Paper
01560

CORROSION2001

Environmentally Friendly Corrosion Protection in Cleaning Systems for United States Coast Guard Aircraft

CLIFF CRACAUER
CORTEC CORPORATION
4119 WHITE BEAR PARKWAY,
ST. PAUL, MN 55110

ABSTRACT

The need to clean and protect military craft from corrosion using an environmentally friendly system is now a reality. The United States Coast Guard has approved and already utilizes the benefits of this system. The approval process included meeting or exceeding military specifications and additional requirements.

INTRODUCTION

The protection of aircraft from corrosion is an important part in the maintenance of such craft. Protecting these aircraft is accomplished in a number of ways including various protective coatings, anodizing, and very rigorous maintenance programs. Nevertheless, corrosion continues to be a concern for the United States Coast Guard, and new ways of protecting their craft from corrosion are always sought after.

Of the routine maintenance performed on the United States Coast Guards aircraft, one of the most important is the cleaning program. This is even more vital in marine environments where high humidity and corrosives such as chlorides are present in the atmosphere. While specifications for aerospace cleaning compounds exists[1], none specify incorporating a corrosion inhibitor for protection of the aircraft from atmospheric corrosion. Additionally, the environmental requirements have limited the ability to incorporate effective corrosion protection.

One solution to this problem is to incorporate Volatile Corrosion Inhibitors (VCIs) into an aqueous cleaning system to provide the required corrosion protection in an environmentally friendly package. VCIs protect both ferrous and non-ferrous alloys, and are classified as ambiotic corrosion inhibitors. For aqueous cleaners, they provide corrosion protection both in the aqueous phase, and in the vapor phase.

In order to implement this new technology into their cleaners, the United States Coast Guard required both field trials, where the VCI cleaner was tested for both cleaning performance and corrosion protection, and laboratory testing to ensure that the VCI cleaner met all of the requirements for aircraft soaps.

EXPERIMENTAL

The approval process for this VCI cleaner included passing a battery of testing before it could be deemed acceptable. Testing was completed by SMI (Scientific Material International), INC.

Compatibility Testing

The purpose of this testing was to ensure that the cleaning compound would not have any adverse effects on the materials it could come in contact with on the craft.

Rubber Compatibility Testing, Cleaning Compound, Aerospace Equipment. This test method was performed for a Type IV cleaner. Test specimens were immersed in a 25% solution of the cleaning compound at room temperature for 30 minutes. Specimens were then removed from the solution, rinsed with tap water, and tested immediately for Shore A hardness changes in accordance with ASTM D 2240.

Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds[2]. This test method covers the determination of the crazing effect of a liquid or semi-liquid test compound on transparent acrylic plastic material that is under bending stress.

Standard Test Method for Effects of Cleaners on Unpainted Aircraft Surfaces[3]. This test method describes the procedure used to determine the effect of cleaners on unpainted aircraft surfaces. Visual observation is used for determining streaking or stains which require polishing to remove.

Standard Test Method for Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces[4]. This test method is used to determine the effects of chemicals and cleaners on the painted surfaces of aircraft. Factors such as streaking, discoloration, or blistering are taken into account.

Corrosion Testing

Corrosion of Low-Embrittling Cadmium Plate by Aircraft Maintenance Chemicals[5]. This test method is intended as a means of determining the corrosive effects of aircraft maintenance chemicals on low-embrittling cadmium plating used on aircraft high-strength steel, under conditions of total immersion by quantitative measurements of weight change.

Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals[6]. Load a minimum of three specimens to 45% of the notched bend strength. Put 800 mL of the VCI cleaner into a plastic container, place the stressed specimens in the test solution and record the time to failure if less than 150 hours. If no failure occurs after 150 hours, the test may be discontinued. The specimen

Sandwich Corrosion Test[7]. Aluminum panels having clad or anodized nonclad surfaces are sandwiched together with filter paper saturated with the test material between the panels. The sandwiched panels are cycled between warm ambient air and warm humid air for seven days. The panels are then inspected to determine whether corrosion more severe than that caused by a reagent water has occurred on the surfaces exposed to the test material.

