NAVAIR Discovering Alternatives to Hexavalent Chromium & Cadmium

NESDI-Sponsored Projects Targeting Primers & Coating Methods

HEXAVALENT CHROMIUM AND cadmium are used in a variety of applications to protect Navy aircraft from corrosion—but both substances are known carcinogens. In 2009, the Office of the Secretary of Defense released a memo restricting the use of hexavalent chromium (Cr6+) unless no cost-effective alternatives with satisfactory performance were available. The use of cadmium faces similar restrictions. Personnel from the Naval Air Systems Command (NAVAIR), sponsored by the Navy Environmental Sustainability Development to Integration (NESDI) program, are working on five separate projects with the goal of eliminating the use of cadmium and hexavalent chromium on Navy and Marine Corps aircraft.

Demonstrating Advanced Non-Chromate Primers & Coatings (Project 458)

Hexavalent chromium (Cr6+) has been subjected to increased scrutiny and regulation from federal agencies, both domestic and foreign. Cr6+ has also become very expensive to use and dispose of due to its classification as a hazardous material. While minimum performance requirements have satisfied other Department of Defense (DoD) agencies, such as the U.S. Air Force and Army, the U.S. Navy's harsh operational environment demands maximum performance and therefore, further evaluation outside of qualification testing. A comprehensive demonstration and validation of mature non-chromate products is necessary to identify a product with corrosion performance that is equivalent or better than the chromate coating systems fielded today.

NESDI project 458 is demonstrating new, state-of-the-art non-chromate replacements for use in primers and coatings for Navy aircraft. The E-2C Hawkeye was one of the first aircraft to be treated with the new non-chromate primer.

MC Seaman Siobhana R. McEwen

This project, leveraged by the Environmental Security Technology Certification Program (ESTCP), has focused on the demonstration/validation of mature non-chromate primers throughout the DoD. The NESDI-sponsored portion of this effort focuses on Navy-specific products and processes. The project team's first task was to identify mature Class N primers (non-chromate based corrosion inhibitors) for extensive laboratory testing. Top performers would be down-selected for accelerated corrosion tests. Initially, two products were selected for demonstration and validation—PPG-Deft 02-GN-084 (qualified to MIL-PRF-23377, Type I, Class N), and Hentzen 17176KEP (qualified to MIL-PRF-23377, Type II, Class N). These commercial-off-the-shelf primers were applied to the outer moldline (OML) on a minimum of two of each kind of aircraft at three different Fleet Readiness Centers (FRC). These aircraft include the H-46 Sea Knight helicopter, V-22 Osprey Helicopter, H-53 Sea Stallion Helicopter, T-6 Texan, T-34 Mentor, T-44 Pegasus, T-45 Goshawk, E-2C Hawkeye, P-3 Orion, and F/A-18A-D Hornet.

The aircraft treated with non-chromate primers are being compared to analogous chromate-primed aircraft that are deployed at the same time and subjected to similar environments. Acceptable performance for full-scale demonstration and validation is two land-based aircraft completing at least two years of operational service, or two carrier deployments for aircraft that normally deploy on a carrier.

To date, the PPG-Deft 02-GN-084 primer has been successfully demonstrated on the E-2C, P-3C, T-6, T-34, T-44, & T-45 aircraft. Service inspections done post-deployment documented good corrosion and adhesion performance. As a result, NAVAIR is drafting an authorization letter which specifies minimum performance of a product in an operational environment. NAVAIR will authorize PPG-Deft 02-GN-084 over chromate conversion coating on the OML of all Navy gloss paint scheme aircraft.

NAVAIR is currently evaluating Hentzen 17176KEP primer on the following aircraft: V-22, H-46, H-53, and F/A-18A-D. Unlike the gloss paint scheme aircraft, which are primarily aluminum on the OML, the OML tactical paint scheme of these aircraft is constructed of both composite and aluminum substrates. The H-53 and F/A-18A-D aircraft were painted in Fiscal Year 2014. Upon successful demonstration, NAVAIR anticipates authorizing the Type II primer for tactical aircraft.

Exploring Cadmium- and Hexavalent Chromium-free Electrical Connector Finishes (Project 451)

Electrical connectors are ubiquitous and essential components of aircraft and other vehicles at maintenance and repair facilities across the DoD. New finishes which contain neither cadmium nor hexavalent chromium have been added to the qualified products list (QPL) for one common electrical connector specification—MIL-DTL-38999L. However, there has been no known Navy-relevant field testing of these products, meaning the corrosion risk is uncertain.

