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ENVIRONMENTAL
EXCELLENCE IN
WEAPON SYSTEM
ACQUISITION,
SMALL PROGRAM

FY 2016 Secretary of Defense Environmental Awards

Army Research Lab Chromium Free Wash Primer Replacement Team

INTRODUCTION

The program consists of the development, demonstration and implementation of hexavalent chromium (Cr(VI))-free chemical pretreatments for mixed metal substrates on various large and small acquisition programs (ACAT III programs highlighted), including ground vehicles, combat service support equipment (e.g., Force Provider, Tactical Quiet Generators), and aviation/missile systems (e.g., AN/TWQ-1 Avenger, BGM-71 TOW, AN/MPQ-64 Sentinel, AN/TPQ-36 Firefinder radar).

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BACKGROUND

The Army relies on hexavalent chromium (Cr(VI)) compounds to protect its ground vehicles, aircraft, communication equipment and armaments from corrosion. Surface pretreatments containing Cr(VI) are applied at nearly all Army depots and many other production/maintenance facilities. Cr(VI) is an excellent corrosion inhibitor, but is known to be highly toxic.

The Environmental Protection Agency (EPA) categorizes Cr(VI) compounds (i.e., compounds with chromium ions with a +6 oxidation state) as known carcinogens via inhalation. These compounds are highly regulated by the EPA, Occupational Safety and Health Administration (OSHA) and European Union (EU), with regulations becoming more and more stringent. For example, in 2006, OSHA lowered the permissible exposure limit 10-fold, from 52 to 5 micrograms-per-cubic-meter, making Cr(VI) among the most stringently regulated materials used in manufacturing and maintenance operations.

Judging Criteria



**Program
Management**



**Orientation
to Mission**



**Impact &
Outcomes**



**Technical
Merit**



**Stakeholder
Interaction**



Transferability



BACKGROUND CONT'D

Continued use of Cr(VI) requires extensive pollution control equipment and personal protective equipment for all spray applications. Cr(VI) exposure/release has led to costly lawsuits, fines, regulatory actions and clean-up requirements.

In 2009, the Under Secretary of Defense (Acquisition, Technology, and Logistics) issued a policy memo, titled “Minimizing the Use of Hexavalent Chromium,” directed at reducing the use of Cr(VI) on weapon systems. This memo highlighted the serious environment, safety and occupational health (ESOH) risks posed by Cr(VI)-based surface treatment processes.

Wash primer is a spray pretreatment applied directly to bare metal to provide corrosion protection and promote coating (i.e., paint) adhesion. It is applied to many different types of weapon systems, including ground vehicles, combat service support equipment (e.g., Force Provider, Tactical Quiet Generators), and aviation/missile systems (e.g., AN/TWQ-1 Avenger, BGM-71 TOW, AN/MPQ-64 Sentinel, AN/TPQ-36 Firefinder radar).

Wash primer controlled by specification DOD-P-15328, “Primer (Wash), Pretreatment (Formula No. 117 for Metals),” constitutes one of the largest sources of Cr(VI) in Army industrial operations since it is the primary surface treatment required for mixed metal applications at both depots and original equipment manufacturers (OEMs). DOD-P-15328 calls out a specific composition that requires 54 pounds of zinc chromate per 100 gallons of paint. Workers and Soldiers may be exposed to this Cr(VI) compound during spray application of wash primer and during routine maintenance throughout the life cycle of systems that have been treated with wash primer.

As a secondary environmental concern, DOD-P-15328 wash primer contains high amounts (about 5.8 lbs./gal.) of volatile organic compounds (VOCs), such as isopropyl alcohol and butanol. VOCs contribute to poor air quality through the creation of ozone and smog, both of which increase human health risks by contributing to higher incidences of asthma attacks, cardiac arrest and respiratory illnesses. State regulators have forced Letterkenny Army Depot

(LEAD) to restrict wash primer usage due to high VOC emissions.

