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NEW AIRCRAFT PRETREATMENT & WASH PRIMER SYSTEM

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ABSTRACT

Today's Department of Defense is charged with the pursuit of environmentally preferable alternatives to products and processes traditionally used. The highly specialized coating process of the military aircraft is one area where such an initiative is underway. NASA, in coordination with the Tri-Services is actively seeking greener alternatives to chromate coatings. This paper will discuss the development of a non-toxic, non-hazardous, self-healing pretreatment as well as a low VOC, water based wash primer. After vigorous in house testing, it has been determined that these products will be included in the NASA study. The products will undergo both real world evaluations in a salt water environment, as well as in-depth laboratory testing.

Key Words: Corrosion, aircraft, coating, pretreatment, wash primer

INTRODUCTION

Currently the Air Force uses a three step system containing a pretreatment, conversion coating/primer and a urethane topcoat.
The replacement of hexavalent chrome [Cr (IV)] in the processing of aluminum for aviation and aerospace applications remains a goal of great significance within the aviation and aerospace community. Aluminum, being the major manufacturing material on structures and components in both the aircraft (military and commercial) and space flight arena, consequently, the processing and maintenance of this material against degradation and corrosion is of prime importance to the US Air Force and NASA in preserving our defense and space operations capabilities.[1]

Key to the operability and preservation of aluminum has been the use of chromated systems (conversion coatings, primers and hard chromium plated). Hard chrome plating on components is done through an electrochemical process; the electrochemically adhered chrome provides barrier protection to the substrate by forming a dense self-healing oxide layer on the surface. The electroplated chromium is chemically resistant to most compounds and offers excellent corrosion protection. Hard chrome plating also confers increased wear resistance and is most frequently used on landing gears, actuators, gearboxes, rotor heads and other high impact/wear components. Conversely, with applied coatings, the high corrosion resistance offered by chromated films is attributed to the presence of both hexavalent and trivalent chromium in the coating. The trivalent chromium is present as an insoluble hydrated oxide, whereas the hexavalent chromium imparts a "self-healing" character to the coating during oxidative (corrosive) attack. Hexavalent chrome coatings also play a critical role in supporting and enhancing the adhesion of the primer coating to the substrate.[1]

OSHA studies have determined that hexavalent chrome poses significant medical risks to users. Hexavalent chromium is considered a potential lung carcinogen; studies of workers in the chromate production, plating, and pigment industries consistently show increased rates of lung cancer. In the interest of worker safety, as well as the cost and operational implications of new and pending environmental, safety and health regulations, both NASA and the US Department of Defense (DoD) continue to search for an alternative to hexavalent chrome in coatings plating applications that meet their performance requirements in corrosion protection, cost, operability, and health and safety; while underlining that performance must be equal to or greater than existing systems.[1]

The development of a non-toxic, non-hazardous, self-healing pretreatment as well as a low VOC, water-based wash primer will address OSHA and military concerns. The purpose of the pretreatment for aluminum is to allow for better adhesion of subsequent coatings to the aluminum substrate, while also providing corrosion protection. The wash primer also serves as an adhesion promoter for the topcoat and also provides another layer of corrosion protection. The new pretreatment and wash primer coating system had to pass 3000 hours of salt spray testing before the products where included in the NASA study.

EXPERIMENTAL PROCEDURE

Two pretreatments, a wash primer and a topcoat were developed as a fully non-chromated coating system, as a replacement for hexavalent chrome coatings in aircraft and aerospace applications. This paper will show the comparison of the currently available chrome free pretreatments to the developed chrome free pretreatments as well as a comparison of how the coating system compared to a currently available topcoat.

The materials that were used and tested are listed below. Company A's pretreatment is a non-chromated metal preparation chemical. Company B's pretreatment is a chrome free conversion coating specifically formulated for treating aluminum. Company
Company C's urethane topcoat is a currently available and used topcoat in the Aerospace and military industry. The developed products are pretreatment 3 & 4, which are non-chromated pretreatments for aluminum and other metals, the water-based wash primer, the water-based acrylic emulsion topcoat and the high solids moisture cured urethane.

<u>Materials</u>

Commercial Products

- Pretreatment 1 – from Company A
- Pretreatment 2 – from Company B
- Urethane Topcoat – Company C

Developed Products
- Pretreatment 3
- Water based wash primer
- Water based acrylic emulsion topcoat
- High solids moisture-cure urethane

Substrate used – 2024-T3 Aluminum 4x6 panels
220 grit sand paper used to roughen the surface of the aluminum panels

Coating the Panels

1. The pretreatments were applied various different ways including dipping and scuffing the product on to the 2024-T3 aluminum.
2. The pretreated panels were then allowed to air dry in ambient conditions for 24 hours.
3. One set of panels was coated with the water-based wash primer at 0.5-1.0 dry mils (12.5-25 microns), while other panels were coated directly with the water-based acrylic emulsion topcoat, moisture-cure urethane or the urethane topcoat.
4. Then a selection of panels coated with the water-based wash primer was top-coated after of air drying in a ambient temperature for 1 hour or for 24 hours with the urethane topcoat.