This project was initiated to perform Navy/Marine Corps field testing to determine relative performance of new and control plating classes including MIL-DTL-38999L, Classes P, T, Z, M, W, J. Performance was quantified using both the real-world marine environment and the dynamic cycling of threaded circular

Under NESDI project 451, field testing was conducted on two new connector finishes. Electrical connectors are found on all military aircraft, including the aircraft shown here.
MC3 Bryan M. Ilyankoff

connector. (Dynamic cycling refers to the opening and closing of connectors in the environment, which is more relevant than static corrosion testing because it incorporates corrosion and wear mechanisms on thread.)

At the end of a 12-month test, the cadmium plated aluminum (Class W) cadmium/Cr+6 controls and high-purity aluminum (Class P) finish appeared to be among the best performers (on aluminum body connectors); however, electrical assessments showed a surprising degree of variation among the various combined finishes tested. Composite connectors Class J and M also performed well.

NESDI project 328 is testing and authorizing a trivalent chromium process as a non-chromated replacement. Post-treatment coatings are used widely on landing gear for the AV-8B and other aircraft.
MC3 Michael Achterling

There have been significant development efforts by other organizations since this testing began in 2010, so the results of this work should be considered alongside these findings. The project's final report, available via the NESDI web site, cites these studies as well.

Testing Non-Chromated Post-treatments (Project 328)

Ion Vapor Deposition (IVD) of aluminum is a vacuum plating process which deposits pure aluminum on metal to enhance corrosion resistance. The IVD process itself is nontoxic; however, for a higher level of corrosion resistance, aircraft parts are typically subjected to a post-treatment process that includes chromated coatings (coatings containing Cr6+). Trivalent chromium is a less toxic alternative to Cr6+ and it was the goal of this project to test and authorize a trivalent chromium process as a non-chromated replacement.

At the onset of this project, the trivalent chromium post treatment (TCP) had already been in use for five years as a pre-treatment for helicopter parts at FRC East in Cherry Point, North Carolina. This project team subjected TCP-treated parts to laboratory testing in 2009. After passing the tests, landing gear parts on two AV-8B aircraft were coated with the TCP at FRC East. After several years of service, there were no reported problems with corrosion or paint adhesion. NAVAIR approval is currently being sought for the treatment so that it can be used Navy-wide.

Validating Nanocrystalline Cobalt Phosphorous Electroplating as an Alternative to Hexavalent Chromium (Project 348)

Electrolytic hard chrome (EHC) plating is a technique that has been in commercial production for more than 50 years. It is used both for applying hard coatings to aircraft components in manufacturing operations and for general rebuild of worn or corroded components during overhaul. Chromium plating baths contain Cr6+. Because of this, plating operations must abide by U.S. Environmental Protection Agency (EPA) emissions standards and Occupational Safety and Health Administration permissible exposure limits. During operation, chrome plating tanks emit a Cr6+ mist, which must be ducted away and removed by scrubbers. Additionally, wastes generated from plating operations must be disposed of as hazardous waste.

Nanocrystalline cobalt phosphorus (nCoP) alloy plating is an alternative electroplating process that uses pulse plating to create a ultra-fine nanocrystalline structure on top of the component part. The nCoP coating exhibits properties that are equivalent to and, in many ways, better than EHC deposits. This technology is a direct drop-in replacement for the existing EHC process and will only require modification of plating power supplies.

Significant reductions in energy consumption and increases in throughput can be achieved with the nCoP process. The overall plating efficiency of the nCoP process is greater than 90 percent, compared to less than 35 percent for EHC. This leads to significantly less hydrogen generation than the EHC process, minimizing the likelihood of hydrogen uptake and subsequent embrittlement of susceptible materials (i.e., high-strength steels). (Hydrogen embrittlement is the process by which various metals, most importantly high-strength steel, become brittle and fracture following exposure to hydrogen. Hydrogen embrittlement is often the result of unintentional introduction of hydrogen into susceptible metals during forming or finishing operations.) Unlike EHC, the nCoP process uses no constituents on the EPA list of hazardous materials and it does not generate hazardous emissions or by-products.