The ARL Camouflage, Coatings and Corrosion Team executed a project to develop, demonstrate and implement low-VOC, Cr(VI)-free pretreatments for mixed metal applications as an alternative to wash primer. In addition to serving as the project principal investigator, ARL held responsibilities as the commodity manager for the Chemical Agent Resistant Coating (CARC) system and the preparing activity for all related military specifications. This put ARL in a unique position to develop and implement new coatings under the CARC system, which is required by Army Regulation 750-1, “Army Materiel Maintenance Policy,” to be used on all tactical and related support equipment.

Correct application of CARC dictates painters follow appropriate surface preparation and pretreatment procedures outlined in TT-C-490F, “Chemical Conversion Coatings and Pretreatments for Metallic Substrates (Base for Organic Coatings).” DOD-P-15328 wash primer is the only Cr(VI)-containing product qualified under TT-C-490F Type III, organic pretreatments. In 2015, ARL qualified three Cr(VI)-free pretreatments for mixed metal substrates under TT-C-490F Type III, paving the way to remove DOD-P-15328 wash primer from the CARC system and eliminate its use on Army weapon systems.

PROGRAM DESCRIPTION

The Army Environmental Quality Technology (EQT) Pollution Prevention (P2) Toxic Metal Reduction (TMR) program funded ARL to demonstrate and qualify Cr(VI)-free chemical pretreatments for mixed metal substrates. This effort, which ended in 2016, addressed a specific requirement for Cr(VI)-free wash primer alternatives that was identified by Army users in the 2012 Army Environmental Requirements and Technology Assessments report. The primary goal of the overarching TMR program is to reduce or eliminate Cr(VI) used in surface finishing on nearly all types of weapon systems, across multiple Program Executive Offices (PEOs) and Program Managers (PMs), by demonstrating environmentally sustainable processes at Army depots, installations and repair facilities.



 The wash primer replacement project was identified and prioritized alongside other Cr(VI) reduction projects by the TMR integrated process team (IPT) which is led by the Army Research, Development, and Engineering Command's Environmental Technology Acquisition Program (ETAP). These projects are managed by the ETAP through semiannual in-process reviews (IPRs), where principal investigators receive feedback on test methods and coordination of demonstration sites. TMR was voted a high priority by the P2 Technology Team user community.

 ARL leveraged an Environmental Security Technology Certification Program (ESTCP) project to compile a test matrix of nine commercially available pretreatments for use on mixed metal substrates. The commercial products were tested against the requirements for chemical pretreatments listed in TT-C-490 federal specifications, with most testing conducted at ARL on mixed metal coupon assemblies. The final test plan included humidity testing, neutral salt fog, cyclic corrosion, outdoor exposure, adhesion, coating hardness, chip resistance, hydrogen embrittlement and other tests, as compiled by group and stakeholder requirements. In addition to laboratory testing, alternatives were subjected to outdoor exposure testing at Cape Canaveral Air Force Base using mixed metal test coupons.

Three alternative products were able to meet all initial test requirements and application standard operating procedures (SOPs): Henkel's Bonderite 7400 (manganese and fluoride-based), Chemetall's Oxsilan 9810/2 (zirconium silane-based) and PPG's 11-TGL-07-Z (zirconium-based). Full scale trial demonstrations began in FY15 on ground support equipment in operational environments.

 For the first phase of the demonstration, ARL had painters at LEAD apply the Bonderite, Oxsilan and PPG products on surplus parts to gauge their ease-of-use and to verify they could be applied using the same painting equipment and processes. LEAD personnel applied each of the three products on one TRICON and one generator trailer. They also pretreated one generator trailer with Bonderite 7400 applied to half of the trailer and the baseline wash primer applied to the other half. All assets were subsequently primed and painted with CARC. Once cured, ARL then

conducted adhesion and hardness tests to confirm the initial laboratory test findings carried onto actual weapon system substrates. All assets remained stored outdoors at LEAD for follow-up evaluations, with the exception of the half-and-half generator trailer. In June 2015, this asset was transported to the ARL corrosion site at Cape Canaveral Air Force Base for exposure in an aggressive tropical environment.

