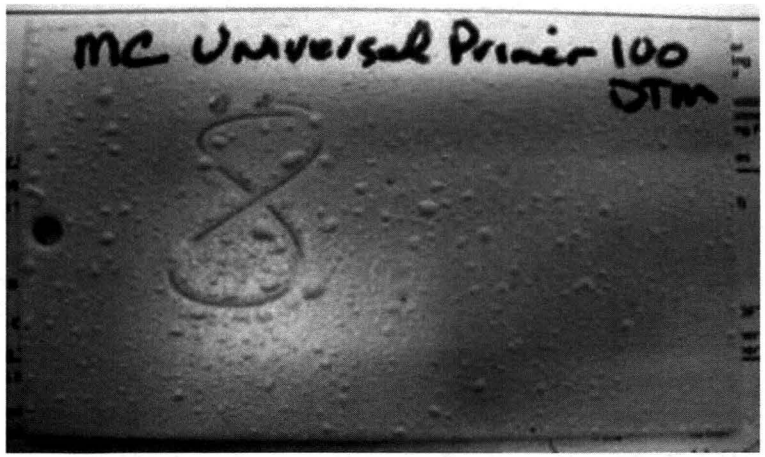
Ease of Application Testing

- This procedure is used to determine how easily a coating system may be applied.
- It is conducted to identify and eliminate those candidate coating systems that are difficult to properly apply under normal maintenance operation conditions.
- Difficult to apply coatings can cause an unacceptable coating resulting in poor performance.
- Evaluation completed during the test panel preparation and based on the Applicator's evaluation.
- Dry Film Thickness (DFT) measurements in accordance with SSPC-PA-2 (*Measurement of Dry Coating Thickness with Magnetic Gages*) are also recorded.

Surface Appearance Testing

- Examine the surface of each coated test coupon for coating defects with unaided eye and with 10X magnification.
- Defects include micro-cracks or an orange peel appearance.
- The surface appearance of the topcoat is evaluated only after the entire coating system has been applied.
- Evaluation completed during the test panel preparation and based on the Applicator's evaluation.





Heat Adhesion Testing

- Evaluates the performance of primers after exposure to prolonged heat as required by NASA-STD-5008B.
- Purpose is to identify a coating's resilience after exposure to high temperatures
- Flat primer-only coated panels will be tested for tensile adhesion using ASTM D 4541 (*Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers*).
- The same primer-only coated panels will then be exposed in a high temperature oven to a temperature of 750° F for 24 hours and allowed to cool at room temperature.
- The coating will then be re-tested for tensile adhesion to check for adhesion loss or film deterioration caused by the heating.

Round 1 Completed Testing Results as Compared to Baseline System

System	Pot Life	Ease of Application	Surface Appearance	Heat Adhesion
1 (Iso-free)	✗	✗	✓	✗
2 (Iso-free)	✓	✓	✓	=
3 (Zinc-free)	✓	✓	✓	✗
4 (Iso-free)	✓	✓	✓	=
5 (Iso-free + Zinc-free)	✓	✓	✓	✗
6 (Iso-free + Zinc-free)	✓	✓	✓	✗
7 (Iso-free + Zinc-free)	✓	✓	✓	✗
8 (Iso-free + Red. Zinc)	✓	✓	✓	✗
9 (Iso-free + Zinc-free)	✓	✓	✓	✗
10 (Zinc-free)	✗	✗	✓	✗

Atmospheric Exposure Testing

- **Test panels were placed at the KSC Beachside Atmospheric Test Facility.**
  - Test racks located approximately 150 feet from Atlantic Ocean high tide line.
- **Panels evaluated for:**
  - Color Changes
  - Gloss Retention
  - Corrosion Ratings
- **Round 1 exposure initiated on 08/23/12.**