This project was formed to demonstrate and validate nCoP plating as an alternative to EHC plating. To achieve this, the team constructed two process tanks at FRC Southeast in Jacksonville, Florida. Various aircraft components were plated and tested using the nCoP process. In 2012, field testing was initiated on a T-45 Goshawk aircraft part. The part was removed for visual inspection after over 700 flight hours. It passed visual inspection and will be placed into another aircraft for continued service.

When testing is complete, this technology is expected to be transitioned to all FRCs, leading to lower health and environmental risks, and reduced lifecycle costs due to superior performance.

Validating a Zinc-Nickel Alternative to Cadmium Tank Electroplating (Project 450)

Cadmium is targeted by the EPA and is also included in NAVAIR's FRC Toxic Metal Control Program, which requires that it be replaced with available alternative technology. Like hexavalent chromium, cadmium has historically been used as a corrosion inhibitor. It is applied to ferrous, aluminum, and copper alloys (via electroplating and other methods) to protect them from corrosion due to contact with dissimilar metals. Besides having excellent corrosion resistant properties, cadmium offers natural lubricity where torque requirements are needed. Cadmium electroplating is used on weapon systems throughout the DoD.

Many alternatives to cadmium tank electroplating have been addressed, but with limited success due to process limitations as a direct drop-in replacement and/or performance drawbacks. For example, earlier formulations of zinc-nickel (Zn-Ni) alloy plating were susceptible to hydrogen embrittlement. Because of this danger, a nickel pre-plate step was added to the process. However, this method still resulted in inferior fatigue performance, which limited the process to use with non-critical structures.

This project is demonstrating and validating an improved alkaline Zn-Ni alloy plating process, and will validate a trivalent chrome post-treatment for use with the demonstrated process. The Zn-Ni

The project 348 team is demonstrating and validating pulsed electroplated nCoP alloy coatings as a technically feasible replacement for the current hexavalent chromium plating process used on components for the T-45 and other military aircraft.
MC3 Nathan Parde

To eliminate the use of cadmium on high-strength steel components, NESDI project 450 is demonstrating and validating an alternative process using alkaline zinc-nickel alloy electroplating. High-strength steel components are found on aircraft such as the F/A-18 series aircraft shown here.
MC2 Timothy A. Hazel

alloy tank plating process (known as DIPSOL IZ-C17+) offers equivalent performance characteristics as current methods, but with reduced hazardous waste treatment and associated environmental/ medical monitoring costs. It also requires minimal capital investment and impact to production, as existing cadmium tanks can be lined and filled with Zn-Ni solution. This process meets the requirements for a non-embrittling process per American Society for Testing and Materials (ASTM) standards. Currently, ASTM testing for corrosion is underway at FRC Southeast. If field testing is successful, DIPSOLVE IZ-C17+ will be an immediate drop-in replacement for cadmium tank electroplating.

For More Information

For more information on any of the above projects, visit www.nesdi.navy.mil then select "Current Projects" and search by project number or keyword. ⚓

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The Basics About the NESDI Program

THE NESDI PROGRAM seeks to provide solutions by demonstrating, validating and integrating innovative technologies, processes, materials, and filling knowledge gaps to minimize operational environmental risks, constraints and costs while ensuring Fleet readiness. The program accomplishes this mission through the evaluation of cost-effective technologies, processes, materials and knowledge that enhance environmental readiness of naval shore activities and ensure they can be integrated into weapons system acquisition programs.

The NESDI program is the Navy's environmental shoreside (6.4) Research, Development, Test and Evaluation program. The program is sponsored by the Chief of Naval Operations Energy and Environmental Readiness Division and managed by the Naval Facilities Engineering Command out of the Naval Facilities Engineering and Expeditionary Warfare Center in Port Hueneme, California. The program is the Navy's complement to ESTCP which conducts demonstration and validation of technologies important to the tri-Services, EPA and Department of Energy.

There are a number of ways you can participate in the NESDI program:

1. Submit a need via the program's web site.
2. Review the technologies already under development.
3. Act as a Principal Investigator on a NESDI project.
4. Provide a demonstration site for a NESDI project.
5. Support the program's integration efforts.

For more information, visit the NESDI program web site at www.nesdi.navy.mil or contact Ken Kaempffe, the NESDI Program Manager at 805-982-4893, DSN: 551-4893 or ken.kaempffe@navy.mil.