In the second phase of the demonstration, ARL down-selected to Bonderite 7400. This was the preferred product because the application process for Bonderite 7400 was the closest to the current process used for wash primer, and the product provided superior corrosion and adhesion performance over the other alternatives. In September 2015, the Bonderite product and the baseline wash primer were applied to two PATRIOT support trailers at LEAD. ARL conducted adhesion and hardness testing to evaluate the application quality. These trailers were deployed and remain in service. In FY16, ARL recommended Bonderite 7400 for implementation at LEAD because it complemented LEAD's existing production processes. However, the other two products were retained at this point as alternatives for end users.

 ARL thoroughly collaborated with wash primer users and receiving installations (primarily Army Depots) during the development of federal specifications TT-C-490 Revision F and subsequent interim revisions (most recently in February 2016) to ensure a clear pathway for the implementation of the alternatives. ARL coordinated all test requirements with customer organizations, such as the U.S. Army Aviation and Missile Command (AMCOM) and the U.S. Army Tank-automotive and Armaments Command (TACOM) to ensure the end product would meet their performance and sustainment needs.

LEAD was chosen as the optimal location to conduct demonstrations due to its high usage of wash primer and its variety of weapon systems maintained. Based on the success at LEAD, ARL is transitioning the alternatives to additional government and contractor users who have expressed interest in Cr(VI)-free pretreatments, including Anniston Army Depot (ANAD), Sierra Army Depot (SIAD), Red River Army Depot, the U.S. Marine Corps, BAE Systems and Raytheon.

In November 2015, ARL listed Bonderite 7400, Oxsilan 9810/2 and PPG 11-TGL-07-Z on the Qualified Products Database (QPD) for TT-C-490F Type III, organic pretreatments. The addition of qualified products enabled ARL to draft a memorandum (for publication in October 2016) announcing the pending cancellation of Chromate Wash Primer DOD-P-15328 to all CARC system users. ARL intends to cancel the specification no later than 30 September 2017, giving users almost one year to transition their processes to Cr(VI)-free alternatives. This action will not negatively impact readiness because ARL has ensured long-term availability of products listed in the QPD.

Incorporating ESOH Integration into Systems Engineering

 The TMR program prioritized and addressed ESOH risks associated with chemical pretreatments by analyzing data from multiple surveys of Army depots and installations, as well as direct interaction with affected users. This process verified the Army's use of wash primer was one of its most significant sources of Cr(VI). As the commodity manager for the CARC system, ARL estimated nearly 400,000 gallons of DOD-P-15328 wash primer are used each year across DoD.

Two other reports served as key data sources for the project. An AMCOM report, entitled "Reduction of Toxic Materials in Army Surface Finishing Processes: Environmental Requirement and Technology Assessment," provided an exhaustive review of alternative solutions commercially available for each Army depot process that uses Cr(VI). A Strategic Environmental Research and Development Program (SERDP) report, entitled "Implementation Plans and Strategic Roadmaps – LEAD," quantified all uses of Cr(VI) at LEAD and outlined a strategy and roadmap to achieve more than 90 percent reduction by FY21. SERDP estimated wash primer was the largest source of Cr(VI) at LEAD, with 610 pounds of Cr(VI) compounds used annually. After the cancellation of DOD-P-15328, LEAD will eliminate this source of Cr(VI) and will reduce over 6,000 pounds of VOCs annually.

ARL prioritized environmentally-preferable products from the start of the program by selecting those that were Cr(VI)-free, did not contain Hazardous Air

Pollutants (HAPs) and contained low levels of VOCs in ready-to-use formulations. Further, ARL partnered with the Army Public Health Center (PHC) to complete Toxicology Assessments (TAs) for the proposed alternatives to ensure they would reduce ESOH risks associated with chemical pretreatments. The TA process is a rational, phased approach that helps reduce risk in the technology development process and helps principal investigators down-select the best alternative materials. The TA process is an integral part of the EQT P2 program; all TMR funded projects are subject to TAs from PHC to ensure alternative surface finishing processes are more environmentally sustainable, both in comparison to the baseline and in an absolute sense. To support the TA for this project, ARL provided composition data to PHC for the baseline and the three most promising alternatives. In January 2016, PHC published a TA with their findings. PHC reviewed all ESOH data available in the literature, verified the three alternatives were preferable to wash primer and identified no other serious ESOH risks that would prevent the alternatives from being implemented. PHC remained involved throughout project execution to provide real-time feedback to ARL as new data became available.

