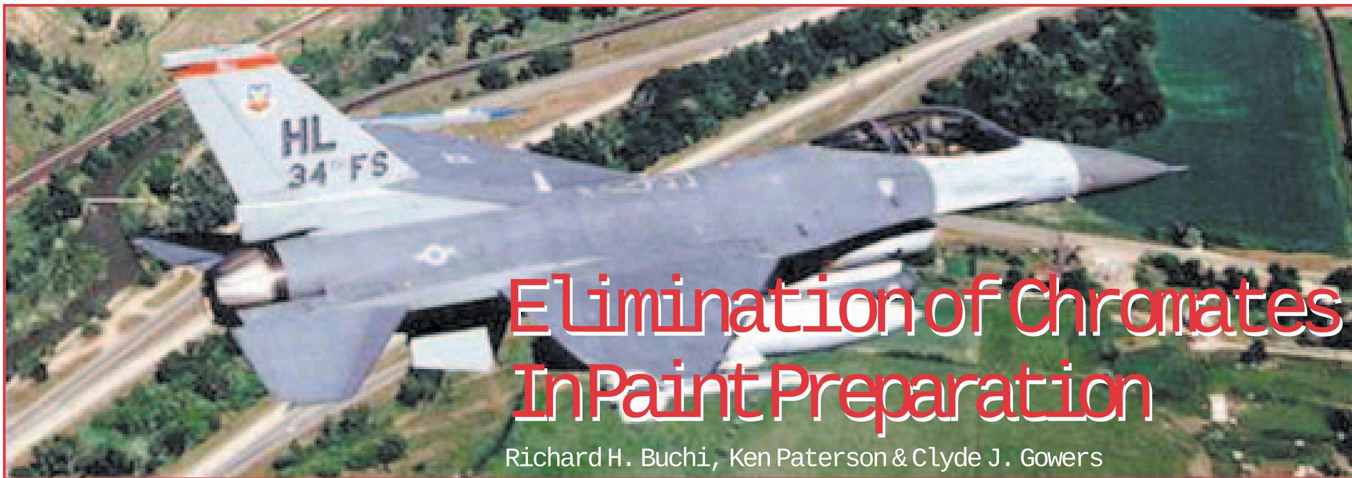

Elimination of Chromates In Paint Preparation

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Reduction and elimination of chromate-containing wastes is a major pollution prevention goal. One of the most pervasive uses of material containing chromate is in the treatment of aluminum with chromate conversion coating. Researchers at Hill Air Force Base in Utah have found an environmentally friendly solution that leaves a thin film on the substrate, which passivates the surface and enhances paint adhesion. The solution has been accepted for the prepping of aircraft. This paper contains test data and a model of the new conversion coating, and covers some of the Hill AFB work on the cleaning of substrates.

Because chromium is a confirmed human carcinogen, reduction and elimination of chromate-containing wastes is a major prevention goal. Material containing chrome is used extensively in the treatment of aluminum with chromate conversion coatings. Chromate conversion coatings help prepare aluminum for the application of paint, as well as provide a corrosion preventive barrier. In aircraft paint systems, chromate conversion coatings are used in conjunction with modern epoxy primers, which also contain chromate, to guard against corrosion. The primers are topped with a tough layer of polyurethane paint. Landing gear, wheels and brakes of military aircraft are similarly treated.

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From a corrosion preventive point of view, continuing to use both the chromate conversion coating and the chromate-containing primer would be preferable. Laboratory testing has shown, however, that as long as there is chrome in the primer, the corrosion-protective properties of modern aircraft paint systems will suffer little.

A study of a substitute for the chromate conversion coating was conducted at Hill AFB. The candidate and the process developed for its use were tested extensively against the current process.

In adhesion and flexibility tests, the new environmentally friendly process performed better than the chromate conversion coating. It performed equally well in all other testing. In addition, it was found that this candidate could eliminate two solvent wipe-downs and the corrosion-removing compound used in the conventional paint preparation procedures. The use of this product also reduces the need to sand anodized surfaces before repainting.

Operational tests have been conducted on several aircraft, and the paint shop at Hill AFB is now using this product on its production line. At the time of this study, more than 50 aircraft had been painted using this product. The study recommended expanded use of this product to eliminate a major source of pollution and hazardous waste. This new product simplifies and reduces the paint preparation steps, saving time and money in painting aircraft.