Total Immersion Corrosion[8]. Aluminum and titanium panels are weighed and immersed in the test solution for a 24-hour period. The panels were then removed, cleaned, and tested for weight loss.

Half Immersion Corrosion[9]. Aluminum and carbon steel panels are weighed and immersed in the test solution, using DI water as control solution. The testing period was determined on the alloy used. The panels were removed after the pre-determined testing period, cleaned, and tested for weight loss.

Environmental

Biodegradation[10]. The biodegradability was determined in accordance with the EPA 28-day test method. The requirement states that the ratio of Biological Oxygen Demand (BOD) to Chemical Oxygen Demand (COD) must be greater than or equal to 60%.

RESULTS

Compatibility Testing

The results of the various material compatibility testing can be found in Table 1 through Table 4. In each of the tests, the VCI cleaner was found to meet the standards required for aircraft cleaning compounds.

Corrosion Testing

The results of the corrosion testing for the low-embrittling cadmium plating can be found in Table 5. In the hydrogen embrittling testing, there was no failure within 150 hours, so the test was terminated. The results for the sandwich corrosion testing can be found in Table 6. The test is rated on a scale of 0-4, depending on the degree of corrosion present at the conclusion of the testing. A rating of one in this testing indicates that less than 5% of the surface area contained corrosion. Since the test coupons did not have corrosion more severe than the control coupons, the VCI cleaner was found to conform.

For the half-immersion testing, the control panels show medium corrosion below the water line after 24 hours for carbon steel, and corrosion above the water line after 72 hours. The aluminum controls have oxidation below the aqueous line after 72 hours. In each of the corrosion tests, the VCI cleaner was found to meet the standards required for aircraft cleaning compounds. The results of the total immersion and half immersion testing can be found in Table 7 and Table 8.

Environmental Testing

The VCI cleaner was found to be considered biodegradable by the performed testing. After the 28 day testing period the BOD/COD ratio was found to be 0.66.

DISCUSSION

The above results show that the VCI cleaner is compatible with the materials it may come in contact with when used on aircraft. There were no adverse affects in the rubber compatibility testing, or in the stress crazing of acrylic polymers test. When the VCI cleaner was applied to unpainted surfaces there was no staining, or ill affects to the metal surfaces. Additionally, the cleaner did not cause any blistering, streaking, or discoloration to the painted surfaces.

The VCI cleaner also passed all corrosion testing, and the results indicate that it provides corrosion protection in the aqueous phase, and the vapor phase. The sandwich corrosion test, and the immersion testing were used to provide data that indicated the VCI cleaner is able to protect against corrosion. Conversely, the low-embrittling cadmium corrosion testing, and the hydrogen embrittlement testing were used to indicate that the VCI cleaner did not cause corrosion, or embrittlement.

The test that provides the greatest indication of the vapor corrosion inhibiting ability of the VCI cleaner is the half-immersion test. In this testing, the control used shows that even DI water is aggressive to both steel and aluminum in a very short time period in both the contact areas, and in the vapor phase. In contrast, the panels placed in the VCI cleaner did not corrode for the entire test period, in either the contact phase, or the vapor phase.

For the low-embrttling cadmium corrosion test, and the hydrogen embrittlement test, the results indicate that the VCI cleaner is not aggressive to the tested materials.

The environmental impact of the cleaner is low, as evident by the results of the biodegradation testing.

The field testing of the cleaner indicated that the VCI cleaner was easy to use, and performed very well as a cleaner. In the past, the aircraft soaps were sufficient in cleaning properties. The new technology in VCI cleaners now allows them to incorporate corrosion inhibition properties into an aircraft soap that is very effective.

SUMMARY

Based on the results of the field testing and the laboratory testing, the United States Coast Guard has implemented VCI cleaner into their standard maintenance program for their aircraft. The VCI cleaner provides the cleaning properties that are required, and in addition incorporates an environmentally safe corrosion inhibiting package.

ACKNOLEDGEMENTS

The author acknowledges the assistance of Dave Schmidt, of the United States Coast Guard, in providing information on the field application of VCI cleaners.