ARL has an inherent relationship with CARC users as the commodity manager and solicits feedback on all changes to the CARC requirements. ARL coordinated pretreatment performance requirements with AMCOM and TACOM, and conducted demonstrations with LEAD, using current production line workers to validate the performance of the top three alternatives. ARL coordinated these demonstrations with production and environmental staff at other interested depots to address questions about performance and ESOH risk. For example, in FY16, industrial hygienists at SIAD initially raised concerns about the high levels of fluorine-based compounds in Bonderite 7400 in the concentrated, as-received state. ARL worked with PHC and the industrial hygienists to clarify that the concentrate formulation did not represent the actual ready-to-use product, which is diluted with water at a 20:1 ratio when used. This helped SIAD and other users to better understand the exposure risks associated with the alternatives.

ARL incorporated ESOH requirements into solicitations, contracts and requirements documents by implementing Cr(VI)-free alternatives to wash primer under TT-C-490, which is already called out in innumerable production and maintenance documents. TT-C-490 is well known and well understood by engineers throughout all services and major OEMs. TT-C-490 is the overarching document referenced in more than 20 military specifications and thousands of drawings for the pretreatment of ferrous and aluminum surfaces, prior to the application of CARC and other organic coatings, so the alternatives can transition seamlessly.

Once DOD-P-15328 is canceled, solicitations and contracts will automatically eliminate Cr(VI) since they already require pretreatment in accordance with TT-C-490. ARL and impacted CARC users will not need to update maintenance documents because existing references to DOD-P-15328 will be superseded by Cr(VI)-free pretreatments under TT-C-490. To allow users to plan for this transition, ARL sent out a memorandum to all CARC users notifying them of the proposed sunset date for DOD-P-15328. Users will be encouraged to start the transition to Cr(VI)-free pretreatments prior to the 2017 sunset date to reduce excess wash primer procurement.

ESOH Risk Management

TMR is a high priority requirement to the Army user community due to the high risks to personnel posed by Cr(VI) use. Wash primer was identified as one of the largest sources of Cr(VI) in Army maintenance operations. Regular coordination with PHC ensured alternative products were more environmentally sustainable. ARL provided the TA for alternative products to all interested depots and OEMs.

Pretreatments qualified under the TMR program can be implemented with similar labor, equipment, training, infrastructure and other costs, as compared to DOD-P-15328 wash primer. The best performing candidate, Bonderite 7400, requires similar spray guns, feed lines and painting techniques; however, it also provides one major advantage over the baseline. Bonderite does not have a “pot-life” like wash primer which means an applicator can leave Bonderite in the spray pot to be used by the next shift or even overnight, without the risk of a chemical reaction that

could the equipment to seize up. Conversely, any unused wash primer must be disposed of as hazardous waste and cannot be reused; therefore, implementing Bonderite will reduce waste disposal costs at depots.

It is also anticipated that eliminating Cr(VI)-based wash primer will reduce the cost of complying with industrial hygiene and environmental regulations. This includes reduced costs in hazardous waste disposal, wastewater treatment, water quality monitoring, air permitting and monitoring, man hours required for recordkeeping, pollution control devices like air scrubbers, and medical screening of workers. For example, ANAD is expected to save \$220,000 annually in disposal costs from its pretreatment line. Eliminating Cr(VI) will reduce the risk of potential OSHA regulatory action, as Navy and Air Force facilities have been fined and required to implement costly housekeeping practices to minimize Cr(VI) dust. Reducing VOCs will eliminate the potential for state regulators to place restrictions on pretreatment operations.

Hazardous Materials Management and Pollution Prevention

ARL ensured there were multiple effective, commercially available alternatives from the outset of this project. ARL sent a request to nine vendors to request pretreatments that met the basic environmental criteria (no Cr(VI), no HAP, low VOC) and received nine products for evaluation in the laboratory phase. One of the down-select criteria for the final demonstrations was commercial availability. One promising product was eliminated from consideration at that point because it was only available at the laboratory scale and had not been commercialized. ARL encouraged the vendor to mature its product for future consideration.