Background

Chromate (chromium VI) in all forms is known to be a serious environmental pollutant. On the other hand, chromate compounds have many uses in the metals finishing industry where the corrosion protective properties imparted by chromium compounds are unequaled. Treating aluminum with chromates to form a chromate conversion coating on aluminum is a common way to enhance corrosion resistance and to prepare the metal to accept paint. When the coating is scratched—leaving the metal bare and susceptible to corrosion—chromate from the surrounding area is believed to leach into the scratch, providing additional corrosion protection. This is a valuable conversion coating function. Chromates in primer coating serve the same purpose.

Elimination and reduction of chromates in Air Force maintenance operations has long been a goal of the environmental community. Modern aircraft coating systems consist of chromated epoxy primer and tough polyurethane topcoats. They do an excellent job for corrosion prevention. As long as the primer contains chromate, the paint system will continue to provide very good corrosion protection, even if the chromate conversion coating is eliminated. Many vendors of proprietary products have been working on "non-chromate" conversion coatings, and have made various claims for their effectiveness. Several factors make such non-chromate conversion coating desirable.

- The process by which the conversion coating is applied is inefficient, especially for large areas (entire aircraft). The chromate-containing compound is brushed, wiped or sprayed on the aluminum surfaces. A small portion contacts the metal and forms the conversion coating, but the bulk

The Air Education and Training Command (AETC) tested Product D on various military aircraft, such as the T-37 (above) and the T-38 (right).

of it either drains off, is rinsed off or is wiped off. The operation results in a hazardous waste stream that must be collected and treated or properly disposed.

- Because chromates are suspected carcinogens, personnel must protect themselves from the chemicals by wearing protective clothing and equipment.
- Special facilities are required for large-scale chromate conversion coating jobs.

History

This study represents a multi-year effort at Hill AFB to reduce or eliminate the use of chromate compounds in the paint-preparation process for aircraft, especially for the F-16s. To understand the approach, priorities and evolution of this project, a brief history is helpful.

In 1989, the paint shop at Hill AFB began to use the new volatile organic compound (VOC)-compliant primers and paints (commonly known as "compliant" or high-solids coatings). The first efforts were unsuccessful because the new paints failed to give adequate adhesion. The Science and Engineering Laboratory was asked to find a cause and cure for the adhesion problem. Use of the compliant coatings was suspended until the paint adhesion problems could be resolved. Studies conducted between the laboratory and the paint shop revealed two separate, but related, problems:

1. The cleanliness of the aircraft was not sufficient for the compliant primer to form a good bond.
2. Bonding the primer to the anodized surfaces of previously painted aircraft was problematic. This is a difficulty unique to aircraft rework, as opposed to original manufacture.

Testing for cleanliness on the surface of the aircraft to determine whether the surface is ready for paint is traditionally accomplished using the "Water Break Test" (T.O. 1-1-8). This test is fairly sensitive to oily contaminants on the metal surface, if conducted properly. The presence of surface-active agents or flooding of the surface with water can give erroneous results. For whatever reason, painters were obtaining good water break results, but the surface was still not clean enough to accept the new high-solids primers. A joint study was initiated with the paint shop to determine when the surface was clean enough for priming. The best simple measure of cleanliness came to be the reaction of the surface with the chromate conversion coating. When the color imparted by the chromate conversion coating was uniform and fairly dark (depending on the alloy and previous surface treatment), paint bonded well.

New cleaning and preparation procedures were established at Hill AFB to consistently give a uniformly colored chromate conversion coating (Fig. 1). Painters were taught to clean areas again on the aircraft where the chromate did not take well, as indicated by the color. For this reason, one of Hill's top priorities for a non-chromate conversion coating was a visual indication of cleanliness.

The F-16 is manufactured with an anodized aluminum aircraft skin. The anodized surface has proven invaluable in the fight against corrosion. Initially, painting the anodize coating presented no problem. Paint bonds well to the fresh, porous anodize coating. Repainting of anodized aluminum is a different story. Paint retained in the pores after stripping adversely affects the adhesion of the paint system. Adhesion difficulties were reported when repainting the stripped aircraft using conventional paints, but the problem intensified when environmentally compliant paints were applied. The F-16 prime contractor was asked for recommendations. In 1990, it recommended that the anodized coating be sanded off in order to obtain the required paint adhesion. Hill AFB engineers decided that this solution must be a last resort. If at all possible, the anodized coating needed to be preserved as a corrosion barrier.