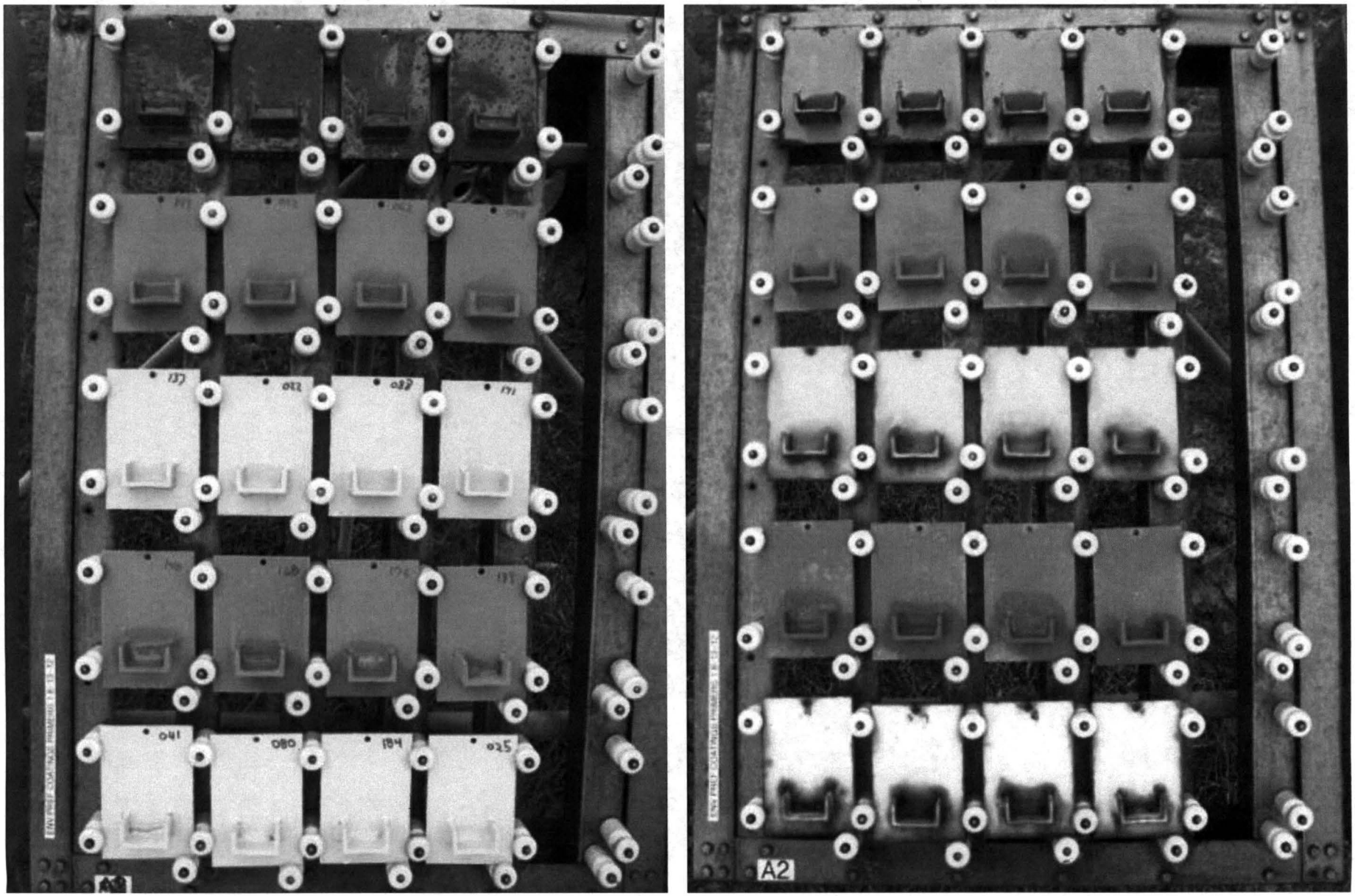
Atmospheric Exposure Testing

- ASTM D 2244, *Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates*
- ASTM D 523, *Standard Test Method for Specular Gloss*
- ASTM D 714, *Standard Test Method for Evaluating Degree of Blistering of Paints*
- ASTM D 610, *Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces*
- ASTM D 1654, *Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments*