Test Panel Preparation

1. After all of the coated panels were allowed to air dry in ambient conditions the panels were then prepared for salt spray testing.
2. All of the exposed and uncoated surfaces were taped with packing tape.
3. A straight line scribe was made on the panel.
4. The panels were then placed in the salt spray chamber and were evaluated at various intervals in the salt spray chamber and the corrosion data was recorded, using the ASTM D1654 for evaluating coated specimens.

Test Methods Used

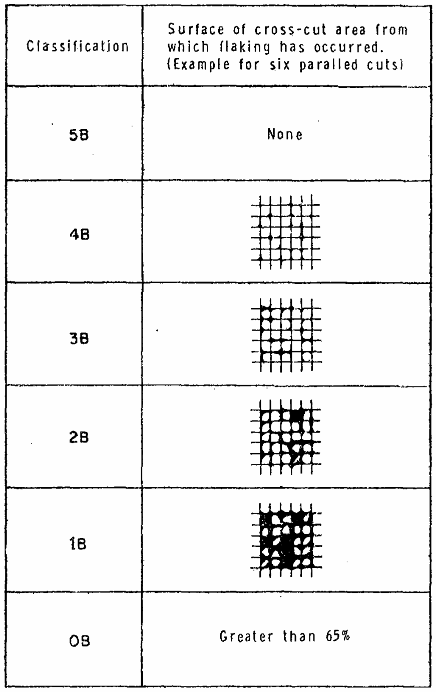
1. ASTM D3359: Standard Test Methods for Measuring Adhesion by Tape Test
2. ASTM B117: Standard Test Method of Salt Spray (Fog) Testing
3. ASTM D714: Standard Test Method for Evaluating Degree of Blistering of Paint
4. ASTM D1654: Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments

Adhesion Testing

1. The 3 step system panels (pretreatment, wash primer and topcoat) were checked for cross hatch adhesion after 120 hours of ambient air drying.
2. The panels were then cross hatched according to ASTM D3359 and then permacel tape was applied, rubbed with a pencil eraser and then the taped was ripped off.

3. The coatings were then evaluated for adhesion using the classifications from the ASTM D3359 in Table 1 shown below.

TABLE 1
ASTM D3359 CLASSIFICATIONS



Classification	Surface of cross-cut area from which flaking has occurred. (Example for six parallel cuts)
5B	None
4B	
3B	
2B	
1B	
0B	Greater than 65%

Grade	Definition
5B	The edges of the cuts are completely smooth; none of the squares of the lattice is detached.
4B	Small flakes of the coating are detached at intersections; less than 5% of the area is affected
3B	Small flakes of the coating are detached along edges and at intersections of cuts. The area affected is 5 to 15% of the lattice.
2B	The coating has flaked along the edges and on parts of the squares. The area affected is 15 to 35% of the lattice.
1B	The coating has flaked along the edges of cuts in large ribbons and whole squares have detached. Area affected is 35 to 65% of the lattice.
0B	Flaking and detachment worse than Grade 1B.

Salt Spray Testing

1. On the other panels, the exposed surfaces were taped with packaging tape and then scribed with a sharp scribing tool in a straight line for salt spray testing, ASTM B117.
2. The coatings were evaluated at various intervals for corrosion resistance using the classifications from the ASTM D714 and ASTM D1654 as defined below.

Scribe Rating
ASTM D1654

Rating #	Millimeters
10	0
9	0 – 0.5
8	0.5 – 1.0
7	1.0 – 2.0
6	2.0 – 3.0
5	3.0 – 5.0
4	5.0 – 7.0
3	7.0 – 10.0
2	10.0 – 13.0
1	13.0 – 16.0
0	over 16.0

Blistering Rating
ASTM D714

D	Dense
MD	Medium Dense
M	Medium
F	Few
10	no blisters
8	smallest blister easily seen by the unaided eye
6, 4, 2	represents progressively larger sizes

RESULTS

The following data shows the compatibility of the available pretreatments as well as the developed pretreatments with the water based wash primer. As stated earlier pretreatment 1 is company A's pretreatment and pretreatment 2 is company B's pretreatment. Pretreatments 3 & 4 are the developed products. The wash primer that was used is the developed product. Table 2 and Figures 1 and 2 show the results of the ASTM B117 salt spray testing that was required by NASA for the above mentioned products.

The test concluded that the new wash primer was most compatible with Pretreatment 2, 3 and 4. Since the pretreatment and the wash primer passed the required 3000 hours of salt spray testing by NASA, it was determined to conduct further tests. The idea was to see if the new coating system could meet the 3000 hours of salt spray testing by taking out a step, such as eliminating the use of the wash primer. Table three discusses the results of just testing the pretreatment with the topcoat.