Eventually, Hill discovered that light sanding of the bead-blasted, anodized surface removes residual primer in the pores of the anodize. By removing the residual primer, good adhesion is obtained. In practice, however, this "light sanding" is difficult to achieve. The visual indicator that the primer has been removed is difficult to see, and only an experienced eye can tell. As a result, the anodized layer is often totally removed. Finding a way to bond environmentally compliant paint without destroying the anodized coating became another priority in the search for a non-chromate conversion coating.

The non-chromate conversion coat project was funded by a Pollution Prevention Project that began in February 1996. The Science and

Preparation Steps

1. Scrub with an alkaline cleaner
2. Hydroblast
3. Dry
4. Wipe clean MEK
5. Sand
6. Rinse with water
7. Apply a corrosion-removing compound
8. Rinse with water
9. Apply chromate conversion coating
10. Scrub it on for five minutes
11. Apply second coat and dwell for one minute
12. Rinse with deionized water
13. Let dry
14. Prime

Fig. 1—Preparation for paint process.

Engineering Laboratory at Hill was commissioned by Hill's Environmental Management directorate to conduct the study and manage the project. Additional funding came from another Environmental Management project, which focuses on improving the procedures and quality of paint operations on the C-130 aircraft. This project was a logical follow-on to previous laboratory studies on paint adhesion.

Objective

The objective of the study was to eliminate the use and subsequent disposal of chromate-containing materials in the paint preparation process on aircraft by substituting an alternate, non-chromated material.

Testing & Criteria

Mil-C-5541, Class 1A, formed the performance basis for the non-chromated product requirements. This specification calls for only three tests:

- Corrosion Resistance
- Paint Adhesion
- Workmanship

To meet the objectives, nine tests were conducted and used to evaluate candidate products. Not all candidate materials were subjected to all the tests. Indeed, all but one was eliminated on the basis of initial testing.

Uniform Color

Coating must produce some type of color or visually detectable indication that the coating has uniformly taken.

Bonding in Presence Of Known Contaminants

The desired product should help create an adequate bond between the paint and substrate. Hill had previously completed extensive paint adhesion testing on the chromate conversion coating process. The objective of this study was to get good paint adhesion with a new product. The paint removal process for F-16s at Hill employs polymethacrylate media blast (PMB). Blasting with PMB leaves a residue on the surface of the planes that is very difficult to remove. Failure to remove this residue results in poor paint adhesion, especially when using high-solids primers. The laboratory also tested candidate products on anodized aluminum panels that had previously been painted and PMB-blasted to simulate the repainting of F-16s.

Corrosion Resistance

Preliminary laboratory testing indicated that none of the candidate non-chromated products would provide the corrosion resistance in a salt spray cabinet required by Mil-C-5541. After consultation, engineering and corrosion personnel authorized a corrosion-resistance test on a primer system, rather than on bare, conversion-coated panels. After all, it is the entire system—metal coated with conversion coating and chromated primer—that must resist corrosion. A 90-day test in a five-percent salt spray environment was prescribed for this test.

Ease of Application

Candidate coating products should be as easy to apply and handle as the current chromate conversion coating materials. Ultimately, the success of any new product or process will depend on acceptance by those who must use it. If the prep for paint process is made harder, it will be difficult to institute.

Hydrogen Embrittlement

This testing is not normally required for conversion coatings, because they are applied, then given a short dwell time and rinsed off. This test was added because one of the candidate materials had a two-hour dwell time, and it was deemed prudent to conduct embrittlement testing.

Kapton Wire Test

Engineering requested that this test be added for candidate materials, even though the possibility of contact with aircraft wiring is remote.

Adhesion Testing

Engineering asked that "Wet Tape Testing" (Fed-Std-141C, Method 6301.2) be accomplished on painted panels. The laboratory added the "Crosshatch Test" (ASTM D-3359-93, Method B) to what was called out in Mil-C-5541E. The final candidate was also tested extensively with the Hesiometer.