Atmospheric Exposure Testing

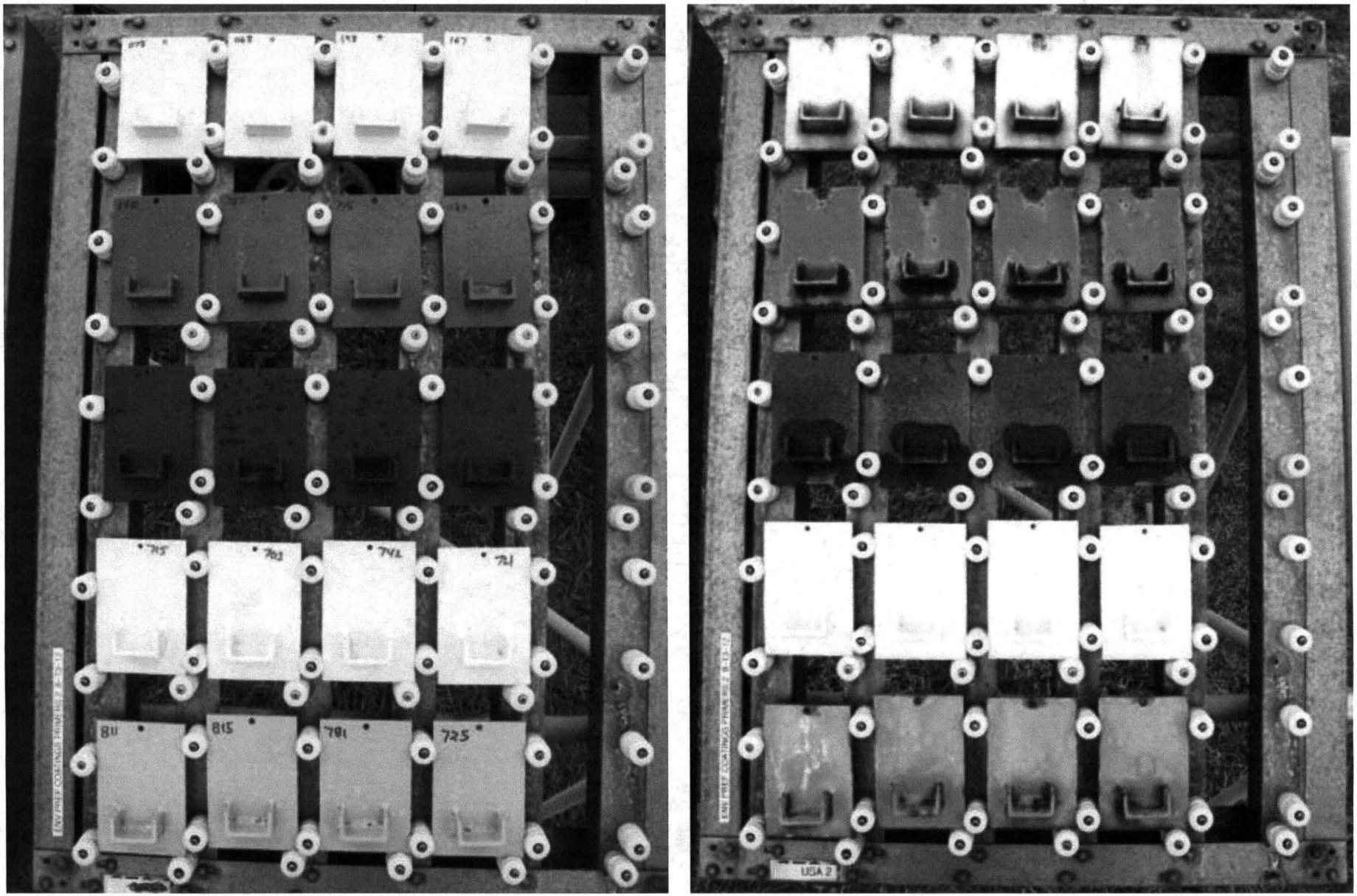
System	Atmospheric Exposure Testing as Compared to Baseline System (after 12 months)			
	Corrosion	Scribe	Color	Gloss
1 (Isocyanate-free)	✗	✗	✗	✗
2 (Isocyanate-free)	✓	✓	✓	✓
3 (Zinc-free)	=	✗	=	✓
4 (Isocyanate-free)	✓	✓	=	✗
5 (Isocyanate- + Zinc-free)	✗	✗	✗	✗
6 (Isocyanate- + Zinc-free)	=	✗	=	✗
7 (Isocyanate- + Zinc-free)	✗	✗	=	✓
8 (Isocyanate-free + Red. Zinc)	=	✗	=	✗
9 (Isocyanate- and Zinc-free)	✓	✓	✗	✗
10 (Zinc-free)	=	✗	=	=