TABLE 2
ASTM B117 Salt Spray Data of Panels coated
With Pretreatments and the Water Based Wash Primer

Products	DFT	ASTM D1654 Scribe Rating	ASTM D714 Blister Rating
Pretreatment 1 and water based wash primer	0.45 mils (11.25 microns)	6 2300 hours	10
Pretreatment 2 and water based wash primer (Figure 1)	0.53 mils (13.25 microns)	10 3044 hours	10
Pretreatment 2 and water based wash primer (Figure 1)	0.68 mils (17 microns)	10 3044 hours	10
Pretreatment 3 and water based wash primer (Figure 2)	0.6 mils (15 microns)	9 3044 hours	10
Pretreatment 4 and water based wash primer (Figure 2)	0.57 mils (14.25 microns)	10 3044 hours	10
Pretreatment 4 and water based wash primer (Figure 2)	0.6 mils (15 microns)	10 3044 hours	10

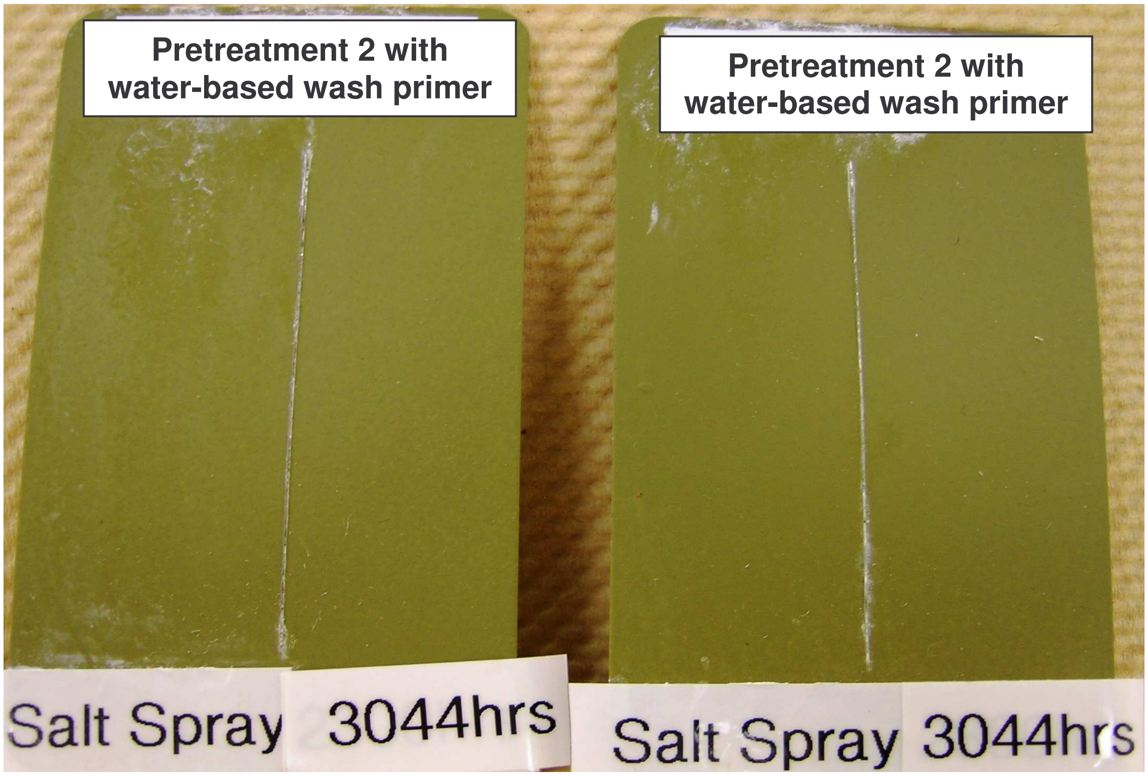


FIGURE 1 - Salt Spray Panels

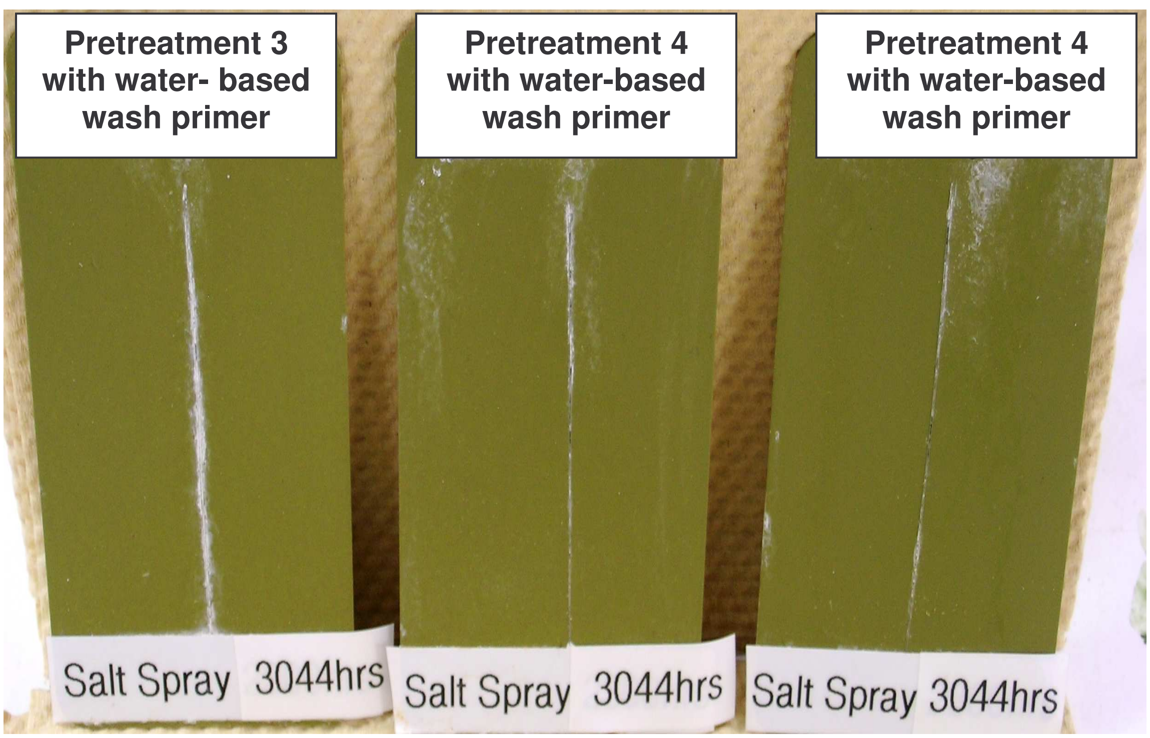


FIGURE 2 - Salt Spray Panels

The results listed in Table 3 showed that having just a pretreatment and a topcoat would pass the 3,000 hours of ASTM B117 salt spray testing. The results that were found was that company B's and the developed pretreatments with companies C's urethane topcoat passed the 3,000 hours of salt spray testing. Also the two developed pretreatments with the developed moisture cure urethane passed the required ASTM B117 3000 hours of salt spray testing as well.

Since the aerospace industry currently uses a three coat system, we still needed to test and find out if the complete coating system would pass the 3,000 hours of salt spray testing. Table 4 will show the results of testing the complete coating system.