Flexibility

Mandrel bend testing was performed on treated painted panels and compared to results with standard chromate conversion coating treatment.

Surface Analysis

The surface of treated panels was analyzed using electron spectroscopy for chemical analysis (ESCA). The purpose was to identify surface changes in the aluminum substrate brought on by the chemical treatment.

Table 1—Product A

Test	Results
Uniform Color	Fail Consistent uniform color could not be obtained, especially when the application temperature dropped below 85° F
Bonding	Does nothing to enhance paint bonding over common contaminants & on previously painted surfaces
Corrosion Resistance	Not tested
Ease of Application	Fail Solution needs to be heated
Hydrogen Embrittlement	Not tested
Kapton Wire	Not tested
Adhesion	Passed wet tape Crosshatch rating=3b-4b
Flexibility	Not tested
Surface Analysis	Not tested

Table 2—Product B

Test	Results
Uniform Color	Fail No color was imparted to the aluminum surface
Bonding	Not tested
Corrosion Resistance	Not tested
Ease of Application	Pass
Hydrogen Embrittlement	Not tested
Kapton Wire	Not tested
Adhesion	Not tested Crosshatch rating=3b-4b
Flexibility	Not tested
Surface Analysis	Not tested

Table 3—Product C

Test	Results
Uniform Color	Pass
Bonding	Pass
Corrosion Resistance	Fail Failed on 2024 & 7075
Ease of Application	Pass
Hydrogen Embrittlement	Pass
Adhesion	Pass Crosshatch rating=3b-4b

Table 4—Product D

Test	Results
Uniform Color	Pass Indicator is not a permanent color, but is a recognizable waxy film on the surface of the metal
Bonding	Enhances bonding of primer to previously painted anodized surfaces & PMB surface contamination
Corrosion Resistance	Pass Anodized, bare 7075 & 2024 Al-primed panels all passed 2000-hr salt spray
Ease of Application	Pass Eliminates soap wash, solvent wipe-down & acid brightener steps
Hydrogen Embrittlement	Pass
Kapton Wire	Pass
Adhesion	Pass wet tape Crosshatch rating=5b
Flexibility	Passed 40-in. drop reverse impact test at 40% elongation; passed one-eighth in. mandrel bend
Surface Analysis	Identifiable coating left on surface that promotes adhesion of primer

Test Results Summary

The laboratory tested four different products alleged to be non-chromate conversion coatings that would give a visual indication that the product was properly applied and the surface was prepared to accept primer and paint. The products are referred to in this report as products A, B, C and D. Testing is summarized in Tables 1–4.

Preparation Steps

1. Hydroblast
2. Spray on Product D & scrub with pneumatic sander
3. Rinse
4. Apply second application of Product D with 180-grit scrub pad (poles) & let dwell on the surface for 2 hr (uniform waxy film forms)
5. Spray a third application of Product D & scrub with poles
6. Rinse with deionized water
7. Let dry
8. Prime

Fig. 2—Preparation for paint process using Product D.

Comparison of Product D To Chromate Conversion Coating

Uniform Color

Although no color is imparted to the metal by Product D, the waxy film produced during the first application of Product D (see Fig. 2) proved to be a reliable indication that the surface is ready to accept paint.

Bonding

Product D enhanced paint bonding to surfaces contaminated by bead blast residue and oily fluids more than current chromate conversion coatings. Most important, Product D-treated samples show excellent adhesion, with little or no sanding when paint is applied to previously painted, anodized aluminum.

Corrosion Resistance

The panels prepared with Product D performed as well as chromate conversion-coated panels when coated with a chromated primer. This is an indication that the Product D does provide a corrosion-protective film. Product C, even though it imparts color to the aluminum, does not seem to enhance the corrosion resistance at all.

Ease of Application

One of Product D's big advantages is the application process. More than just a drop-in replacement for a chromate conversion coating, it eliminates several steps in the preparation process (see Figs. 1 & 2). Most notably, the solvent wipe, alkaline soap wash and acid brightener steps, along with their associated rinses, are eliminated.