Atmospheric Exposure Testing



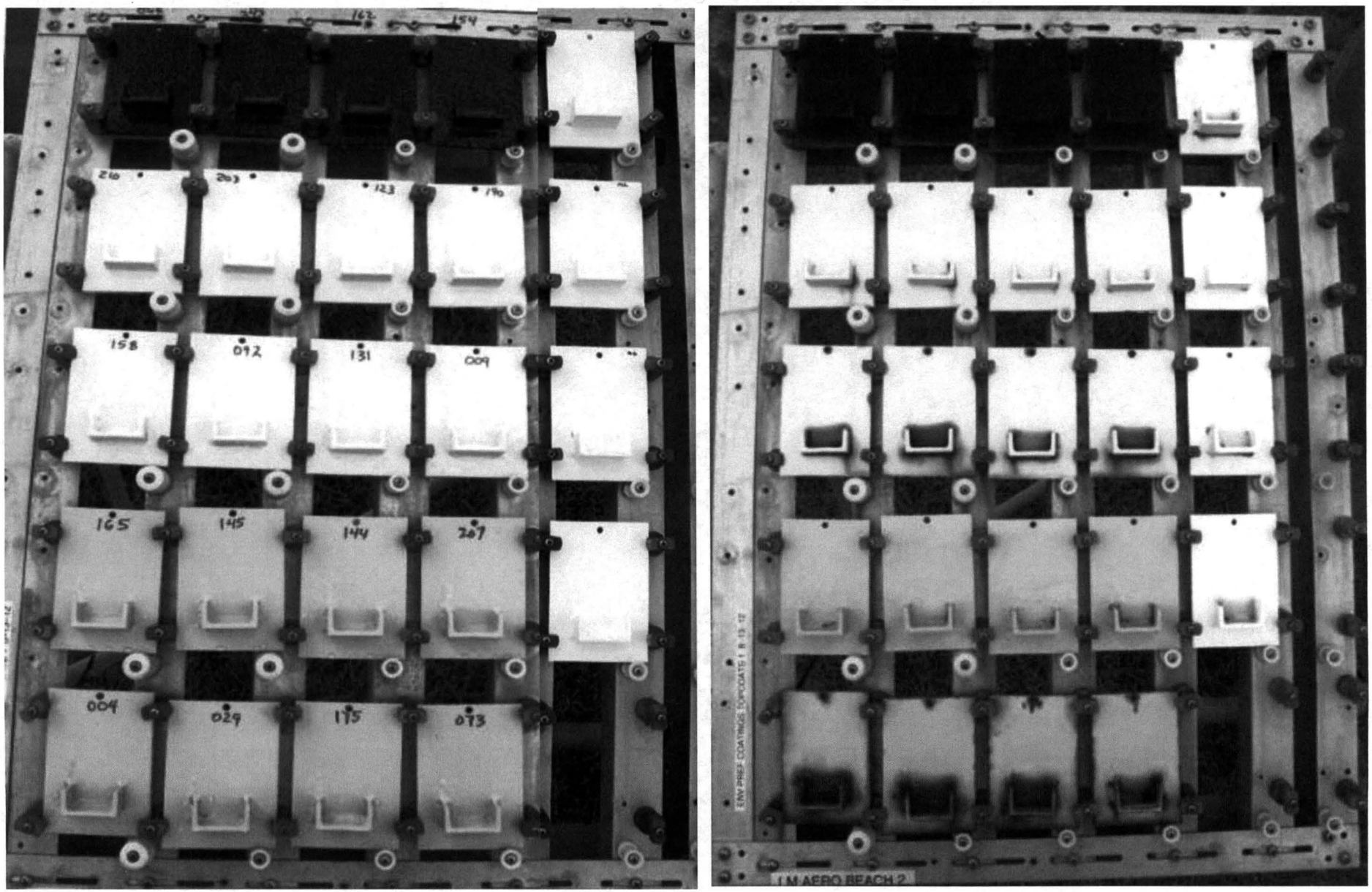
Primers-only Rack 1 – Initial and after 12 months

