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NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
PATUXENT RIVER, MARYLAND

TECHNICAL INFORMATION MEMORANDUM

REPORT NO: NAWCADPAX/TIM-2018/20

WATER-REDUCIBLE EPOXY PRIMERS WITH IMPROVED BARRIER PROPERTIES

by

Craig Matzdorf

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14. ABSTRACT This report documents the assessment of water-reducible primers with potentially better barrier properties for improved corrosion protection, especially galvanic corrosion. Data includes results from the testing of candidate products. No products met the requirements of MIL-PRF-85582 or showed improved galvanic corrosion properties.						
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SUMMARY

Corrosion-inhibiting primers are important protective materials for aluminum alloys and galvanic interfaces on Navy and Marine Corps aircraft, support equipment, weapons, and supporting systems. Prior assessments have shown that “high-solids” solvent-borne primers, especially those based on hexavalent chromium inhibitors, are superior to water-reducible primers at resisting corrosion, especially damage at galvanic couples between materials with dissimilar potentials and high current densities.

The main benefit of water-reducible primers is their faster drying times relative to solvent-borne primers. Currently qualified water-reducible primers are tack-free up to five times faster and dry hard up to 25% faster per the requirements of MIL-PRF-85582. These superior dry times allow for aircraft and components to be processed faster at Fleet Readiness Centers and in the fleet as well as in new production at Original Equipment Manufacturers and their subcontractors. Key is the ability to complete the priming step and allow for application of topcoats or other materials within scheduled work shifts.

A secondary benefit of water-reducible primers is their ability to be cleaned up with water. This leads to less use of hazardous solvents, with a reduction in volatile organic compounds and hazardous air pollutants, key regulated environmental, safety and health measurables at user locations.

A need from Navy users resulted in a search for commercially-available primers which had the potential to perform as well as MIL-PRF-23377 solvent-borne primers yet have the superior dry times of MIL-PRF-85582 water-reducible primers.

This report documents the work completed to assess the properties of these candidate commercial primers, including all MIL-PRF-85582 qualification requirements as well galvanic corrosion performance which is not currently included in the specification. Funding for this effort was provided by the OSD Corrosion IPT project W08NA07.

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INTRODUCTION

The protection of galvanic interfaces on aircraft, typically an aluminum alloy substrate (anode) with a bushing, insert, fastener or other component (cathode), is critical for overall structural life and integrity as well as managing life-cycle maintenance costs. DoD aviation design best practices advocate the use of chromate high-solids (solvent-borne) epoxy primers to be used on general aluminum surfaces and chromate sealants and high-solids primers as “wet installation” products which are applied to surfaces when the galvanic interface is assembled. These best practices are documented in MIL-STD-7179.

Water-reducible primers, per MIL-PRF-85582, are attractive alternatives to high-solids primers, per MIL-PRF-23377, due to faster dry-to-touch times, easier clean up, and reduced odor. To date, MIL-PRF-85582 products have inferior barrier properties to solvent-based on their ability to be “reduced” or thinned with water during application. Water-reducible primers with improved barrier properties will allow for the use of products with the desirable benefits of both primer types.

BACKGROUND

Dry-to-touch times are a key production enabler for primers. Table 1 shows the tack-free and dry-hard requirements for MIL-PRF-85582 (epoxy), MIL-PRF-23377 (epoxy), and TT-P-2760 (polyurethane) primer products. Also shown are proposed dry-to-touch and through-cure times which are important but not currently included in the specifications. The main benefit of MIL-PRF-85582 products is their faster dry times. This allows increased production throughput at Navy Fleet Readiness Centers (FRCs) and Original Equipment Manufacturers (OEMS) and their subcontractors and suppliers. Navy FRCs transitioned to MIL-PRF-85582 primers for general exterior use about 20 years ago. Many OEMs, including Lockheed Martin for the F-35, are using MIL-PRF-85582 primers on production lines.

Table 1: Dry Times for Primer Specifications

Primer/Specification	Dry-to-touch (min)	Tack Free (hrs)	Dry hard (hr)	Through Cure (hr)
MIL-PRF-85582	> 5*	1	6	< 8*
MIL-PRF-23377	> 5*	5	8	< 8*
TT-P-2760	>5*	5	8	<8*

*Proposed requirements. Not currently in specifications

Although these products have comparable adhesion and other primer performance, they have been shown to be inferior to MIL-PRF-23377 products for galvanic interfaces. Non-chromate primers also typically have inferior general corrosion performance compared to chromate primers.