ARL qualified three Cr(VI) - free products to the QPD to ensure all users are able to find a product which meets their unique needs. ARL visited multiple depots during the demonstration phase to help them select the best product for their specific facilities, capabilities and constraints.

Internal Execution and Documentation

ARL led the effort to eliminate Cr(VI)-containing wash primer from Army systems by qualifying alternatives to the overarching pretreatment specification TT-C-490. All CARC users must use pretreatments approved through TT-C-490, and ARL will eliminate Cr(VI) from the CARC system by cancelling DOD-P-15328 as an option under TT-C-490. TT-C-490 will continue to be used widely through existing and future procurements, and users will only be able to select Cr(VI)-free products from the QPD.

Initial transition of alternatives has already begun to reduce Cr(VI) and VOCs across DoD; reductions will accelerate once DOD-P-15328 is canceled. A typical wash primer formulation contains 5.8 lbs./gal. of VOCs, while the alternatives contain an average of 0.1 lbs./gal. of VOCs, as applied. With an annual Army usage of 400,000 gallons, ARL estimates this project will reduce 24,000 lbs./year of Cr(VI) compounds and 2.3 million lbs./year of VOCs. Most of this reduction will be realized after the 30 September 2017 sunset date for DOD-P-15328 when the specification has been officially canceled. ARL will support the user community as they transition to Cr(VI)-free pretreatments, with 100 percent compliance anticipated in FY18.

External Coordination of ESOH Risks Management

To enhance ESOH awareness across all CARC users, ARL drafted a memorandum to announce the pending cancellation of DOD-P-15328 and to direct users to TT-C-490 for approved alternatives. The qualification of alternative products was also broadcast at relevant DoD/OEM conferences, including the Advanced Surface Engineering Technologies for Sustainable Defense (ASETSDefense) Workshop hosted by SERDP, and the SUR/FIN Manufacturing and Technology Trade Show and Conference, a leading industry conference.

ARL provided detailed reports to Raytheon and other interested CARC users to ensure implementation by OEMs. ARL coordinated with TACOM and AMCOM throughout the investigation to ensure Army depots would be ready to implement the new technologies. Alternatives were demonstrated

primarily at LEAD, with participation by other Army depots that use significant amounts of wash primer to ensure widespread implementation. ARL also provided support to other wash primer users, such as BAE Systems, Raytheon and the U.S. Marine Corps, to broaden the scope of implementation. ARL received signed endorsements for this effort from PEO Ground Combat Systems, PM Bradley, PEO Aviation and PEO Combat Support and Combat Service Support.

ARL transferred lessons learned in this effort to other ongoing sustainable surface coating projects throughout DoD to mitigate Cr(VI) use in other applications. For example, technologies demonstrated as alternatives to wash primer are also being evaluated as alternatives to Cr(VI)-based conversion coatings and sealers. Additionally, PHC has expanded the TA process to all surface finishing projects ongoing under the EQT P2 program.

ARL is quantifying the success of this project by completing an economic and environmental impact study to compare the costs and environmental risks of continued use of DOD-P-15328 vs. qualified Cr(VI)-free alternatives.

CONCLUSION

The TMR program qualified three Cr(VI)-free pretreatments for mixed metal substrates to TT-C-490 as alternatives to DOD-P-15328 wash primer. As the Army's overarching pretreatment specification, TT-C-490 enables the use of new Cr(VI)-free technologies and provides a pathway to eliminating baseline Cr(VI)-based products. The availability of qualified, Cr(VI)-free alternatives will facilitate the cancellation of DOD-P-15328 in 2017, eliminate 24,000 lbs./year of Cr(VI) compounds and reduce the emission of 2.3 million lbs./year of VOCs used in Army operations. This project is pivotal in achieving Army goals for Cr(VI) reduction and reducing impediments to readiness from ESOH risks. The foundational Revision F to TT-C-490 was recognized with a Defense Standardization Program Achievement Award in 2013.