Atmospheric Exposure Testing



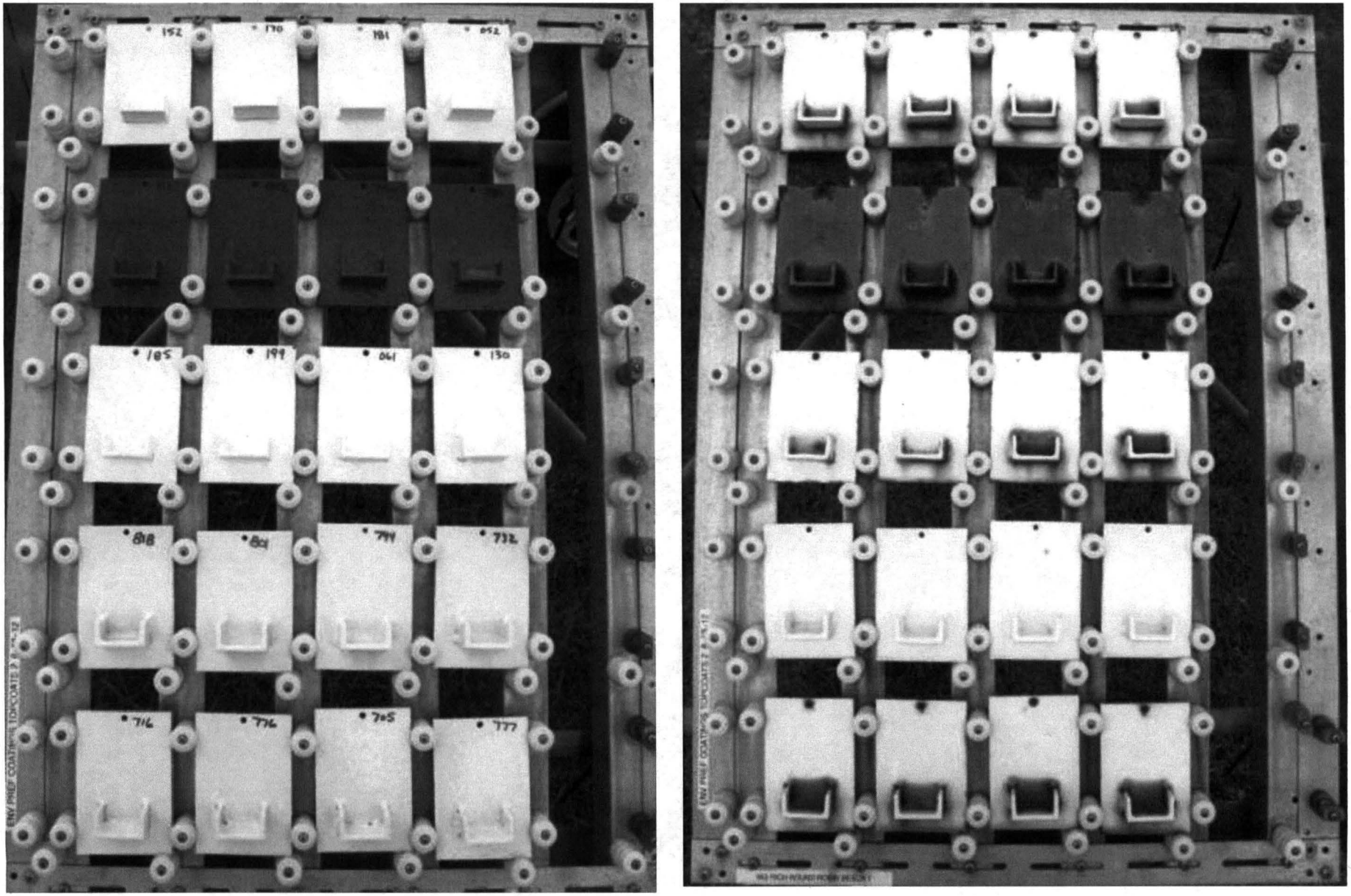
Primers-only Rack 2 – Initial and after 12 months