Table 3 and Figures 3-8 show the results of the salt spray testing. Figures 3, 4, 7 and 8 had the most corrosion resistance during this testing.

TABLE 3
ASTM B117 Salt Spray Data
Salt Spray Data of Panels tested for 3000 hours with Pretreatments and Topcoats

Products	DFT	ASTM D1654 Scribe Rating	ASTM D714 Blister Rating
Pretreatment 1 with urethane topcoat (Figure 3)	1.7 mils (42.5 microns)	7	#2 M
Pretreatment 2 with urethane topcoat (Figure 3)	1.7 mils (42.5 microns)	10	#2 M
Pretreatment 3 with urethane topcoat (Figure 4)	1.7 mils (42.5 microns)	10	#2 F
Pretreatment 4 with urethane topcoat (Figure 4)	1.6 mils (40 microns)	8	#2 F
Pretreatment 1 with water-based acrylic emulsion topcoat (Figure 5)	1.1 mils (27.5 microns)	8	#6 M
Pretreatment 2 with water-based acrylic emulsion topcoat (Figure 5)	1.1 mils (27.5 microns)	9+	#6 F
Pretreatment 3 & water based acrylic emulsion topcoat (Figure 6)	1.0 mils (25 microns)	9+	10
Pretreatment 4 & water based acrylic emulsion topcoat (Figure 6)	1.1 mils (27.5 microns)	9+	10
Pretreatment 1 & moisture cure urethane (Figure 7)	2.5 mils (62.5 microns)	10	#4 F
Pretreatment 2 & moisture cure urethane (Figure 7)	2.5 mils (62.5 microns)	10	10
Pretreatment 3 & moisture cure urethane (Figure 8)	2.2 mils (55 microns)	10	#4 M
Pretreatment 4 & moisture cure urethane (Figure 8)	2.6 mils (65 microns)	10	#2 M