Hydrogen Embrittlement

Because Product D requires a two-hr soak, it was deemed advisable to test the material for hydrogen embrittlement on high-strength steel. Four embrittlement coupons were tested per ASTM F519-93 and four coupons were tested per ASTM F519-97. The coupons were cadmium-plated 4340 steel. Three of the four coupons endured 150 hr at a 45-percent load, and all four coupons endured the required 200 hr at 75-percent load. The specification requirement is for three of four to pass, so Product D would not be considered embrittling to high-strength, cadmium-plated steel.

Kapton Wire Testing

This test was conducted on Product D as a precaution. Many maintenance chemicals damage Kapton wire used in F-16s by breaking down the insulation and allowing arcing. After exposure to Product D, Kapton wire showed no signs of deterioration, and no failure points were detected with impulse dielectric testing.

Adhesion

Paint adhesion is excellent on both Product D and chromate conversion-coated panels. Both passed the wet tape test and both yielded a 5b (highest rating) on the crosshatch adhesion test.

Further testing was conducted using a blade-driven adhesion tester. This instrument has been employed previously by the Hill Laboratory to evaluate paint adhesion. Tests on two different aluminum alloys, anodized aluminum and on panels that were painted and stripped with PMB-confirmed paint adhesion on Product D-treated panels were as good as, or better than, standard chromate conversion coating.

Flexibility

Prior testing at Hill and at Wright Laboratories has revealed that chromate conversion coatings are not extremely flexible. When painted panels are tested to failure on a mandrel bend or a conical bend test, the coating failure usually occurs between the chromate conversion coating and the substrate aluminum. In Hill AFB lab testing, chromate-prepared panels failed a one-half-in. mandrel bend test. On the other hand, panels treated with Product D passed a one-eighth-in. mandrel bend test.

Surface Analysis

Appendix E details the current analysis of Product D-treated aluminum surfaces. It shows that the surface has been modified in such a way that increased adhesion is probable.

Operational Evaluation

Air Education & Training Command (AETC)

Prior to Hill AFB testing, Product D was being evaluated by Air Education and Training Command (AETC). In a memorandum for HQ AETC/LG, dated May 8, 1997, AETC reported on its experience in painting one T-37 and one T-38 aircraft with Product D as a pretreatment. The T-37 was painted in August 1996 and the T-38 in November 1996. AETC felt that test configuration of this first testing of Product D did not provide sufficient data to make an adequate assessment. An amended test plan was devised. The new test plan allowed Product D and a chromate conversion coating to be applied on the same aircraft under the same painting conditions (heat, humidity) to fly the same hours and to be subjected to the same environmental conditions.

The AETC SAS conducted this phase of testing at the 14th Flying Training Wing, Columbus AFB, MS, for a period of 12 months. The final report was dated June 20, 1996.

The results and conclusions of the study were that Product D provides superior paint adhesion and equal corrosion protection as the current chromate conversion coating process. In addition, the report stated the following positive comments of the advantages of Product D:

- The paint is more resistant to stains.
- The aircraft is easier to clean during wash.
- There is less chipping and peeling of the paint surface.
- The paint and primer application is smoother.
- Elimination of several hazardous chemicals.
- Use same process on both aluminum and magnesium.
- Less use of paper and tape.
- Product D is environmentally friendly to both people and the environment.

Hill AFB Operational Tests

The first week in November 1997, the right wings of two F-16 aircraft were prepared for paint using the Product D process. The remainder of each aircraft was prepared using chromate conversion coating. These aircraft had been fully stripped using PMB. After painting, the aircraft were returned to their respective units.

Hill AFB laboratory representatives have examined these aircraft at six-month intervals. The last examination was September 1999. The entire paint job on each aircraft was very good, and the right wings were no exception.

Production

As of September 1999, Hill AFB has painted more than 50 aircraft using the Product D process.

Conclusions & Recommendations

Product D is a viable substitute for pollution caused by chromate conversion coatings in the paint preparation procedure for aircraft. It not only eliminates chromates, it decreases the usage of solvents, detergents and acid brighteners. On the F-16 aircraft, in particular, it will help preserve the highly effective, corrosion-resistant anodize surface, because less sanding is required to obtain the desired paint adhesion.

It is the recommendation of this report that the use of Product D on military aircraft be expanded. The affected aircraft should be examined periodically, although no latent defects arising from Product D use are anticipated. P&SF

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