Figures 1 through 3 show example comparisons of chromate and non-chromate products from different specifications in different test assemblies. In each case, the high-solids products provided better corrosion resistance. This was independent of whether the primers contained chromate or non-chromate corrosion inhibitors.

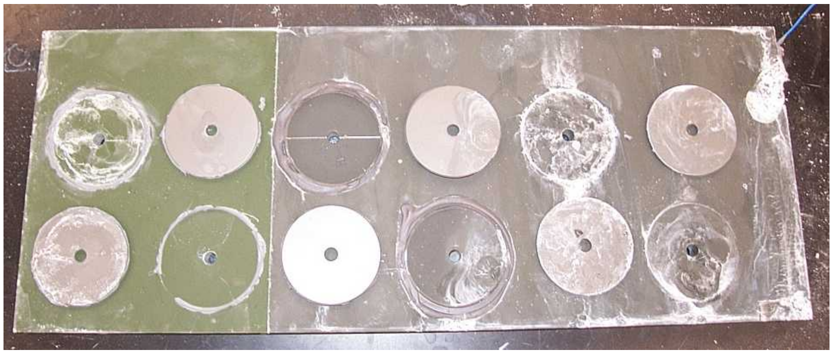

Figure 1a: Ti6Al4V washers placed against 2519-T87 aluminum protected by MIL-PRF-85582 Class N primer and MIL-DTL-81706 Type II conversion coating, after 2000 hours in ASTM B 117 neutral salt fog. Left side of panel has MIL-DTL-64159 topcoat (383 green).

Figure 1b: Ti6Al4V washers placed against 2519-T87 aluminum protected by MIL-DTL-53022 (high solids, non-chromate) primer and MIL-DTL-81706 Type II conversion coating, after 2000 hours in ASTM B 117 neutral salt fog. Left side of panel has MIL-DTL-64159 topcoat (383 green).

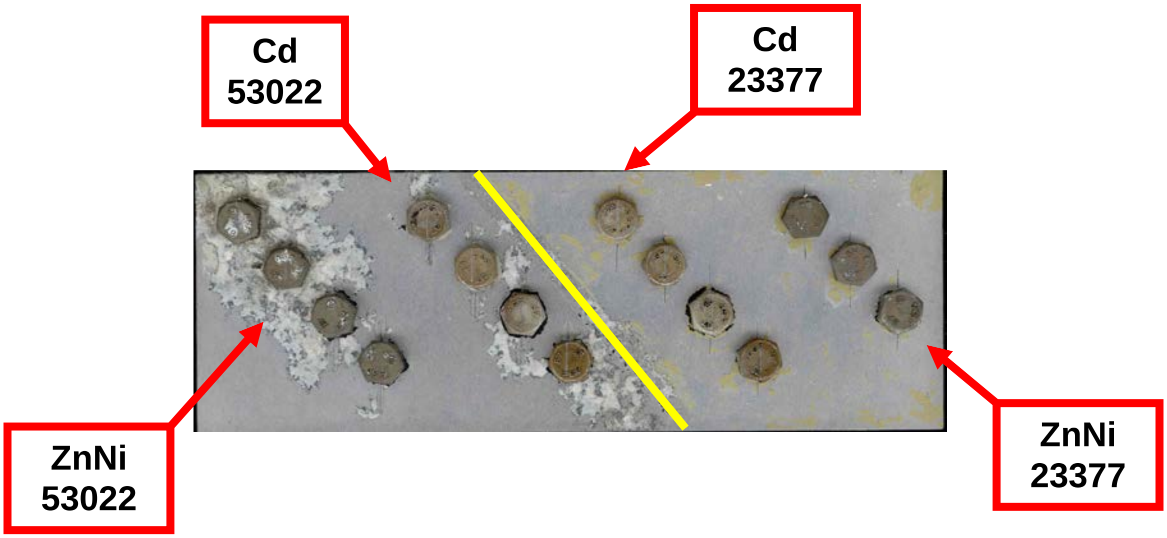

Figure 2: High solids MIL-DTL-53022 (non-chromate) primer compared to high solids MIL-PRF-23377 Class C (chromate) primer. Fasteners are cadmium and zinc-nickel coated. Substrate is 2519-T87 aluminum. The MIL-PRF-23377 primer is on the right of the yellow line and the MIL-DTL-53022 primer on the left.