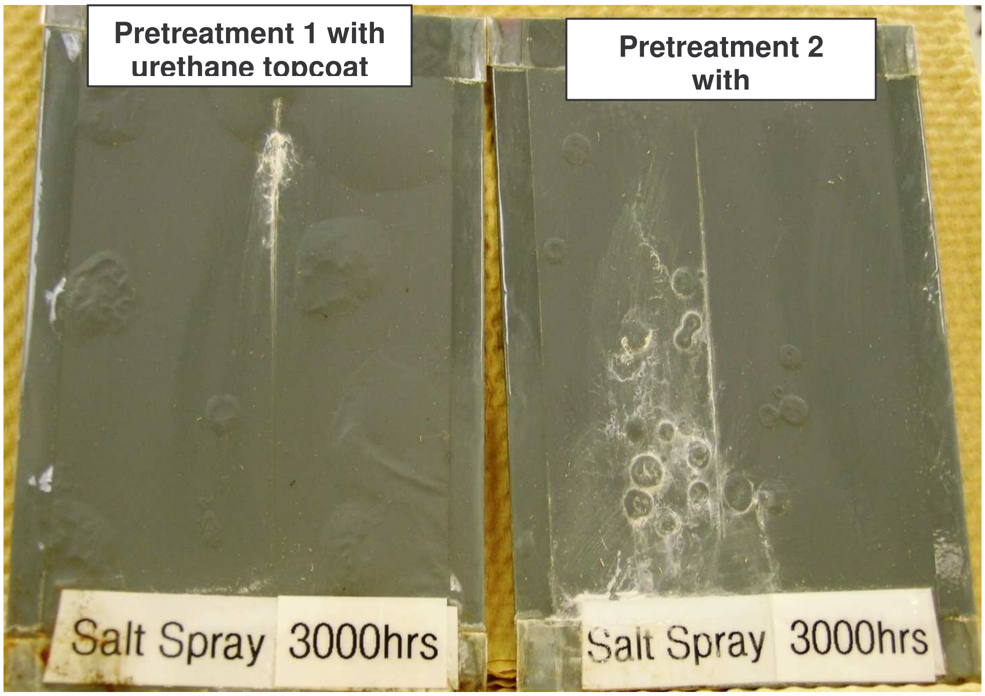


FIGURE 3 - Salt Spray Panels

FIGURE 4 - Salt Spray Panels

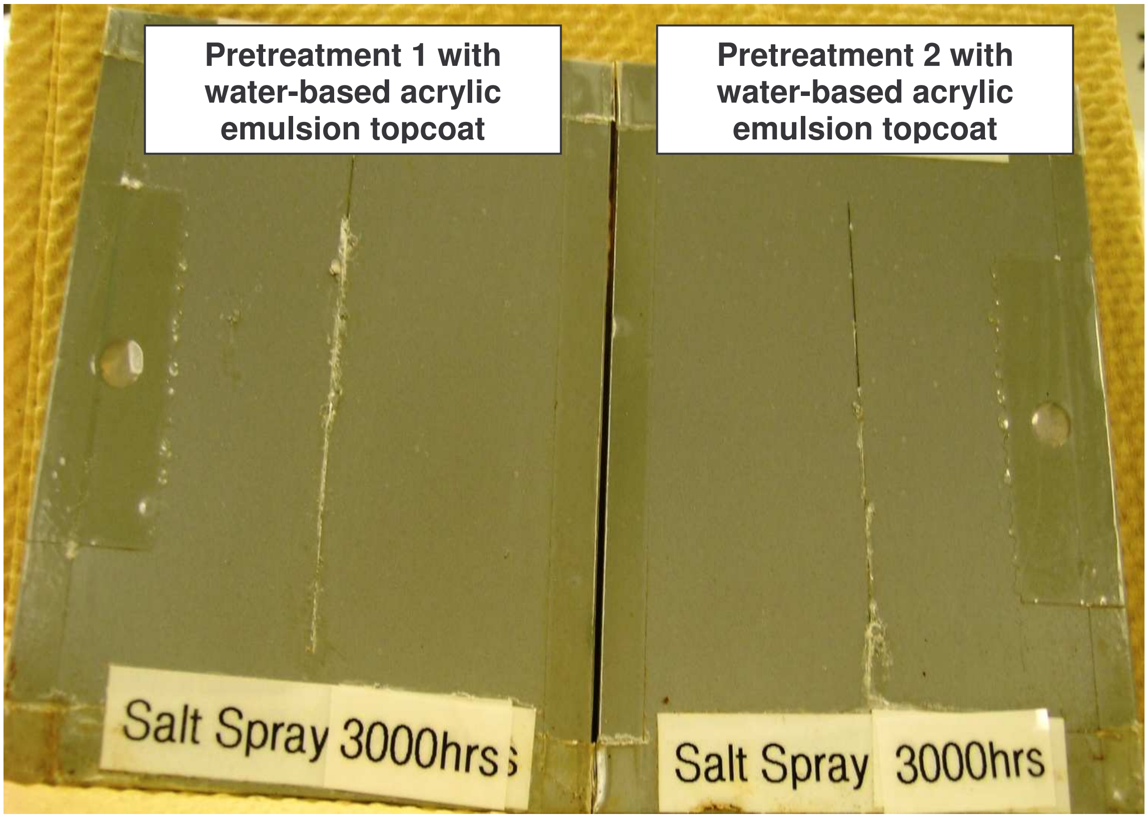


FIGURE 5 - Salt Spray Panels

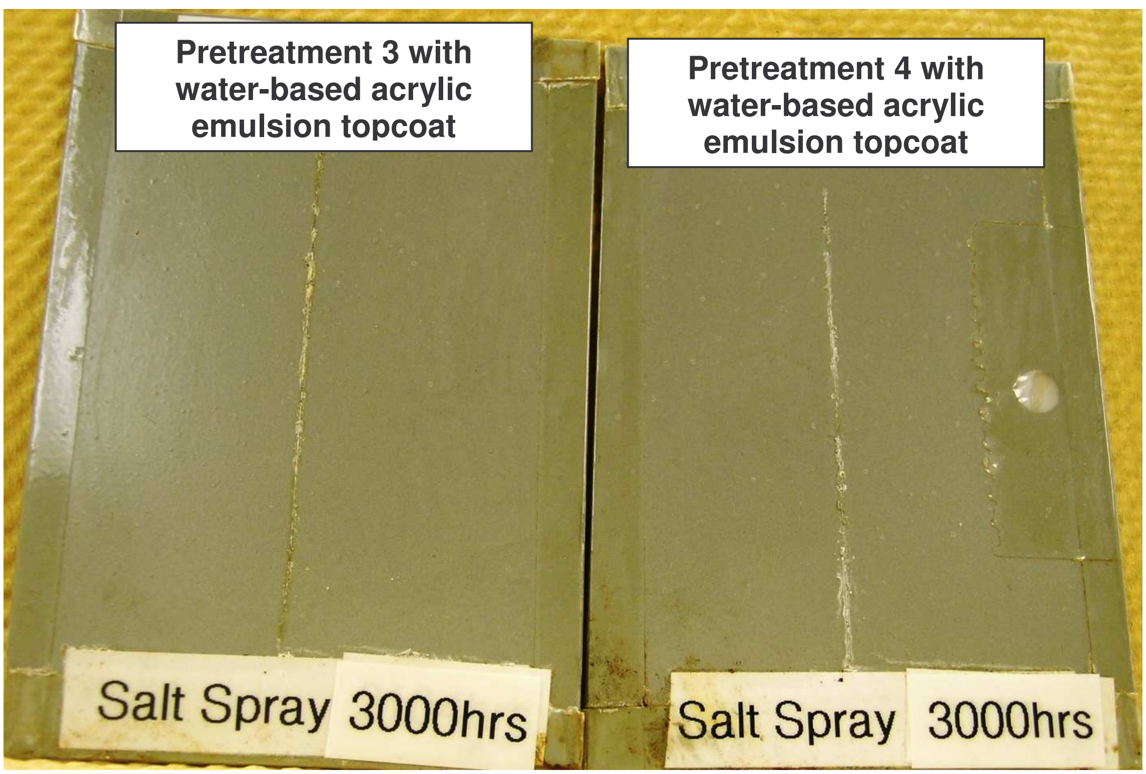


FIGURE 6 - Salt Spray Panels

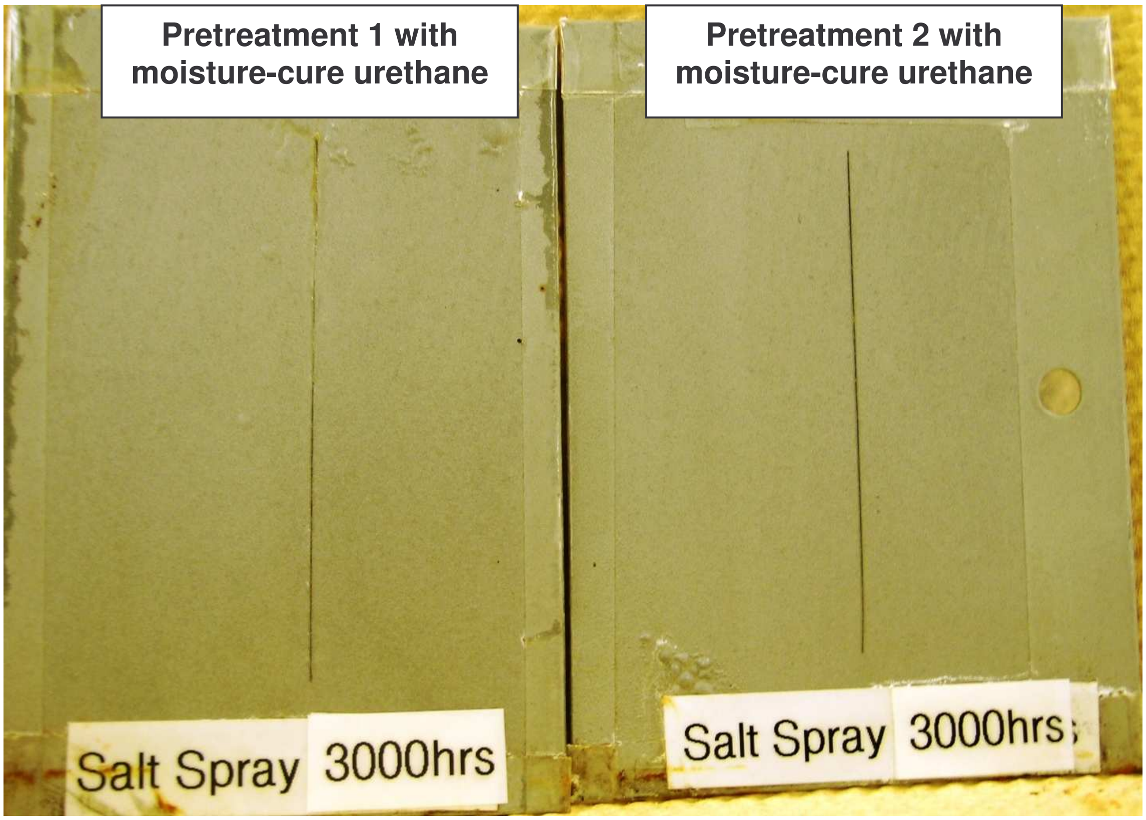


FIGURE 7 - Salt Spray Panels