Atmospheric Exposure Testing



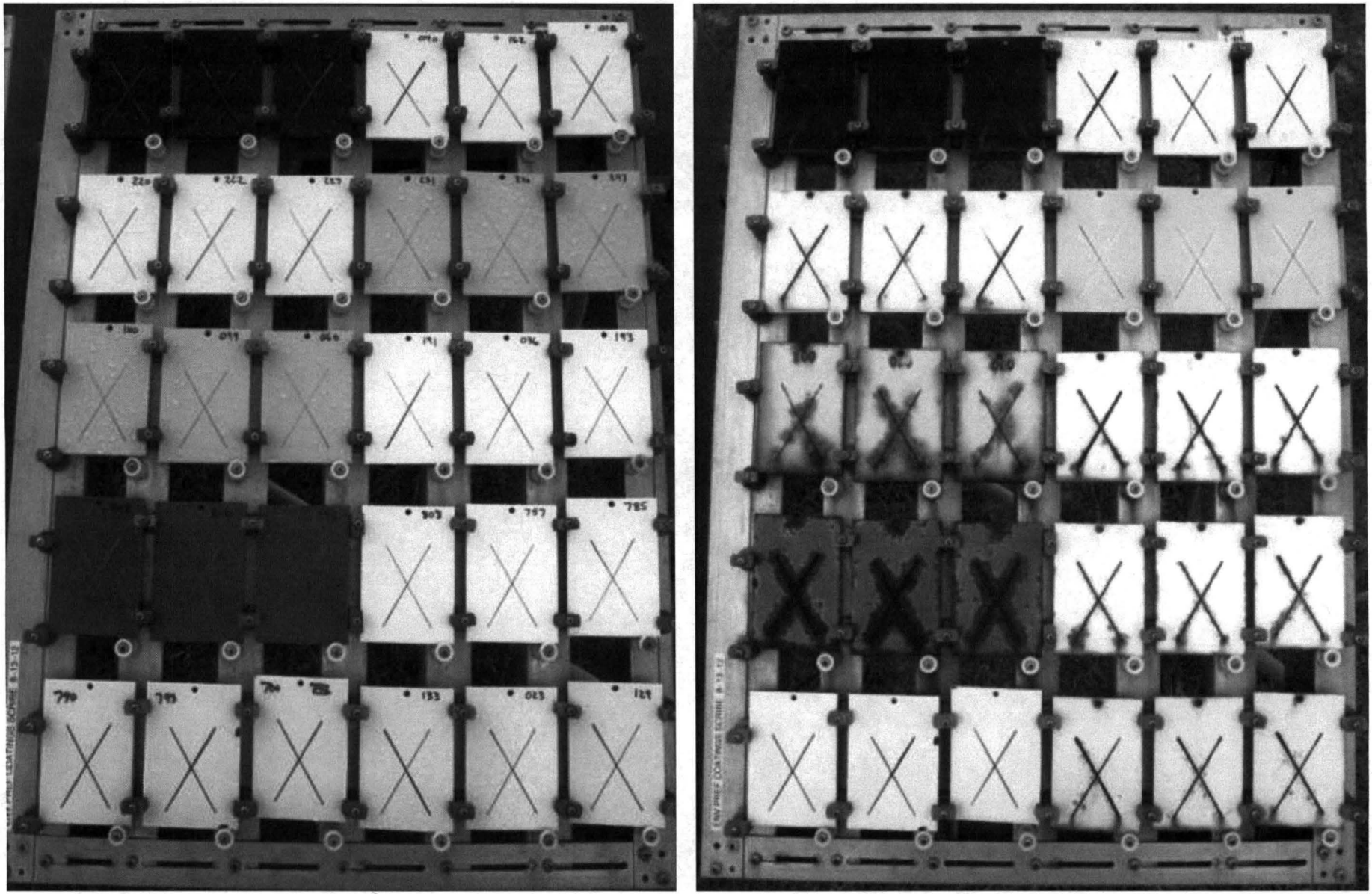
Full Systems Rack 1 – Initial and after 12 months

Atmospheric Exposure Testing



Full Systems Rack 2 – Initial and after 12 months

Atmospheric Exposure Testing



Full Systems Scribed – Initial and after 12 months

Round 2 Selection of Alternatives

- **Identified 23 commercially available potential alternatives**
- **Project stakeholders reviewed information and discussed advantages and disadvantages to down-select those to include in testing**
- **Selected nine (9) alternative coating systems:**
  - Two (2) zinc-free and isocyanate-free systems
  - Two (2) isocyanate-free systems (contain zinc)
  - Three (3) zinc-free systems (contain isocyanates)
  - Two (2) systems containing zinc and isocyanates

Future Work

- **Testing of Round 1 Alternatives continues.**
- **Determining which Round 1 Alternatives will continue to Phase 2 Testing**
  - Hypergol Compatibility
  - LOX Compatibility
  - Cure Time
  - Removability
  - Reparability
  - Mandrel Bend Flexibility
- **Testing of Round 2 Alternatives has recently started**

Project Sponsors

- NASA HQ Environmental Management Division
- NASA Ground Systems Development and Operations (GSDO) Program

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