Figure 3a: Corrosion performance of MIL-PRF-23377 Class C primer and MIL-DTL-64159 topcoat in combination with silver epoxy paint on 2519-T87 aluminum with various pretreatments, after 7 days in ASTM B 117 neutral salt fog.

Figure 3b: Corrosion performance of MIL-PRF-85582 Class N primer and MIL-DTL-64159 topcoat in combination with silver epoxy paint on 2519-T87 aluminum with various pretreatments, after 7 days in ASTM B 117 neutral salt fog.

Based on the superior galvanic protection of MIL-PRF-23377 products and superior dry times of MIL-PRF-85582 products, new MIL-PRF-85582 type products were sought that potentially had improved barrier properties and galvanic corrosion inhibition.

PURPOSE

The purpose of this evaluation was to poll primer suppliers for candidate products, procure samples, screen initial products for key performance requirements, and then assess promising ones for performance against the full requirements of MIL-PRF-85582 as well as galvanic corrosion inhibition using NAVAIR galvanic test specimens.

METHODS

MATERIAL AND SPECIMENS

Aluminum substrates per MIL-PRF-23377 and MIL-PRF-85582 were used for all testing. For galvanic testing, 2024-T3 aluminum was used as a substrate. Nuts, bolts and washers for the fastener assemblies were made from 316 corrosion-resistant steel or Ti6Al4V.

COATINGS

Two groups of primers were assessed as controls:

1- MIL-PRF-23377 and MIL-PRF-85582 Class C
2- MIL-PRF-23377 and MIL-PRF-85582 Class N

A final group of commercial products were assessed for potentially improved barrier properties.

For the Class N primers, products from Deft were selected for each specification as they have similar corrosion inhibitor packages with different resin systems. The MIL-PRF-85582 Class N product, 44GN098 has been heavily studied for potential use on DoD aircraft. It is currently used on the F-35.

The MIL-PRF-23377 Class N product, 02GN084, has also been heavily studied for potential use on DoD aircraft. In laboratory and outdoor testing completed by NAVAIR, the 02GN084 has performed better overall than the 44GN098 and is considered a superior product from a corrosion-resistance point-of-view. This product does have adhesion risks due to restricted recoat intervals compared to other primers.

The following candidate commercial products were identified in the initial part of the project:

1- Akzo Nobel Aerowave 2003: a chromate-inhibited, low volatile organic content product
2- Akzo Nobel Aerowave 2001: a non-chromate-inhibited, low volatile organic content product

GALVANIC CORROSION TEST

Galvanic test panels were designed to provide a "worst-case" scenario for corrosion-protection schemes. These panels mimic materials found on actual aircraft, are easy to prepare and expose to test environments.

The panels for this project were made from 0.25" thick 7075-T6 aluminum which was pre-drilled to accept 0.25" diameter bolts. Panels were cleaned and prepared in the Inorganic Coatings Laboratory, including the application of a chromate conversion coating per MIL-DTL-81706 Type I. Panels were then primed on the front surface and topcoated on the left-hand side only. After curing for 14 days at ambient conditions, and hand scribing an "X" over the lower set of holes, nuts, bolts and washers were assembled in each hole and torqued to 100 inch-pounds.

Figure 6 shows an example assembled galvanic test specimen after coating but prior to exposure to test environment. Fastener materials of both 316 corrosion-resistant steel (CRES) and Ti6Al4V were used. The 316 CRES has a smaller operating potential difference to aluminum, but larger cathodic current density compared to the Ti6Al4V, so although the Ti6Al4V looks worse from a potential design point-of-view, the 316 CRES is actually more corrosive to aluminum in actual use.