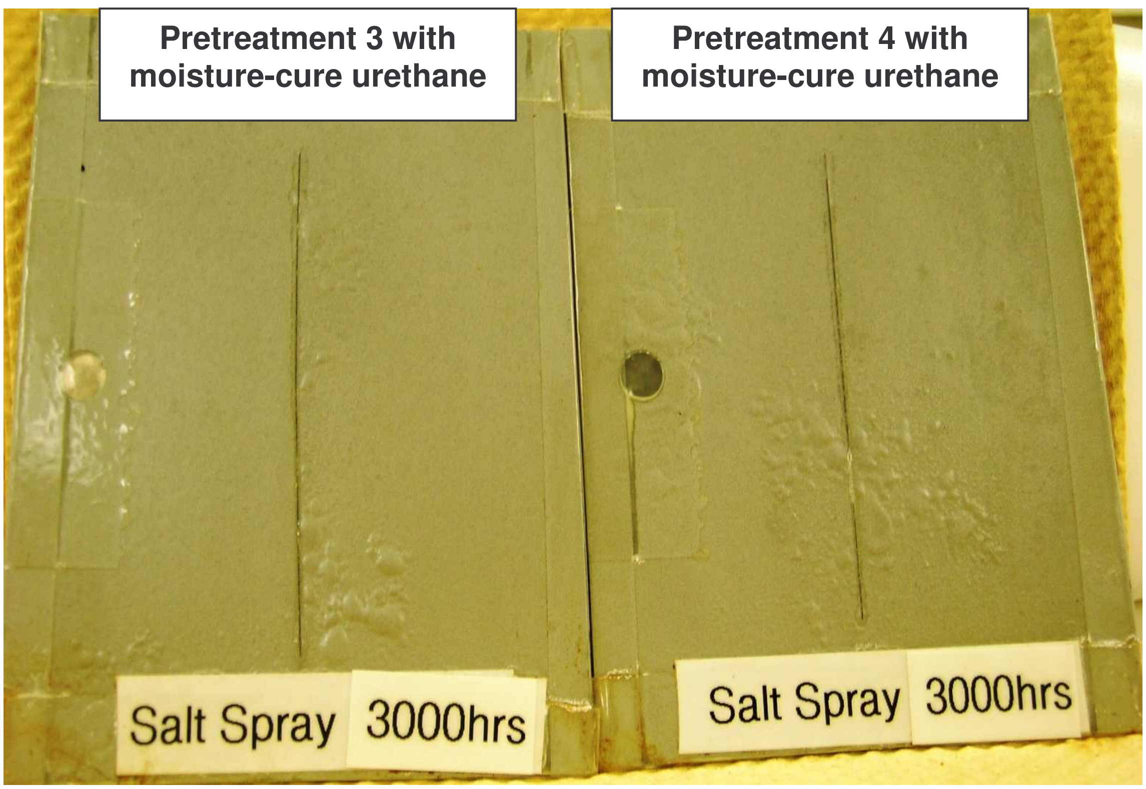


FIGURE 8 - Salt Spray Panels

In Table 4 all three components (the pretreatments, the developed wash primer and the topcoats) of the coating system were applied to the panels and then tested in salt spray until failure The developed pretreatment 3, with the developed water based wash primer along with company C's urethane topcoat proved to be the best coating system in this test and passed the required 3000 hours of salt spray testing required by NASA. Figure 9 and Table 4 and shows the results of ASTM D3359 adhesion and ASTM B117 salt spray testing.