REFERENCES

1. Military Specification, MIL- C-87973 "Cleaning Compounds, Aerospace Equipment"
2. ASTM 484-93 "Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-liquid Compounds"
3. ASTM F 485 "Standard Test Method for Effects of Cleaners on Unpainted Aircraft Surfaces"
4. ASTM F 502-93 "Standard Test Method for Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces"
5. ASTM F 1111-88 "Corrosion of Low-Embrittling Cadmium Plate by Aircraft Maintenance Chemicals"
6. ASTM F 519-93 Type 1C "Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals"
7. ASTM F 1110-90 "Standard Test Method for Sandwich Corrosion Test"
8. ASTM F 483-90 "Standard Test Method for Total Immersion Corrosion Test for Aircraft Maintenance Chemicals"
9. ASTM G 31-72 "Standard Practice for Laboratory Immersion Corrosion Testing of Metals"
10. EPA 600/4-79-020, "Methods for Chemical Analysis of Water & Waste", March 1979
11. "Standard Methods for Examination of Water & Wastewater, 18th Edition, 1992

Table 1
VCI Cleaner – Rubber Compatibility Testing (MIL-PRF-87937C)

AMS 3204	**No change in Shore A hardness**
AMS 3209	**No change in Shore A hardness**

Table 2
Stress Crazing of Acrylic Plastic (ASTM F 484-83)

Plastic Type	Test Conditions	Results
Type A Acrylic (MIL-P-5425)	3000 psi / 8 hours (20.69 MPa/ 8 hours)	**No crazing evident**
Polycarbonate (MIL-P-83310)	2000 psi / 30 minutes (13.79 MPa / 30 minutes)	**No crazing evident**
Type C Acrylic (MIL-P- 25690)	4500 psi / 8 hours (31.03 MPa / 8 hours)	**No crazing evident**

Table 3
Effect of Cleaners on Unpainted Aircraft Surfaces (ASTM F 485-90)

Alloy	Results
Aluminum (7075-T6 Alclad) QQ-A-250/13	**No residue or staining**
Titanium (6Al-4V) MIL-T-9046 Type III	**No residue of staining**

Table 4
Effect of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces (ASTM F 502)

Set-up	Pencil Hardness/Appearance
Painted panel (before exposure)	**4H**
Painted Panel (after exposure)	**4H** **No streaking, discoloration, or blistering**

Table 5
Corrosion of Low-Embrittling Cadmium Plate by Aircraft Maintenance Chemicals (ASTM F 1111-88)

Set-up	Weight Loss
Test Panel 1	**10.4 mg**
Test Panel 2	**10.8 mg**
Average	**10.6 mg (0.38/cm^2/3hrs)**

Table 6
Sandwich Corrosion Test (ASTM F 1110)

	VCI Cleaner	Control
2024-T3 Bare Anodized	1	1
2024-T3 Alclad	1	1
7075-T6 Bare Anodized	1	1
7075-T6 Alclad	1	1

0 = No visible corrosion
1 = Very slight corrosion or discoloration (up to 5% of surface area)
2 = Slight corrosion (5 to 15% of surface area)
3 = Moderate corrosion (10 to 25% of surface area)
4 = Extensive corrosion or pitting (25% or more of surface area)

Table 7
Total Immersion Corrosion (ASTM F 483)

Alloy	Weight Loss (mg) After 24 hrs	Weight Loss (mg) After 168 hrs	WGT Loss mg/cm^2/24hrs
AMS 4037 Bare Al; anodized per MIL-A-8625 Type 1	<0.1	+0.2	<0.01
AM 4037 Bare Al	<0.1	<0.1	<0.01
AMS 4911 Ti MIL-T-9046	<0.1	<0.1	<0.01
AMS 5045 Grade 1020 steel	0.1	<0.1	<0.01
AMS 5504; 410 SS, silver plated Per QQ-S-365 Ty II, Grade B	0.6	0.4	0.02

Note: No visible corrosion on any panel

Table 8
Half Immersion Corrosion (ASTM G 31-72)

Alloy	Time Before Corrosion (Days) Control	Time Before Corrosion (Days) VCI Cleaner
1010 Carbon Steel	<1	>30
3041 Bare Al	<1	>30