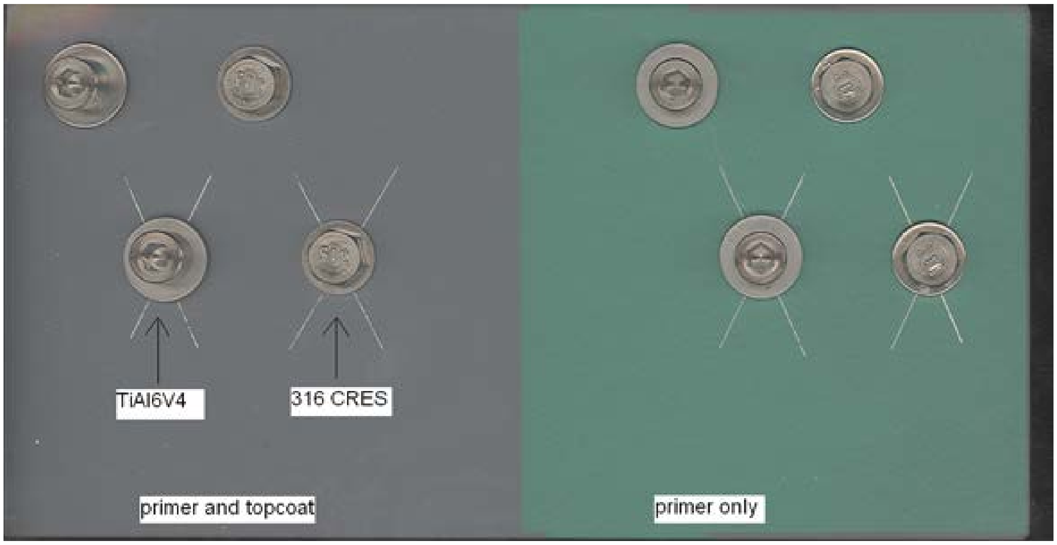

Figure 6: Galvanic Assembly

<u>PRIMER SPECIFICATION TESTS</u>

The following are test requirements for MIL-PRF-85582:

1. Material- toxicity
2. Composition- pigment type and volatile organic content (VOC)
3. Physical properties before mixing- fineness of grind, condition in container, storage stability, accelerated storage stability and freeze-thaw stability
4. Physical properties after mixing- color, odor, viscosity and pot life
5. Physical properties of the film- surface appearance, drying time, lifting, adhesion, and flexibility
6. Film resistance properties- fluid resistance: water, solvents and operating fluids and corrosion: salt spray and filiform

EXPERIMENTAL RESULTS

Detailed experimental data was lost due to a computer failure as well as an employee separation after the project completed. The following general results can be reported.

TEST RESULTS

1. Aerowave 2003- product separated during accelerated storage stability test and was not able to be sprayed to complete specification requirements. This is a basic primer requirement and failure led to its elimination from consideration.
2. Aerowave 2001- product had acceptable process properties like pot life, storage stability, etc. but poor corrosion performance on flat panels and the galvanic assembly. This poor performance led to its elimination from consideration.
3. The Deft 44GN084 performed better than the Deft 44GN098 in corrosion testing. A more recent assessment of these products, as well as other chromate and non-chromate primers, has been completed and will be reported separately.

CONCLUSIONS

The following conclusions can be drawn from the results:

1. No alternative products were able to meet the specification requirements of MIL-PRF-85582 and also perform similarly to MIL-PRF-23377 products in the galvanic corrosion and other corrosion tests.

RECOMMENDATIONS AND LESSONS LEARNED

The following recommendations are offered to support the use of primers in galvanic applications:

1. MIL-PRF-23377 Class C primers are recommended for all applications
2. MIL-PRF-23377 Class N primers are recommended as a superior alternative to MIL-PRF-85582 Class N primers where hexavalent chromium is not allowed, but only with the permission of the cognizant engineering authority for the system or item being considered.
3. Alternatives with faster dry times are still needed. Additional research and development is recommended to reduce dry times of MIL-PRF-23377 products and maintain other performance properties.
4. MIL-PRF-85582 will not be modified to incorporate improved barrier properties as no successful products were identified.

The following lessons learned are offered for future assessments:

1. More thorough primer supplier information should be required and scrutinized before products are assessed for potential improved properties.
2. Lab test data should be backed up to a laboratory computer to mitigate risk of data loss due to principal investigator computer failure, employee separation or retirement.

DISTRIBUTION

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