TABLE 4
ASTM B117 SALT SPRAY AND ASTM D3359 ADHESION DATA OF PANELS COATED WITH PRETREATMENTS, WATER-BASED WASH PRIMER AND URETHANE TOPCOAT

Pretreatments Application Procedure	Total DFT	ASTM D3359 Adhesion rating	ASTM B117 Scribe rating and Hours
Pretreatment 1 pre-scuffed, dipped 5 minutes, no rinse	3.5 mils (87.5 microns)	5B	8 500 hours
Pretreatment 1 scuffed on 2x, rinsed	4.0 mils (100 microns)	4B	8 336 hours
Pretreatment 2 Pre-scuffed, dipped 5 minutes, no rinse	3.0 mils (75 microns)	4B	8 336 hours
Pretreatment 2 scuffed on 2x, rinsed	3.0 mils (75 microns)	4B	8 336 hours
Pretreatment 3 Pre-scuffed, dipped 5 minutes, no rinse	3.6 mils (90 microns)	4B	7 500 hours
Pretreatment 3 scuffed on 2x, rinsed (Figure 9)	3.0 mils (75 microns)	4B	8 3000 hours
Pretreatment 4 Pre-scuffed, dipped 5 minutes, no rinse	3.4 mils (85 microns)	5B-	7 336 hours
Pretreatment 4 scuffed on 2x, rinsed	3.1 mils (77.5 microns)	4B	8 500 hours
Pretreatment 3 Smooth, dipped 5 minutes, no rinse	3.6 mils (90 microns)	5B-	7 500 hours
Pretreatment 4 Smooth, dipped 5 minutes, no rinse	3.0 mils (75 microns)	4B	8 500 hours
Pretreatment 1 Prescuffed panel Dipped 5 minutes and rinsed	4.3 mils (107.5 microns)	4B	8 500 hours
Pretreatment 2 Prescuffed panel Dipped 5 minutes and rinsed	2.8 mils (70 microns)	4B	8+ 500 hours
Pretreatment 1 Smooth, dip, no rinse	4.0 mils (100 microns)	4B	8 500 hours
Pretreatment 2 Smooth, dip, no rinse	3.0 mils (75 microns)	4B	8 500 hours

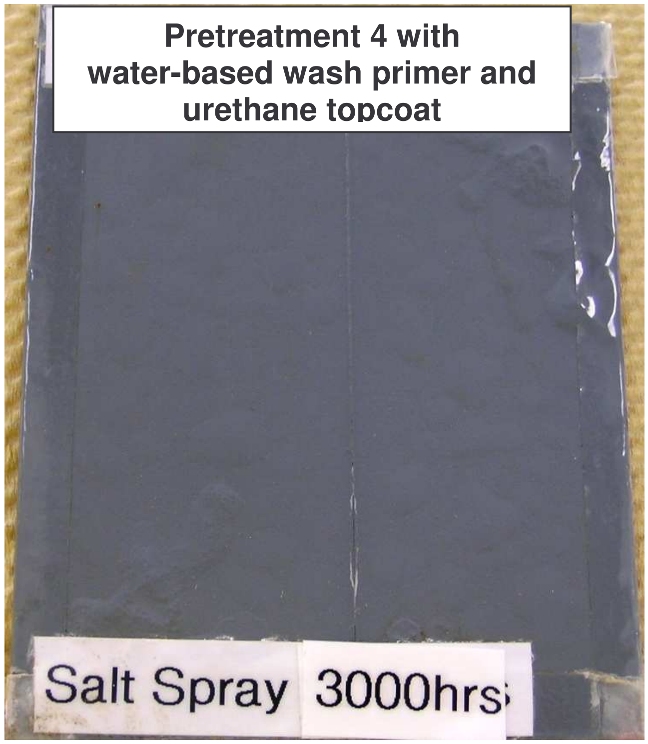


FIGURE 9 - Salt Spray Panels

CONCLUSIONS

1. Extensive formulation work has resulted in a pretreatment and wash primer that provides the needed corrosion protection requirements for NASA and the US Air force.
2. Laboratory measurements show that the formulated pretreatment and wash primer system with the existing urethane topcoat conforms to performance criteria for coating systems for aircraft, according to MIL-PRF-5541F.
3. The benefits of this new coating system is that it provides the same amount of corrosion protection for aluminum substrates as the currently used chrome based pretreatment systems.
4. Another benefit of the coating system is that the second step in the process, the wash primer may be able to be eliminated and a pretreatment and topcoat may be all that is needed to meet the aerospace industries requirements.

REFERENCES

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3. ASTM B117-85: Standard Test Method of Salt Spray (Fog) Testing

4. ASTM D714: Standard Test Method for Evaluating Degree of Blistering of Paint

5. ASTM D1654-79a: Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments