Cadmium and Hexavalent Chromium Alternatives Implementation Plan for Letterkenny Army Depot, Contract # W9128F 12-D-0041

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Executive Summary

The Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) Weapons Systems and Platforms Program Area initiated an effort to develop a strategy to eliminate >90% of cadmium (Cd) and hexavalent chromium (Cr^{6+}) in use at Department of Defense (DoD) maintenance depots over the next five years. To that end, the research team visited Letterkenny Army Depot (LEAD) on 17-18 February 2015, in the preparation of this LEAD Implementation Plan. This plan identifies and describes the processes observed at LEAD, documents the Cd and Cr^{6+} containing materials used in these processes, identifies potential alternatives, and outlines a strategy and roadmap to achieve >90% reduction of Cd and Cr^{6+} at LEAD over the next five years. The LEAD processes and alternatives are shown in Figure ES-1.

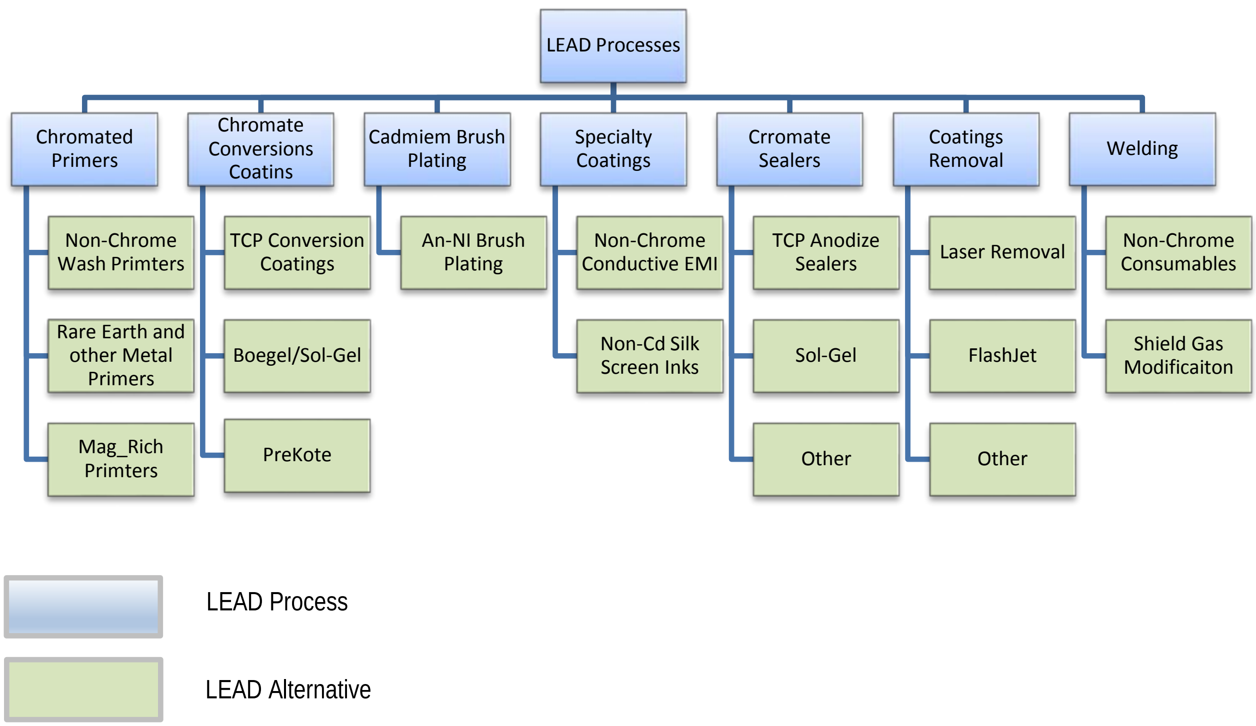

Figure ES-1. LEAD Cd and Cr^{6+} Process and Alternatives

Cr^{6+} and Cd-reduction initiatives have been prioritized using a relative scoring methodology. Four metrics were selected for analysis in the prioritization process: 1) Impact to Readiness; 2) Likelihood of Implementation; 3) Return on Investment; and 4) Impact to Goals. Each metric was qualitatively analyzed.

Tier 1 priority initiatives are critical to achieving Cr^{6+} and Cd reduction goals. If these initiatives are not successfully implemented, the reduction goals cannot be achieved. These initiatives will typically have far reaching impact to other depots, addressing similar critical usages, emissions, exposures, and/or waste streams. Tier 1 priority processes typically have high impacts to readiness, though this is not always the case. Four of the recommended initiatives are considered Tier 1 priorities and, therefore, critical to achieving reduction goals at LEAD

Tier 2 Priority Initiatives are those not critical to achieving Cr^{6+} and Cd reduction goals at LEAD, but address significant usages, emissions, exposures, and/or waste streams. These initiatives may impact similar processes at other depots, therefore, increasing the legitimacy of expending resources to identify and implement alternatives. These initiatives typically have moderate impact to readiness, but may exhibit strong ROIs. Two initiatives are considered Tier 2 priorities at LEAD.

Tier 3 priority initiatives are not critical to achieving Cr^{6+} and Cd reduction goals and address usages, emissions, exposures, and/or waste streams minor enough to call into question the merit of expending resources to identify alternatives. These processes are typically localized, impacting only a single depot or shop and have little impact to readiness. One (1) initiative is considered a Tier 3 priority for LEAD and is described in greater detail below.

Most of LEAD's Cr^{6+} and Cd usage, emissions, exposure, and waste stream reduction goals can likely be met by leveraging ongoing or past initiatives. In fact, 90% Cr^{6+} and Cd usage reduction can be achieved through three initiatives all leveraging ongoing work either within the Army or, in the case of cadmium brush plating, the Air Force. Only three new starts are recommended and only one of those is a Tier 1 priority initiative.

Initiative	Process	Description Summary	Success Metric	Baseline	Initiate	Potential Alternatives
Tier 1 Priority Initiatives						
HAP-Free, Non-Cr(VI) Wash Primer	Chromated Primers: Wash Primers	Army Research Laboratory and the Toxic Metals Reduction (TMR) Program has a project to identify and qualify an approved non-hexavalent chrome alternative to replace DOD-P-15328 wash primer. The alternative must be spray applied with similar process parameters, effective on multi-metal assemblies, and qualify to TT-C-490. The approach is to identify technologies to fill the technology gap created by impending cancellation of DOD-P-15328 through: • Laboratory validation to downselect to best performers for demonstrations • Mid scale demonstration of 3 candidates to assess process parameters • Full scale production demonstration to validate process and performance • Qualify candidate (s) and add to TT-C-490 QPD • Work with PHC, who are writing toxicology assessments for each of the final candidates The product will transition to all weapons systems that currently use DOD-P-15328 in rework and new manufacture, most likely ground vehicles and support equipment (BFV, HMMWV, trailers, shelters, containers, tactical vehicles). The initiative will eliminate DOD-P-15328 wash primer, reducing Cr^{6+} by 24K lbs/year and VOCs by 2.4M lbs/year.	Usage: Reduction in the pounds of Cr^{6+} species (e.g., strontium chromate) as compared to the baseline	606.15 lbs	Ongoing	Non-Chromated Wash Primers • Bonderite 7400 • Oxisilan AL-500 • Zircobond 4200 • Bonderite NT-1 • Chemseal 100 • Zinc-Rich
Non-Chromate Conversion Coatings for Aluminum	Chromate Conversion Coatings	The TMR Program has initiated a project to identify a Cr^{6+} free pretreatment conversion coating for aviation and GSE with application for multi-metal. The goal is qualification and approval for transition to MIL-DTL-5541 and TT-C-490. The aviation demo sites will be CCAD, TASM-G, Ft. Campbell, Wheeler AAF and the GSE demo sites LEAD, RRAD, ANAD, and MDMC. The technical approach includes full scale demonstrations of commercially available products and verification of performance to baseline technologies for transition by PMs and PEOs in 3 years. Benefits of the initiative include reduction of over 100K pounds of Cr^{6+} generated from aluminum conversion coatings each year and over 6M pounds of stripped CARC waste that must be treated as toxic waste. Success would eliminate at least 90% of Cr^{6+} from conversion coating operations, reduce corrosion costs to military for multi-services, manage risks of exposure by being accountable for material used, amount of emissions, and waste generated and disposed, and avoid fines, penalties and house-keeping costs for non-compliance with occupational regulation.	Usage: Reduction in the pounds of Cr^{6+} species (e.g., strontium chromate) as compared to the baseline	412.3 lbs	Ongoing	Rare Earth Conversion Coatings • PPG 11-TGL-27 • Bonderite 5700/5200 • Iridite NCP • Recc 3021 • Recc 3024 Cr^{3+} conversion coatings • NAVAIR TCP • Metalast TCP • Alodine T5900 Boegel/Solgel • AC-130/131 PreKote
Alternative to Cd Brush Plating	Cd Brush Plating	ESTCP Project WP-201412 focuses on elimination of toxic and carcinogenic cadmium (Cd) material for brush plating repair operations, and reduction of solid waste associated with adsorbents used to contain solution leakage attributed with traditional brush plating repair processes. The technical objectives are to: 1. Demonstrate the commercial off-the-shelf (COTS) brush plating tool Dalistick® Station for selective plating, ensuring its safety and cost effectiveness for Department of Defense (DoD) maintenance, repair, and overhaul operations. 2. Test and evaluate the COTS Zinidal Aero (code 11040) zinc-nickel (Zn-Ni) brush plated coating as a Cd replacement on high strength steels (HSS) for repair applications on weapon systems parts and components (landing gear, terminal assemblies, landing gear doors, bushings, etc.	Usage: Reduction in pounds of Cd species (e.g., cadmium sulfamate) as compared to the baseline.	119.07 lbs	2016	Zn/Ni brush plating (Dalistick®)
Reduction of Cr^{6+} and Cd Spent Blast Media	Coatings Removal	This initiative should be implemented in phases. The first phase is an in-depth study of the abrasive media blasting processes at LEAD. This study should identify, in great detail, the components being processed through the blast media cabinets. This detail should include the components, substrate, coatings being removed, and the number of components. In addition, details on the blast media cabinets should be gathered including the type of media used, the purpose of the blasting, the type of cabinet, the recycle ratios, and the configuration of the cyclone systems, filters, and pressure systems. Where possible, components containing Cr^{6+} or Cd should be segregated into specific cabinets connected to separate filters, cyclones, and pressure systems. Where this is not possible, investigation of coating removal technologies such as hand-held lasers, robotic lasers, Flashjet®, and atmospheric plasma can be considered. Each of these technologies result in a dramatic reduction in the amount of waste from the stripping operations.	Waste: Reduction in pounds of spent media and sanding dust as compared to the baseline.	1,325,420 lbs spent media in 2014 18,041 lbs sanding dust in 2012	2016	None identified.

Tier 2 Priority Initiatives						
Non-Chrome Conductive EMI Coating	Specialty Coatings	Cho-Shield is a three-part, copper-filled urethane coating system which has been formulated with special additives and stabilizers to maintain electrical conductivity, even at elevated temperatures, which prevent aluminum surfaces from corroding in high humidity and/or marine environments. In particular, Cho-Shield 2003 contains soluble chromates to minimize the effects of galvanic corrosion of the aluminum substrate, even in the event of a coating scratch. Cho-Shield 2002 is a non-chromate version of the coating and, with the total stack-up, may be a drop-in replacement for Cho-Shield 2003. In addition, there are other formulations that use silver versus copper as the conductive additive. These formulations do not use chromates for corrosion inhibitors and should be tested as part of the coating stack-up as an alternative. In addition to the alternative Cho-Shield formulations, several other coatings companies produce non-chromate EMI shielding coatings, including MG Chemicals and Central Coating.	Usage: Reduction in the pounds of Cr^{6+} species (e.g., strontium chromate) as compared to the baseline	10.22 lbs	2017	None identified.
Non-Chrome Sealer for Phosphate Coatings	Chrome Sealers	Ogden Air Logistics Complex (OO-ALC) and Oklahoma City Air Logistics Complex (OC-ALC) have initiated projects to identify, demonstrate/validate and transition alternatives to sodium dichromate sealer. The technical approach included: determining OO-ALC and OC-ALC sealing requirements; Identifying alternatives to sodium dichromate seal; evaluating alternative sealers through screening and performance tests; conducting a cost-benefit analysis; conducting additional testing; and conducting technology transfer activities. The Air Force selected 2 of the most-promising COTS candidates for laboratory testing along with three baselines and one benchmark and ultimately received OO-ALC Engineering Review Board approval to use the permanganate seal.	Usage: Reduction in the pounds of Cr^{6+} species (e.g., sodium dichromate) as compared to the baseline	8.11 lbs	2017	Cr^{3+} sealers • NAVAIR TCP • Metalast TCP • Alodine T5900 Permanganate sealer SURTEC 580
Tier 3 Priority Initiatives						
Non-Cadmium Silk Screen Red	Specialty Coatings	The preferred approach would be to identify a commercially available epoxy ink that meets the color requirements with a Cd-free formulation. If this proves to be impossible, then a research effort will be required to identify non-Cd pigment additives to achieve the required color and maintain consistent properties.	Usage: Reduction in pounds of Cd species (e.g., cadmium sulfamate) as compared to the baseline.	0.01 lbs	2018	None identified.

Definitions and Terms

Term used in Report	Meaning in this report	Synonyms [Comment]
Hexavalent chrome, Chromate	Chromium compound in the hexavalent state	Hex Chrome, hexavalent chromium, Cr6, CrVI, Cr^{6+} [not used to refer to trivalent materials]
Chromate conversion coating	Chromate treatment used to passivate aluminum and magnesium	Chromate passivation, Alodine,
Passivate (hexavalent, trivalent, non-chrome)	Surface treatment to reduce the corrosion rate of aluminum, magnesium, stainless steels, etc.	conversion coating, ,
Sealer	Treatment used to seal porosity in anodized, phosphated, or plated surfaces.	Chromate sealer, dichromate sealer
Sealant	Material used to fill macro-scale gaps and porosity; typically an organic, polymeric material	gap filler
Wash primer	Chemical treatment used for paint adhesion and corrosion protection, usually on steels	
Primer	Organic coating used to improve paint adhesion and corrosion protection	
Specialty coating	Coating used for unusual or low-volume application	[In this report it does not refer to low observable coating]
Coating removal	Coating removal by any means – Mechanical, chemical, laser, etc.	Stripping, depaint
Brush plating	Localized electroplating using a pad known as a brush or stylus	Stylus plating, selective plating

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AERTA	Army Environmental Requirements and Technology Assessments
AETC	Air Education and Training Command
AFMC	Air Force Material Command
AFRL	Air Force Research Laboratory
ALC	Air Logistics Complex
AMCOM	US Army Air and Missile Command
ANAD	Anniston Army Depot
ARL	Army Research Laboratory
ASETSDefense	Advanced Surface Engineering Technologies for a Sustainable Defense
BIDS	Biological Integrated Detection Systems
CARC	Chemical agent resistant coatings
CCAD	Corpus Christi Army Depot
CITE	Center of Industrial and Technical Excellence
CONUS	Continental United States
COTS	Commercial off-the-shelf
Cr^{+3}	trivalent chromium
Cr^{6+}	hexavalent chromium
CTIO	Coatings Technology Integration Office
DLA	Defense Logistics Agency
DMWR	Depot Maintenance Work Request
DoD	Department of Defense
EOD	Explosive Ordnance Disposal
EMI	Electromagnetic interference
ESTCP	Environmental Security Technology Certification Program
eTCP	Enhanced trivalent chromium process
FMTV	Family of Medium Tactical Vehicles
FRC	Fleet Readiness Center
HAP	Hazardous Air Pollutant
HEMTT	Heavy Expanded Mobility Tactical Truck
HEPA	High efficiency particulate air
HIMARS	High Mobility Artillery Rocket System

HMMWV	High-Mobility, Multipurpose, Wheeled Vehicle
HSS	High strength steel
IED	Improvised Explosive Device
JDSOR	Joint Depot Source of Repair
JERRV	Joint EOD Rapid Response Vehicle
LCMC	Life-Cycle Management Command
LCRS	Laser coating removal system
LEAD	Letterkenny Army Depot
LEV	Local exhaust ventilation
MIG	Metal inert gas
MMPV	Medium Mine Protected Vehicle
MPCV	Mine protected clearance vehicle
MRAP	Mine Resistant Ambush Protected
NAVAIR	Naval Air Systems Command
NSN	National stock number
OC-ALC	Oklahoma City Air Logistic Complex
OCONUS	Outside Continental United States
OEM	Original equipment manufacturer
OML	Outer-mold line
OO-ALC	Ogden Air Logistics Complex
OSD	Office of the Secretary of Defense
OSHA	Occupational Safety and Health Administration
PdM	Product Manager
PLCRS	Portable laser coating removal system
PEO	Program Executive Office
PI	Principal Investigator
PM	Program Manager
PMB	Plastic media blasting
POC	Point of contact
PPE	Personal protection equipment
R&D	research and development
RCV	Route Clearance Vehicles
RDECOM	US Army Research, Development, and Engineering Command

RRAD	Red River Army Depot
RSW	Resistant spot welding
SERDP	Strategic Environmental Research & Development Program
SMAW	Shielded metal arc welding
SON	Statement of Need
TACOM	Tank and Automotive Command
TCP	Trivalent chromium process
TIG	Tungsten inert gas
TMR	Toxic Metals Reduction
TOW	Tube-launched, Optically-tracked Wire-guided
TQG	Tactical Quiet Generators
TTA	Technology Transfer Agreement
TYAD	Tobyhanna Army Depot
UA	Unmanned Aircraft
VMMD	Vehicle Mounted Mine Detection
VOC	Volatile Organic Compound
WR-ALC	Warner Robins Air Logistics Complex

1 Introduction

The Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) Weapons Systems and Platforms Program Area supports the development and demonstration of innovative advanced coating technologies that enable the Department of Defense (DoD) to:

- reduce or eliminate the use of hazardous materials in its production and maintenance processes;
- reduce hazardous waste streams; and,
- understand and mitigate emissions and other environmental impacts that result from its operations.

The objective of this project is to develop a strategy to eliminate >90% of cadmium (Cd) and hexavalent chromium (Cr^{6+}) in use at Department of Defense (DoD) maintenance depots over the next 5 years. The strategy will include a roadmap to demonstrate how this reduction can be achieved through multiple site demonstrations, leveraging DoD resources to replicate the process across the DoD depot community, and developing a future path for success in the advanced coatings area. As part of this effort, installation-specific implementation plans are being developed in coordination with multiple DoD industrial maintenance depots. The Implementation Plans track back to the overall Advanced Coating 5-Year Strategy and Roadmap, maintaining consistency with DoD's strategic vision as it pertains to Cr^{6+} and Cd reduction.

Our research team visited Letterkenny Army Depot on 17-18 February 2015 as our first attempt to survey a DoD industrial depot. This Implementation Plan identifies and describes the processes observed at LEAD, documents the Cd and Cr^{6+} containing materials used in these processes, identifies potential alternatives, and outlines a strategy and roadmap to achieve >90% reduction of Cd and Cr^{6+} at LEAD over the next 5 years.

1.1 Letterkenny Army Depot

Mission Statement

Deliver superior maintenance, manufacturing, logistics, life cycle support and service worldwide to the Joint Warfighter and our International partners.[1]

Vision Statement

LEAD is the depot of choice for Industry, Government, and the Greatest Warfighters in the world.[1]

Letterkenny Army Depot (Figure 1), the Center of Industrial and Technical Excellence (CITE) for Air Defense and Tactical Missile Systems, was originally established in 1942. The depot is under the command structure of the U.S. Army Aviation and Missile Command (AMCOM). The

[1] http://www.letterkenny.army.mil/

facilities at Letterkenny are used to conduct maintenance, modification, storage, and demilitarization operations on tactical missiles, ground vehicles, support equipment, and ammunition.

Figure 1. Aerial View of Letterkenny Army Depot, Chambersburg, PA.

Located primarily in Letterkenny Township and extending into Greene Township and Hamilton Township, all in Franklin County, Pennsylvania, just northwest of the borough of Chambersburg, LEAD consists of nearly 18,000 acres (71 km^2). With over 1.4 million square feet reserved for overhaul, process and assembly work, LEAD is the largest employer in Franklin County, PA, and adds over one-quarter of a billion dollars annually to the region's economy. LEAD's state of the art facilities, combined with a highly skilled workforce, enable Letterkenny to provide superior products and services to the DoD.

Letterkenny has unique tactical missile repair capabilities covering a variety of Defense Department missile systems, including the MIM-104 PATRIOT missile and its ground support and radar equipment. Most recently, Letterkenny has expanded its product line to include designation as the CITE for Power Generation for the Army, the overhaul of tactical wheeled vehicles, material handling equipment, and Mobile Kitchen Trailers. In 2007 during the Iraq conflict Letterkenny began building new Mine Resistant Ambush Protected (MRAP) armored vehicles in partnership with BAE Systems and in 2010 was designated the Joint Depot Source of Repair (JDSOR) for Route Clearance Vehicles for the Department of Defense.

1.2 Letterkenny Army Depot Mission

LEAD possesses all the specialized capabilities to support total weapon system maintenance across multiple commands. Table 1 lists the Army Commands serviced by LEAD and examples of the weapon systems maintained at the depot. LEAD provides full life-cycle depot support, from manufacturer to storage, certification, rebuild, CONUS and OCONUS support, and final demilitarization of systems. The paragraphs that follow provide additional information on the LEAD mission as it pertains to the major weapon system workloads.

Table 1. Commands and Weapons Systems Services at LEAD.

Aviation & Missile Command (AMCOM)	Tank Automotive Command (TACOM)	Communications Electronics Command (CECOM)	Special Operations Command (SOCOM)
Patriot	HMMWV	ESV	Air Force
ATACMs	Force Provider		Army SF
MLRS	MKT		Ranger Ambulance
HAWK FMS	Forklifts		Navy SEALS
AVENGER	Cranes		Ranger
Hellfire	MMPV		War Pig
TOW	Cougar		
AGPU	JERRV		
GANG	Husky MKII		
	RG31		
	Buffalo		
	RG 33L Panther		
	Generators		

LEAD services radars, launchers, communication relay groups, engagement control stations, information control central, antenna mast groups, and numerous specified weapons systems and components. LEAD has recently expanded operations to include the overhaul of tactical wheeled vehicles, namely high-mobility multipurpose wheeled vehicles (HMMWVs), material handling equipment (7.5-ton cranes and 6k-10k forklifts), mobile kitchen trailers, Force Provider systems, and aviation ground power units. LEAD is also recognized as the Center of Technical Excellence for Tactical Quiet Generators (TQG).

As the Center of Industrial and Technical Excellence for Air Defense and Tactical Missile Systems, LEAD provides to DoD the only organic depot for one-stop service for tactical missile maintenance, modification and integration. The depot has unique tactical missile repair capabilities for a variety of Defense Department missile systems, including the Hawk, Tube-launched Optically-tracked Wire-guided (TOW), ITAS, IBAS, TOW Cobra variants, Hellfire, and Javelin systems. Field returned missiles are repaired to factory specification at LEAD and modifications installed to upgrade missile inventory.

The MM-104 Patriot is a guided missile system designed to protect forces and selected geopolitical assets from aerial attack, missile attack, surveillance, and air threats to critical assets in the corps and theater areas. Recap of the weapon system provided at LEAD also includes service to ground support and radar equipment such as the electric power plant (EPP III), 150-kw generators and associated 10-ton heavy expanded mobility tactical truck (HEMTT). Information, command, control, and communication shelters (ICC, TCS, ECS and CRG), and associated 5-ton

MM-104 Patriot

cargo trucks (AN/MSQ-104), and battery command (BCP) HMMWVs, radar sets, launcher and antenna mast groups are also restored at LEAD as part of the overall weapon system.

The Avenger (AN/TWQ-1) weapon system is designed to provide forces with low-altitude air defense against unmanned aircraft (UA), UASs, fixed wing and helicopter aircraft. Avengers are also deployed to provide close-in air defense to combat elements, high-priority maneuver units, and high-priority critical assets. Gunners can launch Stinger missiles or fire machine gun from a gyro-stabilized turret mounted on the high-mobility, multipurpose, wheeled vehicle (HMMWV). LEAD provides complete overhaul of this system, including all major end-items of the HMMWV, optical sights, and electrical components. LEAD has provided Avenger Depot Level Maintenance and total fleet maintenance of all Avenger variants to the Army, Army National Guard Bureau, Marine Corp, and Foreign Military customers since 1992.

Avenger AN/TWQ-1

Enhanced Sentinel Radar sensor system (AN/MPQ-64A3) provides a state-of-the-art three-dimensional battlefield radar sensor using phased-array antenna technology and interfacing networks. The HMMWV is the prime mover and support vehicle for the Sentinel, which also transports the TQG, communications equipment, and cabling. LEAD acquired the Sentinel upgrade workload in 2012 and began rolling out completed units in 2014.

Enhanced Sentinel Radar

The high mobility artillery rocket system (HIMARS) is a light multiple rocket launchers mounted to one of a family of medium tactical vehicles (FMTV). The purpose of HIMARS is to engage and defeat artillery, air defenses, trucks, light armor and personnel carriers, and to support troop and supply concentrations. Configurations include 6 rockets and 1 Army Tactical Missile System. LEAD has accepted a secondary workload for the HIMARS component radar in partnership with Lockheed Martin since 2009.

HIMARS

The mobile chemical and Biological Integrated Detection Systems (BIDS) provided the world’s first battlefield integrated biological detection capability. The M31E2 BIDS includd a fully automated biodetection system, began production in 2002 in partnership with the U.S. Army Edgweood Chemical Biological Center. The BIDS program has recently closed at LEAD.

BIDS

LEAD is recognized as the Joint Warfighter’s Depot of choice for modification, repair, and overhaul of critical Route Clearance Vehicle (RCV) platforms: Buffalo/ Mine Protected Clearance Vehicle (MPCV), Vehicle Mounted Mine Detection System (VMMD) also known as the “Husky,” RG-31 Medium Mine-Protected Vehicle (MMPV), Joint EOD Rapid Response Vehicle (JERRV) and Medium Mine-Protected Vehicle (MMPV) Panther.

The Buffalo/MPCV is a mine-hunter clearance system, which provides a mine blast secure platform for Soldiers engaged in the search for personnel mines and higher-rated Improvised Explosive Devices along roadways. The MPCV clears the path for safe movement of Troops, supplies and commercial traffic. The Buffalo is the key weapon in establishing confidence and stability in areas of operation.

Buffalo/MPCV

The Husky System is comprised of two multiple vehicles and a Mine Detonation Trailer Set that operates as a single mine detection and detonation system. The VMMD provides a blast protected platform for the operator and detects and marks large metallic mines and suspected large metallic explosive hazards such as AT mines and IED.

Husky System/VMMD

RG 31 MMPV provides a blast-protected platform to protect Soldiers conducting Route Clearance missions in order to assure mobility of the force.

RG 31 MMPV

The MMPV Panther is designed to provide enhanced crew protection and system survivability with add-on armor protection, an automatic fire extinguishing system, and a chemical, biological, radiological, nuclear or high-yield explosive overpressure system. There are three variants of the Panther: the XM1226 Engineer (for combat engineers), the XM1227 EOD (for explosive ordinance specialists) and the XM1229 Prophet (for intelligence, surveillance, and electronic warfare and target acquisition operations).

MMPV Panther

The JERRV's primary role is to support first responders such as Army "89D" Explosive Ordnance Disposal Specialist in neutralizing Improvised Explosive Devices (IED), mines and other ordnance. Projects such as converting the MRAP CAT II Cougars into JERRV produce the most protective vehicles equipped with overall armor protection and a V-shaped hull.

JERRV

LEAD also provides complete A1 – overhaul & RESET Direct support and Depot level repairs to ARMY, Marine, Navy, and Foreign Military weapon systems and components. Assets received are completely disassembled and all components rebuilt or replaced to new condition. All major parts and sub-assemblies (i.e. cabinets, brackets, cover plates, etc.), are totally stripped of surface coatings. Some hardware are reused and therefore require re-coating after cleaning.

All items are coated, painted, or otherwise marked in accordance with DMWR/TMs. Circuit cards are sent for testing on the GETS and replaced or repaired as required. Chassis are reassembled and tested. Wire harnesses are replaced or refurbished according to configuration requirements. Parts unavailable for purchase are fabricated on site - adhering to LEAD quality control standards.

2 Letterkenny Army Depot Processes

The LEAD Implementation Plan outlines a strategy and provides a roadmap to meet the goals established in the Advanced Coatings 5-Year Strategy and Roadmap. These goals are >90% reduction in the use of Cd and Cr^{6+} in processes across the depot and >90% reduction in Cd and Cr^{6+} emissions, exposures, and waste streams. The strategy addresses both production processes that use materials containing Cd or Cr^{6+} (e.g., chrome plating) and processes that potentially cause emissions, exposures or waste streams based on legacy materials used on weapon systems (e.g., abrasive blasting). The strategy and roadmap outlined in this implementation plan is a component of the larger DoD strategy. The LEAD Implementation Plan is composed of three parts:

- **Processes, Weapon Systems and Components, and Materials –** This section of the Implementation Plan describes each of the individual Cd and Cr^{6+} processes at LEAD, the weapon systems and components being maintained in each of these processes, and the materials used in the process.
- **Alternatives –** This section of the Implementation Plan briefly describes available and in-process alternatives to each of the Cd and Cr^{6+}-using processes identified at LEAD. An effort is made to examine the applicability of alternatives to LEAD applications and to identify potential barriers to implementation.
- **Letterkenny Army Depot Roadmap –** This section of the Implementation Plan prioritizes recommended initiatives to help LEAD achieve the >90% use and emissions, exposures, and waste stream reduction goals for Cd and Cr^{6+}. The prioritization methodology is described and the initiatives are documented on a timeline to provide a visual for implementation.

2.1 Processes, Weapon Systems and Components, and Materials

A site visit was conducted at LEAD on 17-18 February 2015. The team observed 25 distinct processes in 7 different buildings, documenting process data, Cd and Cr^{6+}-containing materials used in the processes, weapon systems maintained in each process, and efforts to reduce the Cd and Cr^{6+} use or potential emission, exposure, and/or waste streams in these processes. The 25 distinct processes were grouped into process categories consistent with those established in the Advanced Coatings 5-Year Strategy and Roadmap. The process categories observed at LEAD and included in this report are:

- Chromated Primers (both wash primers and traditional primers for wet-apply)
- Chromate Conversion Coatings
- Cadmium Brush Plating
- Specialty Coatings
- Chromate Sealers
- Coatings Removal (both physical and chemical)

- Stainless Steel Welding

Table 2 attempts to tie each process to the major weapon systems on which it is used. Table 2 also lists the number of systems and related system components that were maintained and completed at LEAD during Fiscal Year 2014. The list of weapon systems is not exhaustive, but captures those systems that drive the LEAD workload. Table 3 links each of the weapon systems to the applicable Program Executive Office (PEO) and Project Manager/Program Manager (PM) or Product Manager.

Table 2. LEAD Processes and Weapons Systems.

	MIM104 Patriot	Hellfire	Longbow	BGM-71 TOW Missile	M142 HIMARS	Sentinel AN/MPQ-64A3	AN/TWQ-1 Avenger	M997 HMMWV	FMTV	TRMD	Firefinder	Generators	VMMD Husky	Panther/MMPV	Buffalo/MPCV	RG-31 MMPV	Route Clearance Vehicle	Material Handling Equipment	Force Provider	Cables	Fabrication	Secondaries
FY14 Completion	1226	133	136	638	5	21	188	97	42	349	31	1771	72	52	10	79	124	185	377	2253	16192	7948
Process																						
Physical Coatings Removal	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
Chemical Coatings Removal	●	●	●	●	●	●	●	●														
Wash Primers	●	●	●	●	●	●	●	●	●		●	●						●	●		●	●
Other Primers		●	●	●	●																	
Chrome Sealers	●			●	●	●	●						●	●	●	●	●				●	
Cadmium Brush Plating	●	●	●	●																●	●	●
Chromate Conversion Coatings	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Specialty Coatings	●	●	●		●	●	●				●											
Stainless Steel Welding									●				●	●	●	●	●		●		●	

Table 3. LEAD Weapons System and Program Organization

Weapon System	Command/LCMC	PEO/PM
MIM104 Patriot	AMCOM	PEO Missiles and Space Lower Tier Project Office
Hellfire	AMCOM	PEO Missiles and Space Joint Attack Munition Systems
Longbow	AMCOM	PEO Missiles and Space Joint Attack Munition Systems
BGM-71 TOW	AMCOM	PEO Missiles and Space Close Combat Weapon Systems
M142 HIMARS	AMCOM	PEO Missiles and Space Precision Fires Rocket and Missile Systems
Sentinel AN/MPQ-64A3	AMCOM	PEO Missiles and Space Cruise Missile Defense Systems
AN/TWQ-1 Avenger	AMCOM	PEO Missiles and Space Cruise Missile Defense Systems
M997 HMMWV	TACOM	PEO Combat Systems and Combat Service Support JPM Joint Light Tactical Vehicles
FMTV	TACOM	PEO Combat Systems and Combat Service Support JPM Joint Light Tactical Vehicles
TRMD	AMCOM	Various
Firefinder	AMCOM	PEO Missiles and Space Counter Rocket, Artillery, Mortar
Generators	Various	PEO Combat Systems and Combat Service Support PM Expeditionary Energy and Sustainment Support
VMMD Husky	TACOM	PEO Combat Systems and Combat Service Support APO Mine Resistant Ambush Protected Vehicles
Panther/MMPV	TACOM	PEO Combat Systems and Combat Service Support APO Mine Resistant Ambush Protected Vehicles
Buffalo/MPCV	TACOM	PEO Combat Systems and Combat Service Support APO Mine Resistant Ambush Protected Vehicles
RG-31 MMPV	TACOM	PEO Combat Systems and Combat Service Support APO Mine Resistant Ambush Protected Vehicles
Route Clearance Vehicle	TACOM	PEO Combat Systems and Combat Service Support APO Mine Resistant Ambush Protected Vehicles
Material Handling Equipment	TACOM	PEO Combat Systems and Combat Service Support PM Force Projection PdM Combat Engineer/Material Handling Equipment
Force Provider	TACOM	PEO Combat Systems and Combat Service Support PM Force Projection PdM Force Sustainment Systems
Cables	Various	Various
Fabrication	Various	Various
Secondaries	Various	Various

Table 4 presents the total pounds of Cd or Cr^{6+}-containing products and species (e.g., strontium chromate, barium chromate, and sodium dichromate) used in each of the process categories listed above.

Table 4. Process Cd and Cr^{6+} Usage

Process	Contains	lbs Product	lbs Species
Chromated Primers - Wash Primers	Cr^{6+}	6735	606.15
Chromate Conversion Coatings - Tank	Cr^{6+}	2945	412.3
Cadmium Brush Plating	Cd	476.28	119.07
Specialty Coatings - CHOShield	Cr^{6+}	272.56	10.22
Chromated Primers - Other	Cr^{6+}	62.68	8.71
Chromate Sealer	Cr^{6+}	405.39	8.11
Chromate Conversion Coatings - Touch-up Pens	Cr^{6+}	59.93	1.80
Specialty Coatings - Silk Screen Red	Cd	0.58	0.01
Total All		10957.42	1166.37
Total Cd		476.86	119.08
Total Cr		10480.56	1047.29

Figures 2, 3, and 4 illustrate comparisons between the processes based on pounds of Cr^{6+} or Cd species. Figure 2 compares all of the process categories used at LEAD. Figures 3 and 4 compare the Cr^{6+} and Cd processes respectively.

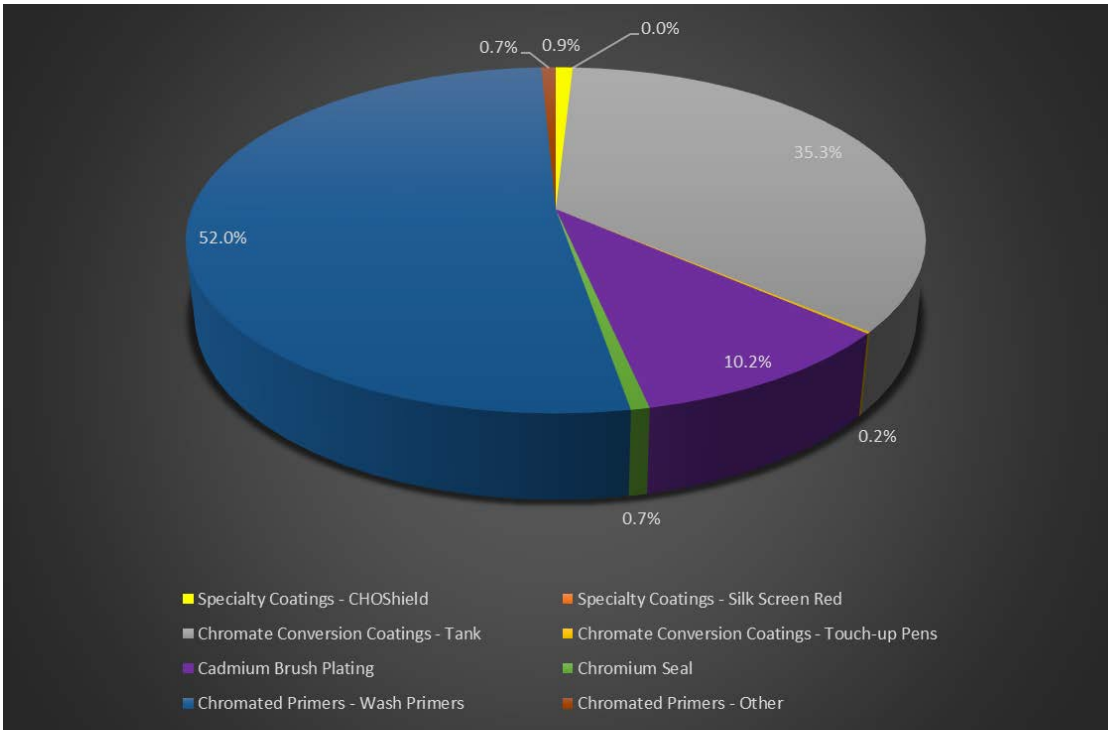

Figure 2. Process Usage at LEAD (based on pounds of Cr^{6+} and Cd species).

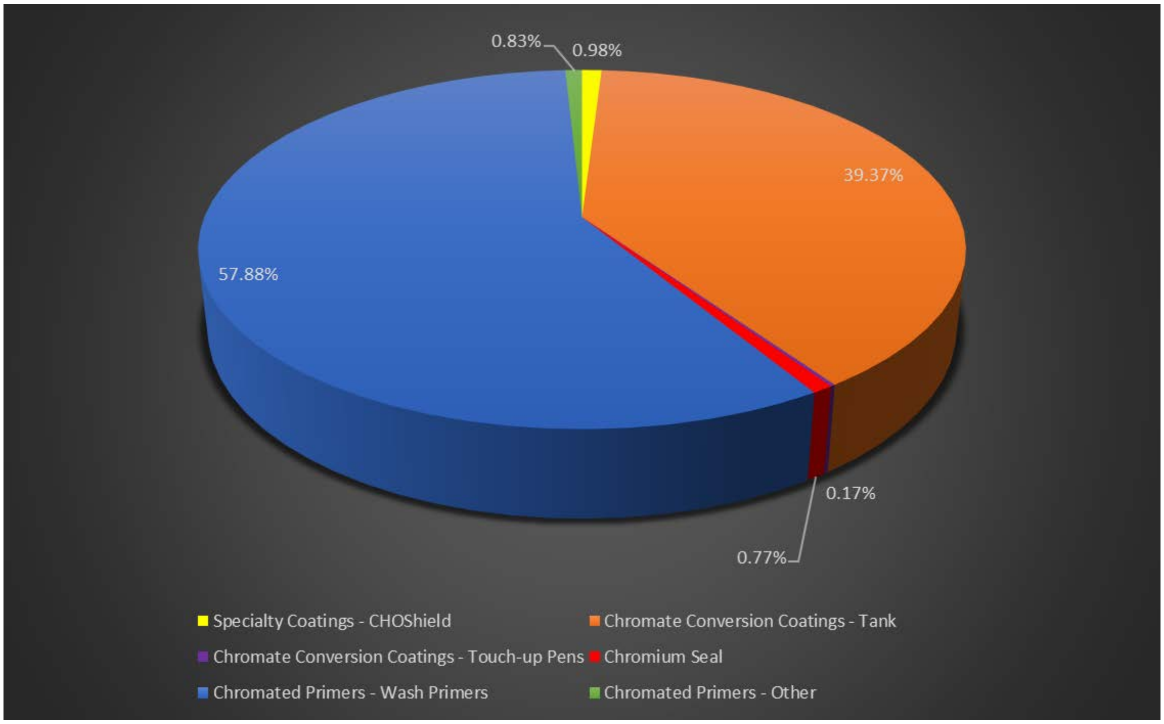

Figure 3. Cr^{6+} Process Usage at LEAD (based on pounds of Cr^{6+} species).

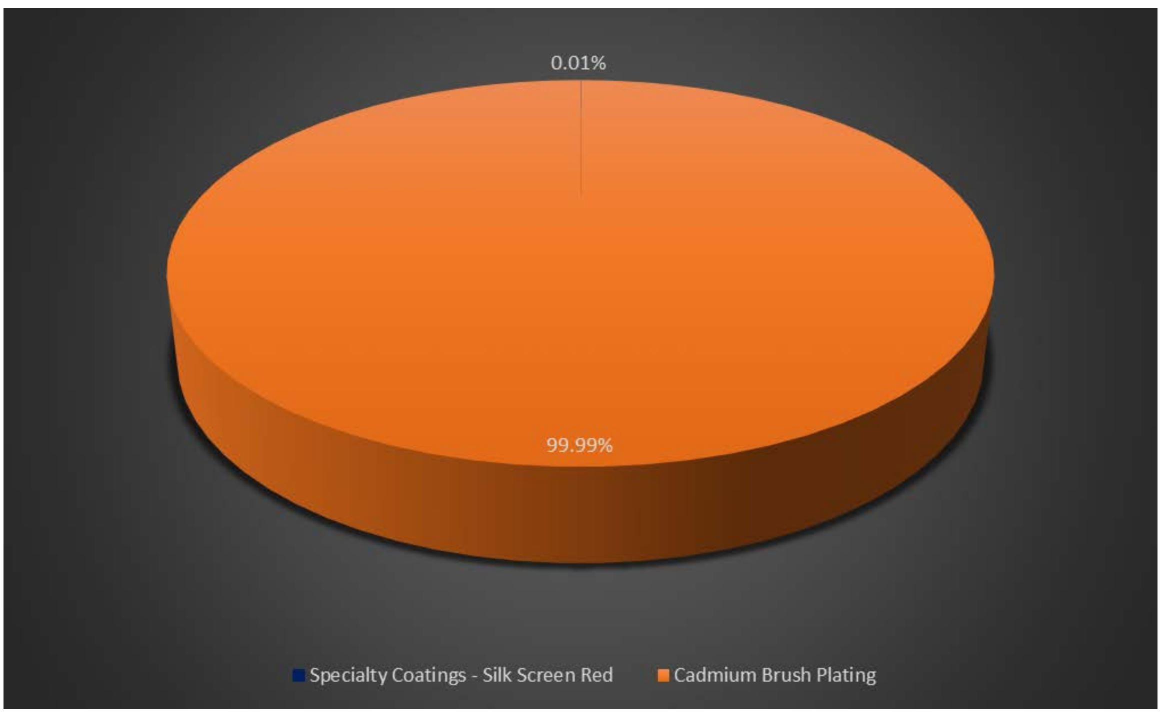

Figure 4. Cd Process Usage at LEAD (based on pounds of Cd species).

Sections 2.1.1 through 2.1.7 describe each of the processes in greater detail and, when possible, describe the weapon system components that are maintained. This section also correlates the process to the materials or trade name products used at LEAD.

2.1.1 Chromated Primers and Wash Primers

Process Description.

A primer or undercoat is a preparatory coating product applied to improve the adhesion a topcoat or finishing paint and, in many cases, provide additional environmental corrosion resistance. Primers are designed to adhere to surfaces and to form a binding layer that is better prepared to receive the paint. Because primers do not need to be engineered to have durable, finished surfaces, they can instead be engineered to have improved filling and binding properties with the substrate. Chromated primers contain hex chrome compounds (e.g., zinc chromate, strontium chromate, and magnesium chromate) as the primary pigment and corrosion inhibitor.

Specification DOD-P-15328D has a low-solids and high volatile organic compound (VOC) content, contains phosphoric acid with zinc chromate, and has hazardous air pollutants (HAP). These characteristics come under the control of the National Ambient Air Quality Standards, Sections 109 and 112 of the Clean Air Act as amended in 1990. In addition, the state of Pennsylvania places restrictions on the amount of VOCs that can be emitted specifically related to wash primer operations under the LEAD Title V permit. Furthermore, the operational capability requires that wash primers can be applied simultaneously to unassembled mixed metal substrates (steel and aluminum) which is not possible with most other pretreatments. In essence although 15328 is called a primer it functions a pretreatment. Over the years, the U.S. Army Research Laboratory (ARL) Coatings Technology Team has reformulated all of the camouflage chemical agent resistant coating (CARC) and ammunition coatings to meet local and Federal regulations. One of the most difficult tasks has been to reformulate a wash primer with reduced VOCs and zero HAPS that will have corrosion resistance similar to DOD-P-15328D without hexavalent chrome. The typical epoxy primers used by LEAD are already Cr^{6+} free.

Wash primers are characteristically thin (0.3–0.5 mil [1 mil = 0.001 in]), cross-linked coatings applied directly to the substrate to provide protection from corrosion and promote adhesion (*3*).

In the U.S. Army's chemical agent resistant coating (CARC) System, the wash primer DOD-P-15328D is overcoated with an epoxy primer and a camouflage urethane topcoat. Several coating procedures specify the use of a wash primer, DOD-P-15328D, as a surface treatment prior to the application of an epoxy primer/polyurethane topcoat CARC system.

The CARC System application specification, MIL-DTL-53072E (*4*), require that metal surfaces on tactical vehicles be treated to improve adhesion and corrosion resistance prior to coating with an epoxy primer and a camouflage topcoat. In addition, MIS-20007AE, which governs missile and ground support equipment, requires the use of chromated pretreatments (e.g., conversion coatings, primers) for Grade 1 substrates and some Grade 3, 4, and 5 substrates. In original equipment manufacturer (OEM) processes, the surface treatment is generally performed by a five-stage dip process, e.g., zinc phosphate prescribed in TT-C-490 (*5*). In depot operations and for touch-up in OEM processes, the surface treatment requirement is met through the wash primer DOD-P-15328D.

It is significant to note that the metal pretreatment (chromate conversion coating or chromate sealed zinc phosphate coating) and the primer perform synergistically and the corrosion resistance of the system is very sensitive to changes in either coating. The primer coating layer contains a much higher mass of chromate than the pretreatment coating layer and some studies have indicated that non-chrome primers can perform effectively with chromate based pretreatments resulting in a significant reduction in chromate usage. Conversely non-chromate metal pretreatments have been shown to perform better with chromate based primers.

Wash-primer pretreatment processes, Army-wide, use an annual average of 400,000 gallons of DoD-P-15328 wash primer that generates 24,000 pounds of Cr^{6+}. Wash-primers account for the primary use of chromate throughout Letterkenny Army Depot. These are applied to steel and aluminum components within ventilated paint booths after cleaning and repair. Wash-primers are not intended to be used as a permanent protective coating, but to increase the adhesion of the corrosion resistant coating system, applied later.

Weapons Systems and Components

Wash-primers are applied to HMMWVs components, and generator frames, along with other various components. The application of pretreatment wash primers for metal surfaces is specified by DOD-P-15328. Zinc-Chromate primers are wet-applied to coat some rivnuts and other inserts on systems. The weapon systems which have components to which wash primers or chromated primers are applied at LEAD include:

- MIM104 Patriot
- Longbow
- M142 HIMARS
- AN/TWQ-1 Avenger
- FMTV
- Generators
- Material Handling Equipment
- Fabrication
- Hellfire
- BGM-71 TOW
- Sentinel AN/MPQ-64A3
- M997 HMMWV
- Firefinder
- Force Provider
- Secondaries

Materials

LEAD uses chromated wash primers in accordance with DOD-P-15328D and chromated resin primers in accordance with TT-P-1757 and MIL-PRF-23377K, Type 1, Class C. TT-P-1757 is a single-component, alkyd resin primer used primarily for convenience in wet installations since it doesn't require mixing multiple components for use. The products, national stock numbers (NSN), and Fiscal Year 2014 usage in pounds are listed in Table 5.

Table 5. Chromate Primers Materials/Products

Trade Name	NSN	2014 Usage (lbs)
Wash Primers		
E90G4 DOD-P-15328D Ordnance Metal Wash Primer Part	8030002812726	6727.5
N-9025A, Chromate Wash Primer	803001E765209	7.5
DOD-P-15328D Green Wash Primer Part A	8010002812726	0
Other Chromated Primers		
TT-P-1757 Composite L Yellow	8010010865359	21.8
200Y02 TT-P-1757B TY. I, CL. C (YELLOW)	8010008352114	13.63
02YO40A Epoxy Comp A, MIL-PRF-23377H, TY I, CL C	8010014166556	21.8

2.1.2 Chromate Conversion Coating (Alodine)

Process Description

Chromate conversion is used to form an amorphous protective coating for enhanced corrosion protection and adhesion of subsequently applied sealants and topcoats on various metal surfaces. The process serves to inhibit corrosion and improve the adhesion of both paint and powder finishes and provides an added degree of protection. When the protective coating or paint is scratched, chromates from the conversion coating deposit on the bare metal recreating a corrosion-resistant layer at the exposed surface.

Chromate conversion coatings are produced by chemical treatment with hexavalent chromium compounds and other activators. When a metal is treated with this mixture, a layer of its surface (nanometers thick) will dissolve, forming a protective film consisting of a complex mixture of both hexavalent and trivalent chromium compounds with the base metal. These coatings can be applied through immersion, spray, or wipe-on techniques.

Chromate conversion processes at Letterkenny Army Depot are performed by immersion, brush-on techniques, and with the use of touch-up pens. Chromate conversion coating lines operate at LEAD in Building 350 using a 3,000 gallon bath (Figure 5) of Chemetall Chromicoat L25 (5-10% hexavalent chromium trioxide) and in building 370 with a 1,000 gallon bath of Bonderite M-CR 600, more commonly known as Alodine 600 (30-60% hexavalent chromium trioxide). The process flows for both lines are shown in Figure 6. Manual brush-on application of chromate conversion coatings are applied when the component is incapable of being immersed within the solution. For example, brush application is required for each of the 5,000 receptacles of the Patriot Phased Array Radar, which involves multiple days of direct personnel exposure to the solution throughout the process. Touch-N-Prep® Alodine 1132 pens are used throughout LEAD to provide spot repair conversion coatings to surfaces as needed.

Figure 5. Chromate Conversion Coating Tanks in LEAD Building 350

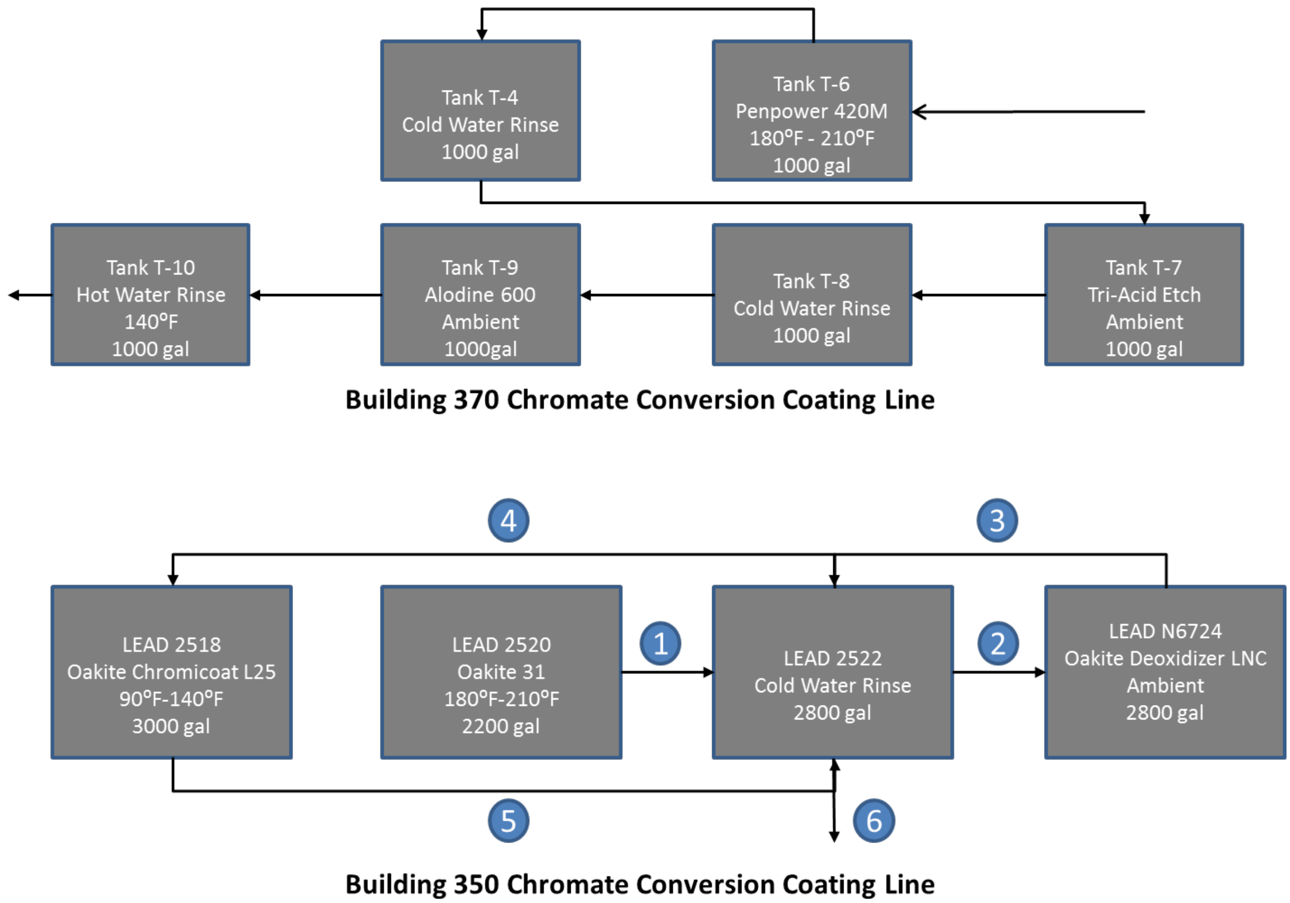

Figure 6. Chromate Conversion Coating Process Lines

Weapons Systems and Components

The weapon systems which have components to which chromate conversion coatings are applied at LEAD include:

- MIM104 Patriot
- Longbow
- M142 HIMARS
- AN/TWQ-1 Avenger
- FMTV
- Generators
- Panther/MMPV
- RG-31 MMPV
- Material Handling Equipment
- Fabrication
- TRMD
- Hellfire
- BGM-71 TOW
- Sentinel AN/MPQ-64A3
- M997 HMMWV
- Firefinder
- VMMD Husky
- Buffalo/MPCV
- Route Clearance Vehicle
- Force Provider
- Secondaries

Materials

The use of chemical conversion coatings for aluminum is conducted in accordance with two specifications, MIL-DTL-5541E–Chemical Conversion Coatings on Aluminum and Aluminum Alloys and MIL-DTL-81706B–Chemical Conversion Materials for Coating Aluminum and Aluminum Alloys. The products, NSN, and Fiscal Year 2014 usage in pounds are listed in Table 6.

Table 6. Chromate Conversion Coating Materials/Products

Trade Name	NSN	2014 Usage (lbs)
Alodine 600	8030013302504	214
Oakite Chromicoat L-25	6850010119875	2740
Touch-N-Prep Coatings Alodine 1132	8030014600246	59.93

2.1.3 Cadmium Brush Plating

Process Description

Brush plating (sometimes called stylus plating) is a localized form of electroplating, in which the surface is cleaned and often etched to activate it, and then the coating is deposited electrolytically. The primary difference with tank plating is that brush plating is a manual process that is carried out over a limited area to correct damage or replace lost coatings. The basic items needed are a power pack, plating tools, masking materials and solutions. The plating is achieved by passing an electric current, via a hand-held anode, through a liquid solution which contains the desired material. The part becomes the cathode and is connected to the negative terminal of the power pack. The appropriate solution -- which can be fed with a pump -- completes the electrical circuit. The deposition rates can be about 0.035 inches/hour, which means quick plating of the part. Brush techniques are suitable for simple geometric shapes such as outer diameters, interior diameters and flat surfaces.

Cadmium functions as a sacrificial coating against uniform and galvanic corrosion, when plated onto steel, providing protection for the surface even if the coating is damaged. Because its galvanic potential is very similar to aluminum, it is often used to prevent galvanic corrosion between steel or stainless steel and aluminum or magnesium. It offers consistent torque tension values on threaded fasteners, low-volume corrosion products, and consistently low electrical impedance, even after corrosion. It is applied to base metal, except in the case of parts made from corrosion resistant alloys on which a preliminary plating of nickel (or strike layer) of copper or nickel may be necessary, or on parts made of aluminum on which a preliminary treatment, such as the zincate process may be necessary. Cadmium offers an exceptional bonding surface for adhesives and is a preferred coating for harsh marine environments. Some cadmium brush plated (Type II) components require a chromate seal finish.

Weapons Systems and Components

The weapon systems which have components that are cadmium brush plated at LEAD include:

- MIM104 Patriot
- Longbow
- M142 HIMARS
- AN/TWQ-1 Avenger
- FMTV
- Generators
- Material Handling Equipment
- Hellfire
- BGM-71 TOW
- Sentinel AN/MPQ-64A3
- M997 HMMWV
- Firefinder
- Force Provider
- Secondaries

Materials

LEAD applies cadmium brush plated finishes in accordance with MIL-STD-865. The products, NSN, and Fiscal Year 2014 usage in pounds are listed in Table 7.

Table 7. Cadmium Brush Plating Materials/Products

Trade Name	NSN	2014 Usage (lbs)
2020/5050 SIFCO PROCESS CADMIUM ACID	6850013498654	476.28

2.1.4 Specialty Coatings

Process Description

Specialty coatings are those process and material combinations that do not fit into any of the more widely used process categories. LEAD uses two products that fall into the specialty coatings category - Cho-Shield-zinc chromate Electro-Magnetic Interference (EMI) shielding (Cr^{6+}) and silk screen red (Cd).

Cho-Shield zinc chromate EMI shielding is an electrically conductive coating that provides a corrosion resistant conductive surface coating on aluminum or composite substrates. By reducing moisture penetration, Cho-Shield offers corrosion protection for enclosure flanges which mate with particular EMI shielding gaskets. Cho-Shield is a urethane coating that offers a highly conductive interface which improves overall EMI shielding performance. When used as a coating on a composite or other non-conductive surface, they provide the conductivity necessary to achieve excellent shielding effectiveness while maintaining their electrical and mechanical stability in hostile environments.

Cho-Shield is a three-part, copper-filled urethane coating systems which has been formulated with special additives and stabilizers to maintain electrical stability, even at elevated temperatures, which prevent aluminum surfaces from corroding in high humidity and/or marine environments. In particular, Cho-Shield 2003 contains soluble chromates to minimize the effects of galvanic corrosion of the aluminum substrate, even in the event of a coating scratch. Cho-Shield 2003 is designed to be used with Cho-Shield 1091 primer on chromate conversion coated (MIL-DTL- 5541 Type I, Class 3) aluminum substrates. Figure 7 shows Cho-Shield 2003 applied to a Patriot electronics cabinet.

Figure 7. Cho Shield 2003 Applied to Electronics Cabinet

M-2-N Red Silk Screen Ink is a permanent, epoxy-based, screen printing ink. These inks are used with a selection of catalysts which cure at elevated and/or room temperatures. When properly applied and cured, they have excellent adhesion to glass, solder resists, plastics and metals. These epoxy inks are extremely resistant to acids, alkalis, solvents, salt spray, thermal shock, and are qualified to MIL-I-43553 and AA56032. These marking inks are used in the electronics, aerospace, automotive, appliance and decorative packing industries and uses include the permanent marking of circuit boards, dials, nameplates, components, edge-lit panels, chassis, glass, and thermoplastics. At LEAD, the epoxy ink is applied to painted surfaces or sometimes on just chromated aluminum. The Silk Screen Red is a particular color that is formulated with cadmium sulfide and cadmium selenide in the pigment. It is a special request color for a specific need.

Weapons Systems and Components

The weapon systems which have components to which specialty coatings are applied at LEAD include:

- MIM104 Patriot
- Longbow
- Hellfire
- Sentinel AN/MPQ-64A3

- M142 HIMARS
- AN/TWQ-1 Avenger
- Firefinder

Materials

The Cho-Shield 2003 EMI shielding is applied in accordance with the Patriot Technical Data Package. Silk Screen Red is applied in accordance with A-A-56032D, Types I, II, or III or MIL-I-43553. The products, NSN, and Fiscal Year 2014 usage in pounds are listed in Table 8.

Table 8. Specialty Coatings Materials/Products

Trade Name	NSN	2014 Usage (lbs)
CHO-Shield 2003. PART A	8030013942514	272.56
M-2-N Red Sild Screen Epoxy	751001E135446	0.58

2.1.5 Chromate Sealers

Process Description

Chromate sealers are used with phosphate coatings where enhanced corrosion resistance is required and where the imparted yellowish color to the coating is important, such as military and industrial applications requiring exceptional corrosion resistance. Potassium or sodium dichromate is usually the preferred chemistry to use for this type of sealing. Many surface treatment processes call for a post treatment chromate seal to enhance the corrosion prevention capabilities of the coating. The application may be done through immersion of the component, but spray or brush-on techniques are also widely used.

At LEAD, phosphate coatings are frequently sealed with chromate sealers, which are the most hazardous chemicals used in the phosphating process. These sealers typically contain both chromic acid and a dichromate salt. LEAD uses the same process tanks for heavy and light zinc phosphate coatings. The process flow for the LEAD phosphate processes in Buildings 350 and 370 are illustrated in Figure 8.

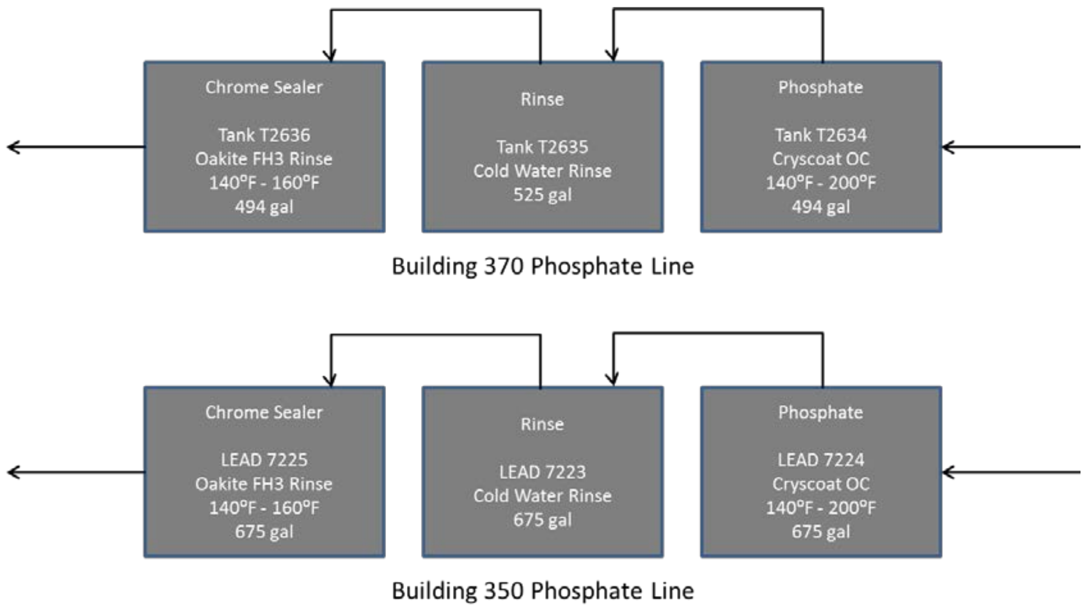

Figure 8. Phosphate Process Lines

In addition, to enhance the corrosion protection of cadmium plated components, a chromate sealer finish coating is applied over the plated metal to prevent the formation of white corrosion products on surfaces exposed to marine environments or high humidity atmospheres. A chromic acid-based SIFCO chromate conversion coating is used as a sealer following cadmium brush plating.

Weapons Systems and Components

The weapon systems which have components to which chrome sealers are applied at LEAD include:

- MIM104 Patriot
- M142 HIMARS
- AN/TWQ-1 Avenger
- Panther/MMPV
- RG-31 MMPV
- Fabrication
- BGM-71 TOW
- Sentinel AN/MPQ-64A3
- VMMD Husky
- Buffalo/MPCV
- Route Clearance Vehicle

Materials

LEAD applies phosphate coatings in accordance with TT-C-490 (light) and MIL-DTL-16232 (heavy). Dichromate sealers are applied in accordance with MIL-M-3171 or MIL-A-8625. Chromate sealers are applied to cadmium brush plated finishes in accordance with MIL-STD-865. The products, NSN, and Fiscal Year 2014 usage in pounds are listed in Table 9.

Table 9. Chromate Sealer Materials/Products

Trade Name	NSN	2014 Usage (lbs)
3002 SIFCO Process Chromic Conversion	13929SSS-3002	220.32
Duracoat O-D-1	685001E055881	44.06
Oakite FH3	685001E048112	141.00

2.1.6 Coatings Removal

Traditional coating removal methods employed throughout DoD involve the use of hazardous chemicals for chemical stripping or abrasive blast media. These conventional chemical stripping methods result in major waste streams consisting of toxic chemicals and spent blast materials. The chemicals that are typically used in this stripping process are high in VOCs and HAPs, both of which are targeted for reduction by environmental regulation. Coatings removal operations that use abrasive blast media instead of chemical methods result in large quantities of solid hazardous waste that is subject to high disposal costs and environmental scrutiny.

A significant concern for all DoD depots that perform the removal of Cd- or chromate-contaminated coatings is the management of the airborne particulates. These airborne particulates are major cause of citations from OSHA for violations related to facility housekeeping.

2.1.6.1 Component Sanding and Abrasive Blasting

Based on component size or geometry, many parts are stripped by mechanical means of dry surface sanding and abrasive blasting. Abrasive cleaning consists of forceful application of abrasive particles against the surface of metal parts. Typical uses include the removal of organic or inorganic coatings, corrosion, and surface conditioning for subsequent finishes. Plastic media blasting (PMB) is designed to replace chemical paint stripping operations and conventional sand blasting. This process uses soft, angular plastic particles as the blasting medium, and has proven more efficient than chemical paint removal with the advantages of reusable media and reduced necessity of chemical use and storage.

PMB is well suited for stripping paints, since the low pressure (less than 40 psi) and relatively soft plastic medium have little effect on the surfaces beneath the paint. PMB is currently authorized by NAVAIR for multiple uses down to 0.016-inch aluminum skins. Used media is typically passed through a reclamation system consisting of a cyclone centrifuge, air wash, vibrating classifier screen, dense particle separator and a magnetic separator. More dense particles, such as paint chips, sand, grit, and aged sealant particulate, are separated. Typically, media can be recycled ten to twelve times prior to degradation. PMB facilities typically use a single type of plastic media for all of their blasting work. The majority of DoD PMB facilities use either Type II or type V media.

Abrasive blasting operations can generate elevated airborne concentrations of Cd, Cr^{6+} and Cr-compounds. Significant concentrations of both cadmium and chromate-contaminated dusts can also be generated during these and subsequent clean-up processes. This dust can be carried into break rooms, office areas, and other unregulated areas of the plant, and are often the source of OSHA citations at depots. Letterkenny Army Depot performs these tasks within specified areas designed to capture dusts in ventilated enclosures (i.e., walk-in booths, drive-through bays, abrasive blasting cabinets, and glove boxes). Most abrasive operations are enclosed to maximize capture efficiency. However sanding or grinding often takes place outside of ventilated areas using hand or pneumatic sanders based on component size, shape, or access to hard-to-reach areas. Recent Industrial Hygiene exposures sampling have been above action-level limits during FY14 for both Cd and Cr-compounds.[2] Open area hand-sanding is required for the 5,000 receptacles that house each of the 39-millimeter flash-elements of the Patriot Phased Array Radar. Between 2006 and 2011, an average of 26,800 pounds of sanding dust has been collected annually at LEAD.[3] Figure 10 shows the amount of sanding dust generated and collected as waste at LEAD from Fiscal Year 2005 through 2012.

Abrasive blasting cabinets and glove boxes throughout Letterkenny Army Depot utilize Garnet, Steel Shot, Glass Beads, and Plastic Abrasives to remove surface coatings from components. A significant amount of waste containing cadmium and hexavalent chromium is generated through the disposal of blast media and dusts generated from these processes. For calendar year 2014, waste streams identified as Blast Media Waste and Blast Media with Vacuum Dust totaled over 1.3 million pounds.[3] Historically, the waste was handled as hazardous waste when removed from the site, but recent rounds of testing has allowed LEAD to reclassify the waste as non-hazardous based on low Cr^{6+} and Cd levels. Figure 9 shows the amount of blasting media generated and collected as waste at LEAD from Fiscal Year 2005 through 2014.

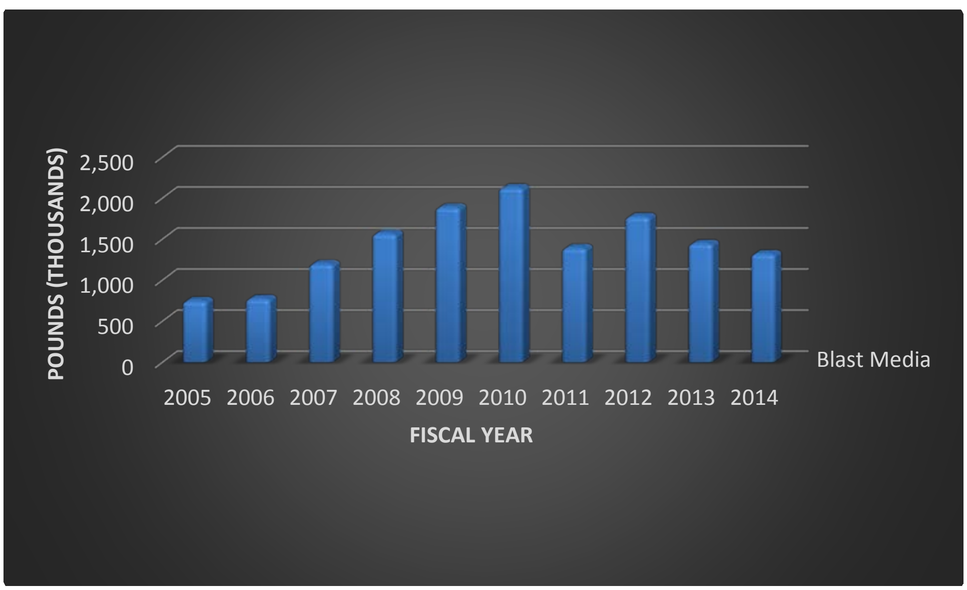

Figure 9. Blast Media Waste at LEAD (in pounds)

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2 Communication with Shawn Mallory, LEAD Industrial Hygiene Program Manager. June 29, 2015.

3 Communication with Thomas Stagg, LEAD Engineering Support Branch. March 21, 2015.

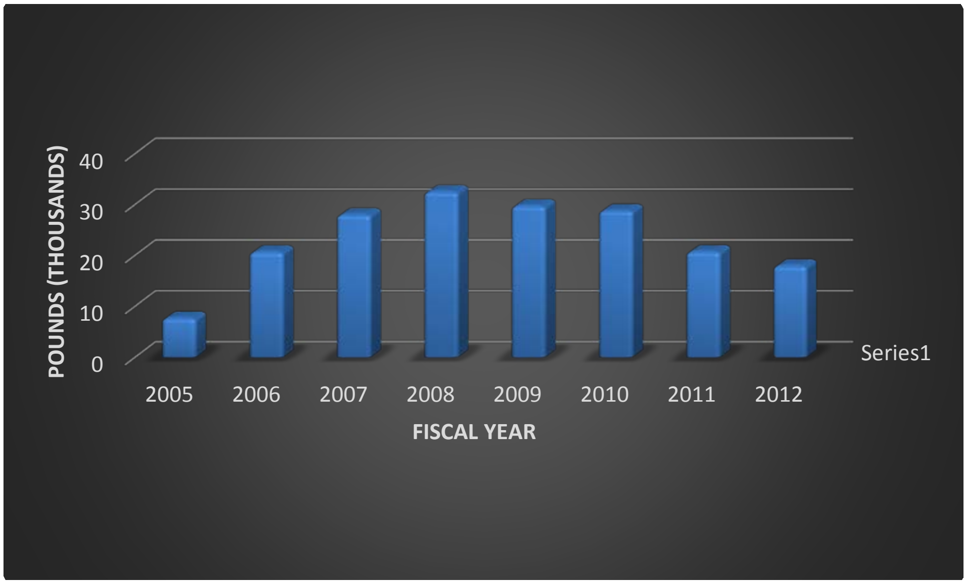

Figure 10. Sanding Dust Waste at LEAD (in pounds)

2.1.6.2 Chemical Coatings Removal

Component parts may be stripped of paints and corrosion using aqueous chemicals at elevated temperatures. Elevated temperatures increase the stripping action for paint, grease, oil, corrosion, and dirt. Though these chemicals are biodegradable, only the rinse water can be discharged in to the local wastewater systems. Hazardous constituents within the removed coatings contaminate the stripping solutions requiring the wastes be drummed and disposed of as hazardous waste.

Parts are immersed into heated solutions and agitated to enhance the stripping process. Agitation ensures that newly formed emulsions and soaps are washed away from surfaces, applying fresh chemical stripping agents to the exposed layers of paint, which speeds the process. In conjunction with filtration systems and skimmers, the chemical solutions may be recycled for extended use. Most of the aqueous strippers are alkaline in nature. These strippers are different from acid strippers in that acid strippers may attack the metal surfaces, causing structural weakening (hydrogen embrittlement). Acid strippers normally require neutralization after the process.

Tanks used for heated aqueous stripping can come in a variety of sizes, from 100-gallon to 2,500-gallon capacities. Average temperatures for the heated solutions range from 180-210° F.

All DoD Service Components currently use hot tank aqueous strippers. At LEAD, these processes are used primarily for weapon system and wheeled vehicle components using several chemical strippers. Eurostrip 7028 and Eurostrip 7031 are combined in a solution to remove powder paints and enamels from aluminum and steel surfaces at 120-160°F. PenPower 420M is a compound used for corrosion removal and applied in at 180-210° F. Oakite 31 is an acidic compound applied at 180-210° F and used for cleaning shop dirt, oxides, flux and welding spatter from steel, stainless steel, and aluminum.

No solvent waste streams are generated with the use of hot tanks and biodegradable cleaning agents. Effluent waste streams comprise the aqueous solutions and sludge products composed of paint, grease, oil, and dirt. Paint solids and sludge products are periodically collected from the tanks and require proper disposal. Spent stripping solutions are pumped from the tanks about once a year and the waste is subject to RCRA requirements.

Weapon Systems and Components

Prior to inspection, overhaul and repair of equipment or component parts, surfaces are washed and stripped of existing primers, paint, anodize, plating finishes, and corrosion prior to rework. Multiple areas at LEAD are designated for washing, stripping, and abrasive blasting of ground vehicle and weapon system components. Every weapon system maintained at LEAD has components that are subjected to abrasive blasting or hand sanding. Fewer systems have components that go through chemical coatings removal. The weapon systems which have components that undergo physical and/or chemical coatings removal at LEAD include:

- MIM104 Patriot
- Longbow
- M142 HIMARS
- AN/TWQ-1 Avenger
- FMTV
- Generators
- Panther/MMPV
- RG-31 MMPV
- Material Handling Equipment
- Fabrication
- TRMD
- Hellfire
- BGM-71 TOW
- Sentinel AN/MPQ-64A3
- M997 HMMWV
- Firefinder
- VMMD Husky
- Buffalo/MPCV
- Route Clearance Vehicle
- Force Provider
- Secondaries

Materials

No materials containing Cd or Cr^{6+} are used in the execution of these processes. However, as described above, each coatings removal process results in significant emissions, exposure potential, and/or waste streams.

2.1.7 Stainless Steel Welding

Process Description

Currently, the DoD spends approximately $36 million annually on personal protective equipment for welding operations. Stainless steel welders can easily be exposed to hexavalent chrome above the OSHA PEL, even though Cr^{6+} is not used in the welding process or present in welded items. Welding is a common repair and maintenance operation throughout DoD depots and shipyards. It uses mild or stainless steel filler material to join like metals. The energy expended during the weld process results in the formation of high concentrations of nano-sized particles (fumes) loaded with Cr^{6+}, nickel, manganese, and other toxic metals. Hexavalent chromium fume is always produced when welding stainless steel because Cr metal is a primary constituent of filler material used in the welding electrode. The intense heat of the process vaporizes the chromium and subsequently oxidizes the vaporized atoms to form Cr^{6+} molecules. Fume particulates are respirable in size and able to travel deeply into the respiratory system, interacting with human cells. Welding fume generation rates, particulate characteristics, and weld quality are affected by current, voltage, and shielding gas flow rates.

The processes required to manufacture or repair through welding are unique to the type of materials used. The largest operation involved with armor repair and modification at LEAD are for the Route Clearance Vehicles (RCV) programs, royal guard (RG) 31 and RG-33 Panther. These platforms require a large number of modifications and welding. The RG-33 Panther requires the most, with an estimated welding time of 800 hours per RCV. The welding process for these platforms require that metal be preheated prior to the weld and temperatures controlled during the process. All welds are subject to non-destructive testing to ensure weld quality.

Throughout DoD maintenance depots, electric arc welding such as TIG, MIG, SMAW, and resistance spot welding (RSW) are the primary means of welding stainless steel. In lesser amounts, DoD maintenance depots and research laboratories may also employ radiation energy (laser) welding and other techniques not fully described here. Welding operations range from small component repair, production workload, to full asset modification and repair. LEAD has a designated 15,000 square foot production area used primarily for welding; MIG in steel and aluminum, TIG in steel and aluminum, titanium, stainless steel, and various other armor grade materials.

Tungsten Inert Gas (TIG) welding maintains energy between a tungsten or tungsten alloy electrode and the work piece, under an inert or slightly reducing atmosphere. The workpiece is struck by the electrons to enhance penetration while the electrode, which is generally made of 2% thoriated tungsten, undergoes very little wear. Filler metals are employed in the form of either bare rods or coiled wire for automatic welding. The arc zone is protected from ambient air with an inert gas flow, enabling a more stable arc. Shielding gases consist mainly of mixtures of argon (Ar), helium (He), and hydrogen (H_2).

Metal Inert Gas (MIG) welding uses a continuously fed consumable metal wire electrode, producing an arc between it and the workpiece under a shielding gas. Most MIG welding is operated manually, but can be fixed to a carriage for automation and use of higher welding power. High current densities in the electrode wire (>90 Amp/mm^2) provide high temperatures to ensure rapid melting of the electrode wire. An argon (Ar) shielding gas is required to prevent oxidation in the welding arc.

Shielded Metal Arc Welding (SMAW) has been employed for over 100 years, yet still remains the most common technique employed in the field due to its flexibility and simplicity of use. The electrode consists of a metal core, usually a solid stainless steel wire rod, covered with a layer of flux. The flux serves to initiate and stabilize the arc, control the viscosity and surface tension of slag, and metallurgically is involved in chemical exchanges in refining of the weld metal.

Resistance Spot Welding (RSW) is extensively used across DoD maintenance depots for joining thin stainless steel sheets. Heat is generated with the passing of a high-current at low-voltage through the workpiece in a small area of contact between the electrodes. Generally, electrodes are copper, cobalt, and beryllium alloys, whose tips form a truncated code to minimize surface area of the weld. In many DoD processes, this type of welding is performed manually.

LEAD primarily conducts TIG welding using 309 flux stainless wire to repair cracks and other faults in the armor on MRAP and route clearance vehicles. They also conduct MIG welding using 308 hard wire to fabricate tanks, latrines, and mobile kitchens for Force Provider.

Weapon Systems and Components

The weapon systems on which stainless steel welding is conducted at LEAD include:

- Panther/MMPV
- RG-31 MMPV
- Fabrication
- Force Provider
- M997 HMMWV
- VMMD Husky
- Buffalo/MPCV
- Route Clearance Vehicle

Materials

Stainless steel welding at LEAD is conducted in accordance with MIL-E-19933E or MIL-E-22200/2, depending upon the stainless steel substrate. TIG welding for cracks and repairs uses 309 Flux Stainless and MIG welding for fabrication of Force Provider commodities uses 308 hard wire. While consumable quantities were not available none of the materials contain Cr^{6+}.

3 Alternatives

This section describes past and ongoing initiatives and potential alternatives available or in current development for each of the processes identified in Section 2.1. Numerous pollution prevention activities have been initiated to eliminate Cd, $Cr^{6+,}$ HAPs, VOCs, and other toxic or regulated hazardous materials or impact major processes. Past and ongoing initiatives that impact the Cd and Cr^{6+} Strategy and Roadmap and, more specifically, the Implementation Plan for LEAD are included in Table 10.

Table 10. Past and Ongoing Initiatives Targeting Cd and/or Cr^{6+} Reduction

Initiative	Lead	Process	Description/Outcome
Cr (VI)-Free, Low VOC Alternatives for Spray-in-Place, Mixed Metal Pretreatment (TMR 12-01)	RDECOM, ARL $1.4M 2012 - Ongoing	Wash Primers	The intended product of this initiative is to identify and qualify an approved non-hexavalent chrome alternative to replace DOD-P-15328 wash primer. The alternative must be spray applied with similar process parameters, effective on multi-metal assemblies, and qualify to TT-C-490. The approach is to identify technologies to fill technology gap created by impending cancellation of DOD-P-15328 through: • Laboratory validation to downselect to best performers for demonstrations • Mid scale demonstration of 3 candidates to assess process parameters • Full scale production demonstration to validate process and performance • Qualify candidate (s) and add to TT-C-490 QPD • Work with PHC, who are writing toxicology assessments for each of the final candidates The product will transition to all weapons systems that currently use DOD-P-15328 in rework and new manufacture, most likely ground vehicles and support equipment (BFV, HMMWV, trailers, shelters, containers, tactical vehicles). The initiative addresses AERTA PP-2-02-04 by eliminating Cr^{6+} in wash primer (pretreatments), OSD Policy, DFARS 2009-D004 and local and Federal regulations limiting VOC emissions, and cancellation of DOD-P-15328. The initiative will eliminate DOD-P-15328 wash primer, reducing Cr^{6+} by 24K lbs/year and VOCs by 2.4M lbs/year.
Replacement Alternatives to the Chromate Wash Primer DOD-P-15328	ARL 2002-2004	Wash Primers	In this project, three vendor formulations (Aqua Zen by Hentzen, Kem Aqua by Sherwin Williams, and RWE1033 by Spraylat) were evaluated against the control DOD-P-15328D. The initial effort consisted of evaluating various coating candidates in a laboratory environment and selecting a suitable candidate for field testing at a renovation facility. Laboratory results and a wide range of data exist for the four different systems and five substrates. The results show dependence on many factors including substrate/material coating thickness, condition of testing, and the interpretation of results. Pretreatment performances vary among alloys. So far, the replacements are similar in performance to the control DOD-P-15328D wash primer, and the results are very promising. The result of replacing the DOD material with one of the alternative systems is imminent, and the impact of this change will be positive across the board. Affected installations, facilities, and weapons systems will include all tactical combat vehicles and U.S. Army aviation helicopters and equipment, and depots that are currently looking for viable alternative hexavalent chromate free wash primers. The elimination of hexavalent chromium and much of the solvent in wash primer would have a direct positive impact on worker health and safety. It will eliminate 12,600 lb of zinc chromate, 16,800 gal of package solvents, and 18,900 gal of thinner solvents emitted annually as the result of DOD-P-15328D. In addition, it will help to eliminate the need to dispose of 6,000,000 lb of CARC-stripped wastes as hazardous wastes. At this point, the major challenge is to reconcile the differences observed between accelerated weathering and the natural world, because there has been no coating failure after 2 years at the two exposure sites. The natural environmental testing will continue for another year and will be compared to the simulated, controlled laboratory results.

Initiative	Lead	Process	Description/Outcome
Cr(VI)-Free Conversion Coatings (TMR 14-02)	RDECOM, ARL $2.4M 2014-Ongoing	Chromate Conversion Coatings	The intended end-product is a Cr^{6+} free pretreatment conversion coating for aviation and GSE with application for multi-metal. The goal is qualification and approval for transition to MIL-DTL-5541 and TT-C-490. The aviation demo sites will be CCAD, TASM-G, Ft. Campbell, Wheeler AAF and the GSE demo sites LEAD, RRAD, ANAD, MDMC. The technical approach includes full scale demonstrations of commercially available products and verification of performance to baseline technologies for transition by PMs and PEOs in 3 years. Current state of the art for pretreatment of metallic substrates is hexavalent or trivalent chromium containing materials for aluminum and zinc phosphate for ferrous substrates. Alternative technologies are currently at a TRL level of 7 and at project completion will be at an 8. The technology will be transitioned to the following weapon systems: • Army Aircraft—UH-60, AH-64 and CH-47 • Tactical GSE equipment—FMTV, MRAP, HMMWV • Missile Systems Support Equipment—Patriot Trailers The initiative addresses elimination of Cr^{6+} in military surface finishing processes, AERTA requirement PP-2-02-04 by eliminating Cr^{6+} in pretreatments, Defense Federal Acquisition Regulation Supplement (DFARS): Prohibition (223.7302), and OSHA Regulation 1910.1026. Other benefits of the initiative include reduction of over 100K pounds of Cr^{6+} generated from aluminum conversion coatings each year and over 6M pounds of stripped CARC waste that must be treated as toxic waste. Success would eliminate at least 90% of Cr^{6+} from conversion coating operations. Reduction of corrosion costs to military for multi-services. Managing risks of exposure by being accountable for material used, amount of emissions, and waste generated and disposed. Avoid fines, penalties and house-keeping costs for non-compliance with occupational regulation.
ESTCP WP-200906	Jack Kelley, ARL		https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Surface-Engineering-and-Structural-Materials/Coatings/WP-200906/WP-200906/%28language%29/eng-US

In addition to the initiatives described in Table 10, LEAD has also eliminated their chrome plating line by out-sourcing plating requirements. This does not alleviate the requirement to chrome plate weapon system components during depot maintenance, but does eliminate the immediate hazardous material burden to LEAD by transferring the burden to other platers. In the long run this approach to mitigating the use of hazardous materials is not sustainable and bypasses DoD goals. No information was available on the number or type of components out-sourced for chrome plating.

Sections 2.3.1 through 2.3.7 present a summary of potential alternatives, applicability to LEAD processes, known barriers to the technology or implementation, and recommendations for initiatives, studies, and/or implementation. Table 11 provides a non-exhaustive list of potential alternatives for each of the processes at LEAD.

Table 11. Potential Alternatives to LEAD Processes

Process	Potential Alternative(s)
Chromated Primers (e.g., wash primers, wet apply)	Wash Primers: Bonderite 7400, Oxisilane, Aqua Zen by Hentzen, Kem Aqua by Sherwin Williams, and RWE1033 by Spraylat Epoxy Primers: Deft non-Cr primer, BoeAero TC, BoeAero 7500h, Rare Earth Primers, Aerodur 2100 Mg-Rich Primer Zn-rich primer now used in production on USMC MRAPs at Red River, approved by USMC CPAC
Chromate Conversion Coatings (Alodine)	X-Bond 4000 (Zirconium oxide)—PPG Industries, RECC 3012 (Rare earth/Cerium) used in conjunction with RE primer—Deft/PPG, Bonderite/Oxsilan—Henkel/Chemetal NAVAIR TCP, Metalast TCP, Chemetall (Gardobond X-4707, Gardobond X-4650)
Cadmium Brush Plating	Zinc nickel brush plating (SIFCO, Dalistick)
Specialty Coatings (e.g., Cho-Shield-zinc chromate EMI shielding, silk screen red)	Alternative Cho-Shield Products (non-chrome) No known alternatives for the silk screen red
Chromate Sealers (phosphate coatings)	TCP, Pantheon PreKote, Boeing AC 131, Hot water seal, Chemetall (Gardolene D-6800/6, Gardolene D-6871, Gardolene D-6907, PhosGard 800HP); Heatbath Phoseal 25 Surtec 580
Physical Coatings Removal (e.g., abrasive blasting and sanding)	Segregation, Laser coating removal, Flashjet®, Atmospheric Plasma
Chemical Coatings Removal	Laser coating removal, Flashjet®, Atmospheric Plasma
Stainless Steel Welding	Down-draft tables, extractor hoods, ventilation, friction-stir welding, silica precursor (shield gas), Cr-free weld rods

3.1 Chromated Primers - Alternatives

Over the past two decades, significant effort has been spent on identifying, evaluating, and demonstrating non-chromated primers for application on DoD weapon systems. Work on non-chrome wash primers has been primarily accomplished by the Army Research Laboratory (ARL) and ESTCP. These efforts are summarized below. Work on non-chromate epoxy primers has been more widespread and has included SERDP, ESTCP, Naval Air Systems Command (NAVAIR), Air Force Research Laboratory (AFRL), the Coatings Technology Integration Office (CTIO), and Air Force Materiel Command (AFMC).

Significant progress has been made during the execution of SERDP Project WP1521, "Non-Chromate, Non-VOC Coating Systems for DoD Applications." The project, which was completed in"FY2008 assessed a number of promising coatings and pretreatments in the laboratory when used singularly or in combination with each other. The system for steel substrates consisted of a trivalent chromium conversion coating or non-chromium solution pretreatment, primed with non-chromated primer and topcoated with Low-VOC CARC topcoat. These are available at through the ASETS Defense database[4].

An ESTCP project (WP-201132[5]) will provide a comprehensive evaluation and assessment of non-chromated paint primers. Class N primers are currently undergoing validation by DoD Component Services and NASA. NAVAIR has successfully demonstrated the PPG Deft 02-GN-084 non-chromated primer on the E-2C Hawkeye, P-3C Orion, T-6 Texan, T-34 Mentor, T-44 Pegasus, and T-45 Goshawk aircraft. Service inspections done post-deployment documented good corrosion and adhesion performance. As a result, in 2014 NAVAIR drafted an authorization letter [6]for the use of this primer over conversion coatings qualified to MIL-DTL-81706, Type I, Class 1A, on the outer-mold-line (OML) of all Navy gloss paint scheme aircraft. Also, Deft 44-GN-098, a chrome free water reducible low density epoxy primer is used in production throughout the F-35.

NAVAIR is currently evaluating Hentzen 17176KEP primer on V-22 Osprey Helicopter, H-46 Sea Knight Helicopter, H-53 Sea Stallion Helicopter, and F/A-18A-D Hornet aircraft. Unlike the gloss paint scheme aircraft, which are primarily aluminum on the OML, the OML tactical paint scheme of these aircraft is also incorporates composite substrates. Upon successful demonstration, NAVAIR anticipates authorizing the Type II primer for tactical aircraft as well. Once signed and released, each applicable Program will have the option to implement the primer at OEM and depot level. NASA previously implemented a Hentzen non-chromate primer on the shuttle fuel tanks however, they are no longer in service.

Work has focused on both metal-rich as well as rare-earth materials. These technologies and efforts are summarized below.

3.1.1 *Alterative:* Non-Chrome Wash Primers

Since 2004, US Army Research Laboratory (ARL) has been evaluating Cr^{6+}-free wash primers for use on vehicles and ground support equipment. This includes testing of Bonderite 7400, Oxisilane, Aqua Zen by Hentzen, Kem Aqua by Sherwin Williams, RWE1033 by Spraylat and others. Recently, Army Research Laboratory qualified Bonderite 7400 as a Type IV (inorganic)

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4 http://db2.asetsdefense.org/fmi/webd#Surface%20Engineering

5 Julia Russel at NAVAIR WP-201132
https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Surface-Engineering-and-Structural-Materials/Coatings/WP-201132/WP-201132/%28language%29/eng-US

6 http://db2.asetsdefense.org/fmi/webd#Surface%20Engineering and search for Documents\ Chromate Primer Alternatives\ Authorizations

pretreatment, in accordance with TT-C-490F, as a drop-in-replacement to legacy wash primers. The product will transition to all weapons systems that currently use DOD-P-15328 in rework and new manufacture, most likely ground vehicles and support equipment (BFV, HMMWV, trailers, shelters, containers, tactical vehicles).

USMC CPAC has authorized use of Zn-rich primers in place of wash primer on USMC vehicles, and the process is used in production on USMC vehicles at Red River Army Depot.

Related Efforts

Table 12 is a list of efforts related to the research, development, testing, and evaluation of non-chromated wash primers. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the Advanced Surface Engineering Technologies for a Sustainable Defense (ASETSDefense) Database.

Table 12. Non-Chromated Wash Primers Related Efforts

Effort	Systems	Technology	Points of Contact
Examination of Alternative Pretreatments to Hexavalent Chromium-Based DOD-P-15328D Wash Primer for MIL-A-46100D High Hard Steel Armor	All vehicles BFV		Brian Placzankis US Army Research Laboratory plaz@arl.army.mil (410) 306-0841
Wash Primer Replacement Based on the Superprimer Technology (WP-1675)	All aircraft All helicopters All ships All vehicles	Zinc-phosphate silane-based super-primers	Danqing Zhu ECOSIL Technologies LLC zhud@ecosiltech.com (513) 858-2365
Replacement Alternatives to the Chromate Wash Primer DOD-P-15328	All aircraft All helicopters Missiles Ground support equipment	Aqua Zen by Hentzen, Kem Aqua by Sherwin Williams, RWE1033 by Spraylat	Pauline Smith US Army Research Laboratory
Cr (VI)-Free, Low VOC Alternatives for Spray-in-Place, Mixed Metal Pretreatment (TMR 12-01)	All vehicles Ground support equipment	Bonderite 7400, Oxisilane	John Kelley US Army Research Laboratory jkelley@arl.army.mil
Non-Chromate, Zero-VOC Coatings for Steel Substrates on Army and Navy Aircraft and Ground Vehicles (ESTCP Project WP-0906)	All vehicles	Oxisilan AL-500 Zircobond 4200 Bonderite NT-1 Chemseal 100	John Kelly US Army Research Laboratory jkelley@arl.army.mil
Environmentally Friendly Anticorrosion Coating for High Strength Fasteners (SERDP Project WP-1617)	Fasteners, all systems	Zinc-rich multi-layer system, electrodeposition	Matt Scott PPG Industries (412) 492-5594

Applicability

All of the above efforts and technologies are applicable to LEAD weapon systems and processes. However, US ARL has qualified the Bonderite 7400 as a drop-in replacement for current DOD-P-15328 wash primers and is moving forward with additional testing and implementation.

Barriers

Technical

To date, most non-chromate processes have failed to satisfy relevant engineering requirements, such as the American Society for testing and Materials Standard Practice for Modified Salt Spray (Fog) Testing (G85.A4), galvanic assemblies, and beach exposure. However, Bonderite has proven to an acceptable drop-in replacement for DOD-P-15328 wash primers, so the technical challenges have been met.

Financial

None. As a drop-in replacement, there are no up-front capital costs associated with the alternative.

Acceptance

While Bonderite 7400 has been tested on several pieces of equipment at LEAD, there is still the possibility of non-acceptance by those weapon systems not part of the testing. This would require additional evaluation, increased cost, and increased time to implementation. Failure to coordinate with the Command, Research and Development Engineering Center, and Programs could result in no implementation or failure to transition the coating to other systems.

Logistics

Once Bonderite 7400 is qualified and accepted on weapon systems, the Technical Manuals, Depot Maintenance Work Request (DMWR), and drawings must still be changed to reflect cancellation of DOD-P-15328 and adoption of TT-C-490F.

3.1.2 *Alternative:* Rare-Earth and Other Metal Primers

Considerable research, development, testing and evaluation has focused on so-called rare earth primers, most containing Praseodymium Oxide (CAS # 12036-32-7) as an active ingredient. Praseodymium is a rare earth metal under the Lanthanide group. Lockheed-Martin applies the RE primer 44GN098 throughout the F-35 Joint Strike Fighter, while 02GN084 is used on a number of helicopter platforms. As part of this ongoing work, this non-chromate epoxy primer has been newly incorporated into the processing of F/A-18 aircraft. The new primer has two components and is being tested for the prevention of corrosion on aircraft. As of January 2015, only two aircraft have been primed. The Materials Laboratory is leading the experimental trial and will determine suitability for the use of this alternative for Navy aircraft.

Alternative coatings based on the use of rare earth metals. This group consists of yttrium and the 15 lanthanide elements (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium). Scandium is found in most rare earth element deposits and is sometimes classified as a rare earth element. The International Union of Pure and Applied Chemistry includes scandium in their rare earth element definition. The rare earth elements are all metals, and the group is often referred to as the "rare earth metals." These metals have many similar properties and that often causes them to be found together in geologic deposits. They are also referred to as

"rare earth oxides" because many of them are typically sold as oxide compounds."
http://geology.com/articles/rare-earth-elements/

Cerium is the most abundant of the rare earth metals and is mined in the United States. The major producers of Praseodymium are China, Russia, and Malaysia. Zirconium is also mined in the United States. The current permissible exposure limit for Zirconium compounds is 5 mg/m3. Tungsten and Molybdenum are not rare earth metals but are also important strategic metals in a market dominated by China. These metals along with Zirconium are often considered in the formulation of non-chromate conversion coating alternatives.

Related Efforts

Table 13 is a list of efforts related to the research, development, testing, and evaluation of rare-earth primers. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 13. Rare Earth and Other Metal Primers Related Efforts

Effort	Systems	Technology	Points of Contact
Non-Chromate/No-VOC Coating System for DoD Applications (SERDP Project WP-1521)	All	16708TEP/16709CEH EWDY048A/B EWAE118A/B 44GN098 02GN083 02GN084 65GN015	John La Scala US Army Research Laboratory jlascala@arl.army.mil 410-306-0687
Corrosion and Adhesion Testing of MIL-PRF-23377 Class N and MIL-P-53022 Primers (with and without a Zinc Rich Tie-coat) on Steel Substrates	All aircraft	16708TPE/16709CEH 02GN083 02GN084	Steven Brown NAVAIR Patuxent River Aircraft Division Steven.a.brown@navy.mil 301-342-8101
Surface Treatment Implementation – Deft Non-Chrome Primer on F-35	F-35 JSF	44GN098	Scott Fetter Lockheed Martin Scott.d.fetter@lmco.com
Chromium Alternatives Qualification Testing		44GN098 02GN083 02GN084 02GN098	Concurrent Technologies Corporation (CTC) 814-266-2874
Surface Treatment Implementation – AH-64 Deft Non-Chrome Primer	AH-64 Apache	44GN098	Ed Babcock Boeing Mesa Ed.a.babcock@boeing.com 480-891-3000
C-130J Phase I – ACFL07PV02	C-130	44GN098 02GN084 16708TEP/16709CEH Aerodur 2100 Mg-rich primer (Akzo Nobel)	Gene McKinley Wright Patterson AFB Gene.mckinley@wpafb.af.mil 937-255-3596

Authorization, implementation, 02GN084 non-Chrome Primer	UH-60 CH-47 AH-64 Apache OH-60 UH-1 H-60 Blackhawk	02GN084	

Applicability

LEAD uses primers (TT-P-1757 or MIL-PRF-23377) for wet-install of fasteners on the Hellfire, Longbow, and Javelin launch assemblies. Most of the above alternative technologies are applicable to this application, though some testing might be necessary to ensure the replacement meets corrosion standards. Because the only use of chromated primers at LEAD is for wet install, Mg-rich would not be recommended because of possible galvanic interactions with students and the adhesion. This leaves the rare each primers as the best options.

Barriers

Technical

To date, most non-chromate processes have failed to satisfy relevant engineering requirements, such as the American Society for testing and Materials Standard Practice for Modified Salt Spray (Fog) Testing (G85.A4), galvanic assemblies, and beach exposure.

Financial

Capital costs associated with alternative non-chromated primers should be minimal as most are implemented as drop-in replacements. There may be cost impacts based on chemical prices, but these should be offset by the decrease in medical monitoring, training, protective equipment and engineering controls necessary to meet OSHA "housekeeping requirements" which are some of the biggest costs and risks for the depots.

Acceptance

As these are drop-in replacement technologies, acceptance should not be an issue once it is confirmed that the alternatives meet corrosion and other standards.

Logistics

Once a non-chromated primer is qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings may still need to be changed to reflect adoption of the new technology.

3.1.3 *Alternative:* Magnesium (metal) Rich Primers

Another approach to the development of non-chromated primers employs a sacrificial metal-rich primer in the overall protection scheme, like the use of zinc-rich coatings for steel substrates to provide galvanic corrosion protection. The metal in the coating of a galvanic protection system acts as an anode, which oxidizes preferentially to the substrate. The substrate acts as a cathode, and is protected from corrosion at the point of sacrifice of the anodic metal in the coating. Magnesium is more anodic than aluminum and its alloys, giving it the ability to protect aluminum substrates. High loading of Mg particles in the primer coating ensure more contact between each particle and with the substrate. This electrical contact of metal particles is a key requirement in the corrosion protection mechanism. Improvements to Mg-rich primers have increased their overall corrosion performance, but these formulations have not shown to be equivalent to current hexavalent chromium alternatives.

Related Efforts

Table 14 is a list of efforts related to the research, development, testing, and evaluation of metal-rich primers. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 14. Metal Rich Primers Related Efforts

Effort	Systems	Technology	Points of Contact
Non-Chromate/No-VOC Coating System for DoD Applications (SERDP Project WP-1521)	All	16708TEP/16709CEH EWDY048A/B EWAE118A/B	John La Scala US Army Research Laboratory jlascala@arl.army.mil 410-306-0687
Corrosion and Adhesion Testing of MIL-PRF-23377 Class N and MIL-P-53022 Primers (with and without a Zinc Rich Tie-coat) on Steel Substrates	All aircraft	16708TPE/16709CEH	Steven Brown NAVAIR Patuxent River Aircraft Division Steven.a.brown@navy.mil 301-342-8101
C-130J Phase I – ACFL07PV02	C-130	16708TEP/16709CEH Aerodur 2100 Mg-rich primer (Akzo Nobel)	Gene McKinley Wright Patterson AFB Gene.mckinley@wpafb.af.mil 937-255-3596
Naval Air Systems Command Implementation Plan for Non-Chromated Paint Primer	All aircraft	EWAE118A/B 10PW22-2	Jack Benfer NAVAIR Jacksonville, FL 32212 john.benfer@navy.mil Tel: (904) 790-6405
KC-135 Non-Chromate Primer Operational Test and Evaluation Initial Inspection for KC-135 Aircraft 59-1472	KC-135, F-15, C-17, C-130, F-18	EWAE118A/B 10PW22-2	Larry Triplett The Boeing Company 314-232-2882
Improved Metal-Rich Primers for Corrosion Protection	All aircraft All helicopters	Aerodur 2100 Mg rich primer (Akzo Nobel)	Craig Price NAVAIR Patuxent River 301-342-8050
Observations on the Testing of Mg-rich Primers for Total Chromate-free Corrosion Protection of Aerospace Alloys	All aircraft All helicopters	Aerodur 2100 Mg rich primer (Akzo Nobel)	Gordon Bierwagen North Dakota State University Gorden.bierwagen@ndsu.edu 701-231-8294
Battelle Magnesium Rich Primer Project – ACFL07PV59	All aircraft	Aerodur 2100 Mg rich primer (Akzo Nobel)	Thomas Lorman Wright Patterson AFB Thomas.lorman@wpaft.af.mil 937-255-3530
Demonstration of a Nanomaterial Modified Primer for Use in Corrosion Inhibiting Systems		Primer Zn-rich	Susan Drozdz US Army Engineer Research and Development Center Susan.A.Drozdz@usace.army.mil (217) 373-4467

Magnesium Rich Primers and Related Development for the Replacement of Chromium Containing Aerospace Primers	All aircraft All helicopters	Aerodur 2100 Mg rich primer (Akzo Nobel)	Akzo Nobel Aerospace Coatings (847) 623-4200

Applicability

LEAD uses primers (TT-P-1757 or MIL-PRF-23377) for wet-install of fasteners on the Hellfire, Longbow, and Javelin launch assemblies. As mentioned previously, we would not recommend the use of Mg-rich primers for wet-install of fasteners without significant testing because of the possibility that galvanic dissolution of the magnesium filler could be expected to increase the porosity of the primer, permitting water ingress.

Barriers

Technical

To date, most non-chromate processes have failed to satisfy relevant engineering requirements, such as the American Society for testing and Materials Standard Practice for Modified Salt Spray (Fog) Testing (G85.A4), galvanic assemblies, and beach exposure.

Financial

Capital costs associated with alternative non-chromated primers should be minimal as most are implemented as drop-in replacements. There may be cost impacts based on chemical prices, but these should be offset by the decrease in medical monitoring, training, and protective equipment.

Acceptance

As these are drop-in replacement technologies, acceptance should not be an issue once it is confirmed that the alternatives meet corrosion and other standards.

Logistics

Once a non-chromated primer is qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings may still need to be changed to reflect adoption of the new technology.

3.2 Chromate Conversion Coatings – Process Improvements and Alternatives

Chromate conversion coatings are unique in the way they work, in that they react chemically with the surface to produce a converted layer of substrate. When wet, the chromate dissolves in water and precipitates out at corrosion locations. Conversion coatings are based on Cr^{6+}, while passivation coatings may be based on either Cr^{6+}, Cr^{3+} or other non-chrome chemistries.

Unlike chromates, non-chromate passivates are not hydrated, which allows them to act as an electrically insulating film and offers greater stability at higher temperatures. Electrical stability becomes an issue for applications calling for aluminum enclosures for electronics and aluminum electrical connectors. If chromates are heated above 212°F (100°C) they dehydrate and become ineffective. Most of the chromate-free passivates can be heated at least to 375°F (190°C), which is the temperature required to bake the hydrogen out of steels. If a steel product needs to be heated, chemical conversion has to be applied after the heat treat, which often requires that the surface be re-activated. Chromate-free passivates avoid this problem by making it possible to heat treat after passivation.

While there may be products that perform exceptionally well for specific materials and applications, overall the chromate-free passivates are not as effective as chromates for inhibiting corrosion, or as robust, requiring more care in processing and application conditions. The probability of corrosion failure is increased unless the processing is done with strict specifications and process controls.

3.2.1 Process Improvements

Oakite Chromicoat L25 and Alodine 600 solutions are normally unheated but can be operated between 70F and 110F. The process cycle time and coating thickness are dependent upon both concentration and temperature and the process can be optimized to run at a higher temperature and lower concentration to reduce drag out and facilitate evaporative recovery of rinse water. As much as 75% drag out reduction is possible with best management practices to control drag out. Drag out recovery efficiency is dependent upon the evaporation to drag out ratio. The tank evaporation rate at these temperatures is relatively small, however the concentration of the solution is also low, and upwards of 85% drag out recovery is possible with two countercurrent recovery rinses followed by a third open rinse discharging to wastewater treatment.

Chromate conversion processes (and all other conversion coatings) require some bleed as substrate (Al, Zn, Ni, Cd) metal builds up as a contaminant in the solution. Drag out is a natural bleed and the bleed rate is inherently a function of workload. Effective solution control and waste reduction can be optimized by calibrating drag out reduction and recovery to maintain solution contaminants within a specified range.

3.2.2 *Alternative:* Trivalent Chromium Process (TCP) Conversion Coatings

Non-chromate passivates do not function in the same way as chromate conversion. The most successful passivates are based on trivalent chrome (Cr_2O_3) with a passivate species. For aluminum, one of the most successful passivates is a hexafluorozirconate (i.e. based on Zr), which was developed as a trivalent chromium process (TCP) by the Naval Air Systems Command (NAVAIR). This is the basis for Alodine 5700/5900, Aluminescent, MacDermid TCP, METALAST, SurTec and other coatings. There are also non-chrome passivates based on titanates, vanadates, permanganates and other inhibitors. NASA has implemented a non-chromate coating system for use on aluminum alloy Solid Rocket Roosters (SRB) that recommends Alodine 5700 for implementation as a pretreatment alternative.

Related Efforts

Table 15 is a list of efforts related to the research, development, testing, and evaluation of tri-chrome conversion coatings. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 15. TCP Related Efforts

Effort	Systems	Technology	Points of Contact
Non-Chromate Aluminum Pretreatments	Solid rocket booster F-16 LCAC S-3 F-18 C-46 AAAV BFV MLRS Commercial aircraft	PreKote Alodine 5200/5700 AC-130/131 (Boegel) TCP (NAVAIR)	Craig Matzdorf NAVAIR Patuxent River Aircraft Division craig.matzdorf@navy.mil (301) 342-89372
Validation of Non-Chromate Aluminum Pretreatments	All aircraft All helicopters	PreKote Alodine 5200/5700 AC-130/131 (Boegel) Aklimate Chemidize 727ND Oxsilan AL-500 Sanchem 7000 Alodine 1200S TCP (NAVAIR)	Craig Matzdorf NAVAIR Patuxent River Aircraft Division craig.matzdorf@navy.mil (301) 342-9372
Evaluation of Modified Zirconium/Trivalent Chromium Conversion Coatings by Accelerated Corrosion and Electrochemical Techniques	All aircraft All helicopters	Conversion: Hexavalent Cr Conversion: TCP-license (Trivalent Chrome Pretreat) Conversion: Adhesion promoter TCP (NAVAIR)	Craig Matzdorf NAVAIR Patuxent River Aircraft Division craig.matzdorf@navy.mil (301) 342-9372
Qualification of Trivalent Chromate as a Hexavalent Chromate Alternative for Propellant and Cartridge Actuated Devices	Propellant and Cartridge Actuated Devices	TCP (NAVAIR)	Harry L. Archer Naval Surface Warfare Center Indian Head, MD (301) 744-4284
Non-Chromate/No VOC Coating System for DoD Applications (ESTCP Project WP-1521)	All	Alodine 5200/5700 Alodine 1200S TCP (NAVAIR)	John J. La Scala US Army Research Laboratory jlascala@arl.army.mil (410) 306-0687
NDCEE Demonstration Projects: Task No. 000-01 Subtask 4 - Nonchromated Conversion Coatings for Weapon Systems Rework and Repair	All aircraft All vehicles	Alodine 5200/5700 AC-130/131 (Boegel) Chemidize 727ND Oxsilan AL-500 TCP (NAVAIR)	US Army Research Laboratory Fred Lafferman Fred.lafferman.civ@mail.mil 410-306-1520

Effort	Systems	Technology	Points of Contact
Data for Test 3.1 Neutral Salt Fog Exposure to Unpainted, Pretreated Coupons	Solid rocket booster F-16 LCAC S-3 F-18 C-46 AAAV	Alodine 5200/5700 Sanchem 7000 Alodine 1200S TCP (NAVAIR)	Brian Placzankis US Army Research Laboratory, Aberdeen Proving Ground, MD plaz@arl.army.mil (410) 306-0841
Nonchromate Aluminum Pretreatments Project Number: S-00-OC-016	Solid rocket booster F-16 LCAC S-3 F-18 C-46 AAAV C-130 H-46 Missiles	PreKote Alodine 5200/5700 AC-130/131 (Boegel) Aklimate Chemidize 727ND Oxsilan AL-500 Sanchem 7000 Alodine 1200S TCP (NAVAIR)	NAVAIR Patuxent River Aircraft Division 1-800-787-9804
TCP Application and Field Validation on AAAV P1	AAAV	TCP (NAVAIR)	Craig Matzdorf NAVAIR Patuxent River Aircraft Division craig.matzdorf@navy.mil (301) 342-9372
Hexavalent Chromium (Cr^{6+}) Reduction at U.S. Air Force Plant 44 in Tucson, Arizona		TCP (NAVAIR)	Paul Fecsik Raytheon Missile Systems (520) 794-3000
Accelerated Corrosion and Adhesion Assessments of CARC Prepared Aluminum Alloy 2139-T* Using Three Various Pretreatment Methods and Two Different Primer Coatings	M113 EFV	Alodine 5200/5700 TCP (NAVAIR) Metalast TCP-HF	Brian Placzankis Elizabeth A. Charleton Amy L. Fowler Army Research Lab Aberdeen Proving Ground plaz@arl.army.mil (410) 306-0841
Implementation Summary: Metalast TCP-HF, Red River Army Depot	BFV MLRS M800 M900 HEMTT HMMWV	Metalast TCP-HF	Mike Starks Red River Army Depot mike.starks@redriver-ex.army.mil (903) 334-3103
METALAST TCP-HF® - Hexavalent Free Trivalent Chromium Post-treatment Compositions and Processes	All aircraft All vehicles	Metalast TCP-HF	David Semas METALAST International Inc (775) 782-8324
Non-Chromated Post Treatments (trivalent Cr post treatment or TCP)		TCP (NAVAIR)	Ken Kaempffe NAVFAC EXWC, EV NESDI PM ken.kaempffe@navy.mil 805-982-4893

Effort	Systems	Technology	Points of Contact
Scientific Understanding of Non-Chromated Corrosion Inhibitors Function (SERDP Project WP-1620)	All aircraft All helicopters All ships All vehicles	Conversion: Trivalent Cr - not TCP	Gerald Frankel Ohio State University frankel.10@osu.edu (614) 688-4128
Determination of Hexavalent Chromium in NAVAIR Trivalent Chromium Process (TCP) Coatings and Process Solutions	All aircraft All helicopters	Alodine T5900 Alodine 1200S Surtec 650 - ChromitAl TCP	Steven L. Suib University of Connecticut steven.suib@uconn.edu (860) 486-2797
Characterization of NAVAIR Trivalent Chromium Process (TCP) Coatings and Solutions	All aircraft All helicopters	Alodine T5900 Alodine 1200S Surtec 650 - ChromitAl TCP	Aparna Lyer University of Connecticut
Demonstration and Validation of Trivalent Aluminum Pretreatment on U.S. Navy S-3 Aircraft	S-3	TCP (NAVAIR)	Craig Matzdorf NAVAIR Patuxent River Aircraft Division craig.matzdorf@navy.mil (301) 342-9372
Non-Chromate Aluminum Pretreatments – (ESTCP Project WP-200025)	All aircraft All helicopters All vehicles C-130 CH-46 CH-47 F-16 F-18 S-3 BFV EFV LCAC Solid rocket booster	PreKote Alodine 5200/5700 AC-130/131 (Boegel) Aklimate Chemidize 727ND Oxsilan AL-500 Sanchem 7000 Alodine 1200S	NAVAIR Patuxent River Aircraft Division 1-800-787-9804
ASTM B 117 Screening of Nonchromate Conversion Coatings on Aluminum Alloys 2024, 2219, 5083, and 7075 Using DOD Paint Systems	All aircraft All helicopters All ships All vehicles	PreKote Alodine 5200/5700 AC-130/131 (Boegel) Aklimate Chemidize 727ND Oxsilan AL-500 Sanchem 7000 Alodine 1200S	Brian Placzankis US Army Research Laboratory plaz@arl.army.mil (410) 306-0841
Enhanced trivalent Chromium Pretreatment for Improved Coloration and Corrosion Performance of Aluminum Substrates (NESDI Project 514)	All aircraft	Enhanced TCP	Ken Kaempffe NAVFAC EXWC, EV NESDI PM ken.kaempffe@navy.mil 805-982-4893

Applicability

Given the wide range of testing, evaluation, demonstration, and validation on an array of weapon systems, TCP should be applicable to LEAD processes and systems. Some testing will remain on specific components and/or substrates, but most will have already been tested.

Barriers

Technical

Widespread use of trivalent chromium processes have been hampered due to insufficient color change following conversion coating with trivalent chromium. This visual change in color is preferred to ensure process quality control. An enhanced trivalent chromium process (eTCP) is being developed with the addition of a color additive to the approved TCP formulation.[7] In general, the non-chrome systems do not perform as well as the trichrome.

Financial

Capital costs associated with alternative chromate conversion coatings should be minimal as most are implemented as drop-in replacements. There may be cost impacts based on chemical prices, but these should be offset by the decrease in medical monitoring, training, and protective equipment. Another major cost reduction is that most trivalent treatments are done at room temperature rather than high-temperature. A cost analysis will indicated that the cost of running a bath 24/7 at a high temperature is very expensive, and a room temperature bath far outweighs the additional cost of the trivalent chemicals. This was demonstrated for trivalent sealant for phosphate coatings in an ESTCP project.

Acceptance

The Toxic Metals Reduction (TMR) Program is currently testing and evaluating several potential alternatives to chromated conversion coatings and LEAD is slated as the platform for ground equipment. Given this effort and the Technology Transfer Agreements (TTA) from AMCOM, an alternative that meets the system requirements should be readily accepted.

Logistics

Once a non-chrome conversion coating is qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings may still need to be changed to reflect adoption of the new technology.

3.2.3 *Alternative:* Boegel/Sol-Gel

The adhesion promoters represent an entirely different way of protecting the surface of aluminum. The earlier formulations of sol-gels do not contain any inhibitors, but instead work by ensuring excellent adhesion between the surface and the overlying primer, preventing water from entering and disbonding the primer from the metal surface. Boeing developed the original silane-based sol-gel (Boegel), which is now sold by 3M under the trade name AC 131. This product was originally designed as a cure for “rivet rash”, which is a condition often seen on passenger aircraft where the paint comes off the rivets even though it adheres well to the aluminum skin (you will often see this as you board a plane if you look along the fuselage). It is used on all new Boeing commercial aircraft fuselages. There are various versions of these sol-gel coatings

[7] “Enhanced trivalent Chromium Pretreatment for Improved Coloration and Corrosion Performance of Aluminum Substrates”. NESDI Project 514.

available in the market, and they are a good way to ensure paint adhesion over surfaces that contain different materials. A new sol-gel chemistry containing zirconium inhibitors is now available from Socomore in France, and has been approved by Airbus.

Related Efforts

Table 16 is a list of efforts related to the research, development, testing, and evaluation of Beogel/ Sol-Gel type conversion coatings. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 16. Beogel/Sol-Gel Related Efforts

Effort	Systems	Technology	Points of Contact
Non-Chromate Aluminum Pretreatments	Solid rocket booster F-16 LCAC S-3 F-18 C-46 AAAV BFV MLRS Commercial aircraft	PreKote Alodine 5200/5700 AC-130/131 (Boegel) TCP (NAVAIR)	NAVAIR Patuxent River Aircraft Division 1-800-787-9804
Validation of Non-Chromate Aluminum Pretreatments	All aircraft All helicopters	PreKote Alodine 5200/5700 AC-130/131 (Boegel) Aklimate Chemidize 727ND Oxsilan AL-500 Sanchem 7000 Alodine 1200S TCP (NAVAIR)	Craig Matzdorf NAVAIR Patuxent River Aircraft Division craig.matzdorf@navy.mil (301) 342-9372
NDCEE Demonstration Projects: Task No. 000-01 Subtask 4 - Nonchromated Conversion Coatings for Weapon Systems Rework and Repair	All aircraft All vehicles	Alodine 5200/5700 AC-130/131 (Boegel) Chemidize 727ND Oxsilan AL-500 TCP (NAVAIR)	US Army Research Laboratory Fred Lafferman Fred.lafferman.civ@mail.mil 410-306-1520
Nonchromate Aluminum Pretreatments Project Number: S-00-OC-016	Solid rocket booster F-16 LCAC S-3 F-18 C-46 AAAV C-130 H-46	PreKote Alodine 5200/5700 AC-130/131 (Boegel) Aklimate Chemidize 727ND Oxsilan AL-500 Sanchem 7000 Alodine 1200S TCP (NAVAIR)	NAVAIR Patuxent River Aircraft Division 1-800-787-9804

Effort	Systems	Technology	Points of Contact
	Missiles		
Non-Chromate Aluminum Pretreatments – (ESTCP Project WP-200025)	All aircraft All helicopters All vehicles C-130 CH-46 CH-47 F-16 F-18 S-3 BFV EFV LCAC Solid rocket booster	PreKote Alodine 5200/5700 AC-130/131 (Boegel) Aklimate Chemidize 727ND Oxsilan AL-500 Sanchem 7000 Alodine 1200S	NAVAIR Patuxent River Aircraft Division 1-800-787-9804
ASTM B 117 Screening of Nonchromate Conversion Coatings on Aluminum Alloys 2024, 2219, 5083, and 7075 Using DOD Paint Systems	All aircraft All helicopters All ships All vehicles	PreKote Alodine 5200/5700 AC-130/131 (Boegel) Aklimate Chemidize 727ND Oxsilan AL-500 Sanchem 7000 Alodine 1200S	Brian Placzankis US Army Research Laboratory plaz@arl.army.mil (410) 306-0841
Commercial Aircraft non-Cr Finish	Boeing 737 Boeing 747 Boeing 767 Boeing 777	AC-130/131 (Boegel)	Joe Osborne Boeing Commercial Aircraft joseph.h.osborne@boeing.com (206) 544-4651
Non-Chromated Coating Systems for Corrosion Protection of Aircraft Aluminum Alloys	All aircraft All helicopters	AC-130/131 (Boegel)	N. Voevodin University of Dayton Research Institute 937-229-2113
Surface Treatment Implementation	Commercial Aircraft F-22 B-2 AH-66 C-46 CH-47 F-18 Delta-IV Rocket B-1 CH-64 CH-47	AC-130/131 (Boegel)	Joe Osborne The Boeing Company Joseph.h.osbourne@boeing.com 562-797-2020

Effort	Systems	Technology	Points of Contact
	C-5 V-22 F-16 C-130		
Dissimilar Metals Corrosion Testing of Non-Chrome Coating Systems	All aircraft	PreKote Alodine 5200/5700 AC-130/131 (Boegel) XP417	John D. Patterson The Boeing Company 562-797-2020

Applicability

Given the wide range of testing, evaluation, demonstration, and validation on an array of weapon systems, Boegel/Sol-Gel/3M AC 131 alternatives should be applicable to LEAD processes and systems. Some testing will remain on specific components and/or substrates, but most will have already been tested.

Barriers

Technical

Technical challenges still remain with the Boegel/Sol-Gel alternatives. They are primarily adhesion promoters and, therefore, do not offer the same level of corrosion protection as hexavalent chromium conversion coatings or even trichrome conversion coatings. They are not applicable to non-painted surfaces. However, on painted surfaces, the adhesion promoters help ensure a bond with the total system to inhibit corrosion. Significant testing remains to determine how effective Boegel/Sol-Gel alternatives are on LEAD applications.

Financial

Capital costs associated with alternative chromate conversion coatings should be minimal as most are implemented as drop-in replacements. There may be cost impacts based on chemical prices, but these should be offset by the decrease in medical monitoring, training, and protective equipment.

Acceptance

The Toxic Metals Reduction (TMR) Program is currently testing and evaluating several potential alternatives to chromated conversion coatings and LEAD is slated as the platform for ground equipment. Given this effort and the Technology Transfer Agreements (TTA) from AMCOM, an alternative that meets the system requirements should be readily accepted.

Logistics

Once a non-chrome conversion coating is qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings may still need to be changed to reflect adoption of the new technology.

noblis

3.2.4 *Alternative:* PreKote

PreKote is an entirely different product, but acts similar to sol-gels to improve primer adhesion to metal surfaces and does not contain corrosion inhibitors. Widely used by the US Air Force on military aircraft, F-16, T-37, T-38, and T-1 SPOs have approved the use of PreKote, and HQ Air Education and Training Command (AETC) has mandated its use on all AETC aircraft for which it is approved.

Related Efforts

Table 17 is a list of efforts related to the research, development, testing, and evaluation of PreKote. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 17. PreKote Related Efforts

Effort	Systems	Technology	Points of Contact
Non-Chromate Aluminum Pretreatments	Solid rocket booster F-16 LCAC S-3 F-18 C-46 AAAV BFV MLRS Commercial aircraft	PreKote Alodine 5200/5700 AC-130/131 (Boegel) TCP (NAVAIR)	NAVAIR Patuxent River Aircraft Division 1-800-787-9804
Validation of Non-Chromate Aluminum Pretreatments	All aircraft All helicopters	PreKote Alodine 5200/5700 AC-130/131 (Boegel) Aklimate Chemidize 727ND Oxsilan AL-500 Sanchem 7000 Alodine 1200S TCP (NAVAIR)	Craig Matzdorf NAVAIR Patuxent River Aircraft Division craig.matzdorf@navy.mil (301) 342-9372
Nonchromate Aluminum Pretreatments Project Number: S-00-OC-016	Solid rocket booster F-16 LCAC S-3 F-18 C-46 AAAV C-130 H-46 Missiles	PreKote Alodine 5200/5700 AC-130/131 (Boegel) Aklimate Chemidize 727ND Oxsilan AL-500 Sanchem 7000 Alodine 1200S TCP (NAVAIR)	NAVAIR Patuxent River Aircraft Division 1-800-787-9804

Effort	Systems	Technology	Points of Contact
Non-Chromate Aluminum Pretreatments – (ESTCP Project WP-200025)	All aircraft All helicopters All vehicles C-130 CH-46 CH-47 F-16 F-18 S-3 BFV EFV LCAC Solid rocket booster	PreKote Alodine 5200/5700 AC-130/131 (Boegel) Aklimate Chemidize 727ND Oxsilan AL-500 Sanchem 7000 Alodine 1200S	NAVAIR Patuxent River Aircraft Division 1-800-787-9804
ASTM B 117 Screening of Nonchromate Conversion Coatings on Aluminum Alloys 2024, 2219, 5083, and 7075 Using DOD Paint Systems	All aircraft All helicopters All ships All vehicles	PreKote Alodine 5200/5700 AC-130/131 (Boegel) Aklimate Chemidize 727ND Oxsilan AL-500 Sanchem 7000 Alodine 1200S	Brian Placzankis US Army Research Laboratory plaz@arl.army.mil (410) 306-0841
Surface Treatment Implementation – PreKote on USAF Training Aircraft	T-1 T-37 T-38 T-6 F-16	PreKote	Brett Seuferer Air Education and Training Command Brett.seuferer@randolph.af.mil 210-652-9748
Surface Treatment Implementation – PreKote on Apache	AH-64 Apache	PreKote	Ramesh Patel The Boeing Company Ramesh.j.patel@boeing.com 480-891-2876
Surface Treatment Implementation – PreKote on A-10, F-16, C-130	A-10 F-16 C-130	PreKote	
Surface Treatment Implementation – PreKote on C-5	C-5 C-130	PreKote	
Surface Treatment Implementation – PreKote on B-1	B-1 C-130	PreKote	Brian Koehl Tinker AFB Brian.koehl@tinker.af.mil
PreKote Implementation – Dassault Aviation	Falcon 7X Falcon 900LX Falcon 900EX Falcon 900DX Falcon 2000LX Falcon 2000DX	PreKote	Pierre Michelin Dassault Aviation Pierre.michelin@dassaultaviation.com 302-322-7000

Applicability

Given the wide range of testing, evaluation, demonstration, and validation on an array of weapon systems, PreKote should be applicable to LEAD processes and systems. Some testing will remain on specific components and/or substrates, but most will have already been tested.

Barriers

Technical

Technical challenges still remain with PreKote. It is primarily an adhesion promoter and, therefore, does not offer the same level of corrosion protection as hexavalent chromium conversion coatings or even trichrome conversion coatings. Multiple laboratory tests, by various organizations, indicate PreKote is one of the best performing non-chromated surface treatments, but its corrosion protection is still less than that of chromated Alodine 1200S. It is not applicable to non-painted surfaces. However, on painted surfaces, the adhesion promoter helps ensure a bond with the total system to inhibit corrosion. Significant testing remains to determine how effective PreKote is in LEAD applications.

Financial

Capital costs associated with alternative chromate conversion coatings should be minimal as most are implemented as drop-in replacements. There may be cost impacts based on chemical prices, but these should be offset by the decrease in medical monitoring, training, and protective equipment.

Acceptance

The Toxic Metals Reduction (TMR) Program is currently testing and evaluating several potential alternatives to chromated conversion coatings and LEAD is slated as the platform for ground equipment. Given this effort and the Technology Transfer Agreements (TTA) from AMCOM, an alternative that meets the system requirements should be readily accepted.

Logistics

Once a non-chrome conversion coating is qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings may still need to be changed to reflect adoption of the new technology.

3.3 Cadmium Brush Plating – Process Improvements and Alternatives

Zinc-nickel brush plating is the alternative to cadmium brush plating and there are COTs products available. Two products include one developed by Dalistick® and one by SIFCO. Both of these are known as no-bake ZnNi applications. Both products including solutions and plating equipment do work; reportedly the advantage of the Dalistick is better process control and recirculated electrolyte to prevent dripping and contamination of adjacent areas.

In the following paragraphs, the technology is described in greater detail, the applicability to LEAD weapon systems is addressed, and known barriers to implementation are documented.

3.3.1 Process Improvements

Brush plating specifications typically limit the total surface area and/or amp-hrs plated per liter of solution. Cadmium waste can be minimized by monitoring amp-hrs and fully utilizing brush plating solution within the specification. This requires segregation of solution collection and rinsing to avoid dilution and premature disposal of unspent cadmium plating solution.

3.3.2 *Alternative:* Zn-Ni Brush Plating

Ongoing efforts (ESTCP project WP-201412) [8]focus on elimination of Cd for brush plating repair operations, and reduction of solid waste associated with adsorbents used to contain solution leakage attributed with traditional brush plating repair processes. The technical objectives are to:

1. Demonstrate the commercial off-the-shelf (COTS) brush plating tool Dalistick® Station for selective plating, ensuring its safety and cost effectiveness for Department of Defense (DoD) maintenance, repair, and overhaul operations.
2. Test and evaluate the COTS Zinidal Aero (code 11040) zinc-nickel (Zn-Ni) brush plated coating as a Cd replacement on high strength steels (HSS) for repair applications on weapon systems parts and components (landing gear, terminal assemblies, landing gear doors, bushings, etc.

These efforts evaluate the ability of a novel brush plating tool Dalistick® Station to plate the COTS product Zinidal Zn-Ni coating on HSS. The Dalistick® Station is a mobile electroplating system that enables selective electrochemical treatments without generating any leakage of electrolyte during the plating process. The Dalistick® Station recovers residual brush plating solution and recycles it for reuse in a closed-loop process at the point of contact with the part. It is designed to perform plating and surface finishing operations on steels or light alloys on site, at depots, or in the field. It performs these treatments on curved, horizontal, and/or vertical surfaces and edges without any leakage of electrolyte and minimal generation of waste (spent solution and pads). The Zinidal coating is a promising candidate to replace Cd plating. The Zinidal Aero Zn-Ni solution deposits a coating with 10-16 weight% Ni and 84-90 weight% Zn at varying thicknesses. The coating provides sacrificial corrosion protection to steels, and the process does not require the hydrogen embrittlement relief baking when plated on HSS.

Related Efforts

Table 18 is a list of efforts related to the research, development, testing, and evaluation of Dalistick® and Zinidal Zn-Ni as alternatives to Cd brush plating. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

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[8] https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Surface-Engineering-and-Structural-Materials/Coatings/WP-201412

Table 18. Zn-NI Related Efforts

Effort	Systems	Technology	Points of Contact
Cadmium-Free Alternatives for Brush Plating Repair Operations (WP201412)	High strength steel applications	Zinidal Zn-Ni using the Dalistick	Mr. Richard Slife Air Force Materiel Command Phone: 478-926-0209 Richard.slife@robins.af.mil
Cadmium Brush Plating Alternative on the Minuteman	Low strength steel applications on the Minuteman	Zinidal Zn-Ni using the Dalistick	Dr. Elizabeth Berman Air Force Research Laboratory

Applicability

Based on observation of the process and knowledge of the substrates, the Zinidal Zn-Ni solution applied with the Dalistick is an applicable technology that will not cause embrittlement in high strength steels.

Barriers

Technical

Brush plating with substituted alloys for cadmium is basically the same; however, attention must be paid to proper surface cleaning and activation. It is more critical to control this process to maintain proper performance of the brush plated alloys. Substrates will have to investigated, but should not pose any issues. Corrosion requirements and criticality of the components are not beyond what has already been tested, so the Zn-Ni solution should have no problem passing additional Army-requested testing.

Financial

Initial capital costs associated with the Dalistick station are approximately $160,000 not including spares, parts, or solutions so the equipment will require programming and planning in the budgeting process. Solution costs are decreasing and there is a drastic reduction in solid waste associated with the Dalistick station, so operating costs should not be a barrier. Reliability costs to determine maintenance costs are not yet available for use in DoD production environment.

Acceptance

Zinidal and the Dalistick station have not been tested on any of the systems maintained at LEAD, however, they have been evaluated against common substrates. Significant testing will still have to take place to qualify the technology on LEAD-maintained weapon systems.

Logistics

Once Zinidal Zn-Ni and the Dalistick station are qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings must still be changed to reflect adoption of the new technology.

3.4 Specialty Coatings - Alternatives

As described in section 2.1.4, specialty coatings are those process and material combinations that do not fit into any of the established process categories of chrome plating, cadmium brush plating, chromate conversion coating. LEAD uses two products that fall into the specialty coatings category - Cho-Shield-zinc chromate Electro-Magnetic Interference (EMI) shielding (Cr^{6+}) and a red silk screen epoxy ink (Cd).

3.4.1 *Alternative:* Non-Chrome Conductive EMI Coating Chemistries

Parker Chomerics, the makers of the chromated Cho Shield 2003, do make non-chromated version of the EMI shielding coating, but they are primarily for composite components and do not offer the corrosion protection of the chromated formulations. In addition, Acheson (Henkel), Lord Corporation, Creative Materials, Spraylat, Randolph, and more offer EMI shielding coatings.

Related Efforts

None identified.

Applicability

Commercial off-the-shelf (COTS) alternatives should have applicability to LEAD operations, substrates, and weapon systems. However, there has been no documented testing of other products, so it is not known if they do or will meet EMI shielding and corrosion requirements.

Barriers

Technical

Alternative coatings must meet EMI shielding, corrosion, and coatings durability requirements of the weapon systems at LEAD. To date, it is not known that any of this testing has been accomplished. Passing the EMI shielding capabilities and the corrosion protection of the existing coating are the two major technical risks.

Financial

The alternative coatings are all spray-on applications that should require no capital costs to implement. Cost of the materials appear to be comparable.

Acceptance

The alternative COTS coatings have not been tested on LEAD components or weapon systems, therefore, each would have to be thoroughly evaluated against system requirements.

Logistics

Once a new COTS coating is qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings may still need to be changed to reflect adoption of the new technology.

3.4.2 *Alternative -* Non-Cadmium Epoxy Silk Screen Inks

M-2-N Red Silk Screen Ink is a permanent, epoxy-based, screen printing ink qualified to MIL-I-43553 and AA56032. At LEAD, the epoxy ink is applied to painted surfaces or sometimes on just alodined aluminum. The Silk Screen Red is a particular color that is formulated with cadmium sulfide and cadmium selenide in the pigment. It is a special request color for a specific need. There are COTS alternatives to the epoxy silk screen ink, but none that exactly match the special-request red color. To identify an alternative, either the color requirements will have to change or research will be necessary to determine how to duplicate the color without the use of cadmium compounds in the pigment.

Related Efforts

None identified.

Applicability

Since no potential alternatives have been identified, it is not possible to judge applicability.

Barriers

Technical

Color matching the existing coating without the use of cadmium compounds in the pigment appears to be the greatest technical challenge. The question remains is whether this precise color is really necessary since it does not appear to have any clear purpose that not be equally well served by another color.

Financial

The cost of other COTS epoxy silk screen inks appear to be comparable and no capital costs are necessary to implement.

Acceptance

Color match seems to be the greatest challenge and once an alternative is found that meets MIL-I-43553 and the color request, acceptance should not be an issue.

Logistics

As long as the alternative coating meets MIL-I-43553, the Technical Manuals, DMWR, and drawings should not need to be changed to reflect adoption of the new technology.

3.5 Chromate Sealers – Process Improvements and Alternatives

Some of the same technologies identified as alternatives to chromate conversion coatings are applicable for use as non-chrome sealers for anodized or phosphated components. This primarily pertains to the trivalent chromium technologies and some permanganate alternatives. The following paragraphs discuss ongoing research and related efforts, the applicability to LEAD processes, and the barriers to be overcome to implementation.

3.5.1 Process Improvements

Seal solutions are typically batch dumped on an arbitrary calendar schedule resulting in unsteady state process control and excessive waste generation. Seal solution waste streams can be reduced, and process control improved by controlling solution bleeds and feeds with automated conductivity and pH control of the solutions. Chemical feeds can be controlled by monitoring solution pH and bleeds controlled by monitoring solution conductivity.

Drag out is a natural bleed and the bleed rate is inherently a function of workload. Effective solution control and waste reduction can be optimized by calibrating drag out reduction and recovery to maintain solution contaminants within a specified range.

3.5.2 *Alternative:* TCP Anodize Sealers

The U.S. Navy has found their hydrofluorozirconate-inhibited trivalent passivate (TCP) process capable of sealing sulfuric acid anodizing layers. However the method has not yet been qualified for this application although it is moving that direction.

Related Efforts

Table 19 is a list of efforts related to the research, development, testing, and evaluation of TCP as an alternative to chromated sealers on anodizing or phosphate processes. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 19. TCP Anodize Sealers Related Efforts

Effort	Systems	Technology	Points of Contact
Non-chromate Sealers for Zinc Phosphate ESTCP Project WP-200906 [9]	Army and Navy Aircraft and Ground Vehicles:	Surtec 580 and Chemseal 100	Jack Kelley US Army Research Laboratory jkelley@arl.army.mil PH: 410-306-0837
Chromate Alternatives for Metal Treatment and Sealing	All	PreKote TCP (NAVAIR) Tagnite-8200 Iridite NCP	Keith Legg Rowan Technology Group klegg@rowantechnology.com (847) 680-9420
Trivalent Chromium Process (TCP) as a Sealer for MIL- -A-8625F Type II, IIB, And IC Anodic Coatings	All aircraft	TCP (NAVAIR) Metalast TCP-HF	Craig Matzdorf NAVAIR Patuxent River Aircraft Division craig.matzdorf@navy.mil (301) 342-9372

Applicability

Testing to date on TCP as a non-chromated sealer has been conducted on anodized components and phosphated parts.

Barriers

Technical

Further testing and evaluation would be necessary to determine if the technology can be used with these components and if it meets the corrosion, adhesion, and durability standards.

Financial

The TCP process is a drop-in replacement and would have little capital costs associated with its implementation. There are some differences in chemical costs, but these should be offset with

[9] Available from ESTCP at: https://serdp-estcp.org/content/download/35499/340712/file/WP-200906-FR%20Non-Chromate%20Sealers.pdf

reductions in medical monitoring and regulatory costs. There is some evidence that it will be significantly cheaper because it operates at room temperature.[10]

Acceptance

TCP has not been tested as a sealer for phosphated components on any of the weapon systems at LEAD. However, as a drop-in replacement, the technology should gain easy acceptance assuming it meets all of the corrosion, adhesion, and durability requirements.

Logistics

Once TCP is qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings must still be changed to reflect adoption of the new technology.

3.5.3 *Alternative:* Sol-Gel Sealers

Some European organizations are reformulating the sol-gels used for aluminum passivation as anodize sealers, but have also not yet been fully tested.

Related Efforts

Table 20 is a list of efforts related to the research, development, testing, and evaluation of TCP as an alternative to chromated sealers on anodizing or phosphate processes. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 20. Sol-Gel Sealers Related Efforts

Effort	Systems	Technology	Points of Contact
Chromate Alternatives for Metal Treatment and Sealing	All	PreKote TCP (NAVAIR) Tagnite-8200 Iridite NCP	Keith Legg Rowan Technology Group klegg@rowantechnology.com (847) 680-9420

Applicability

Testing to date on Boegel/Sol-Gel as a non-chromated sealer has been conducted on anodized components and not phosphated parts. Initial testing would have to focus on the applicability of Boegel/Sol-Gel as a sealer for components that have gone through the phosphate process.

Barriers

Technical

To date, Boegel/Sol-Gel has not been tested or evaluated as an alternative sealer to phosphated components. Testing and evaluation would be necessary to determine if the technology can be used with these components and if it meets the corrosion, adhesion, and durability standards.

[10] https://serdp-estcp.org/content/download/32459/317176/file/WP-200906-CP.pdf

Financial

Boegel/Sol-Gel is a drop-in replacement and would have little capital costs associated with its implementation. There are some differences in chemical costs, but these should be offset with reductions in medical monitoring, PPE, and regulatory costs.

Acceptance

Boegel/Sol-Gel has not been tested as a sealer for phosphated components on any of the weapon systems at LEAD. However, as a drop-in replacement, the technology should gain easy acceptance assuming it meets all of the corrosion, adhesion, and durability requirements.

Logistics

Once Boegel/Sol-Gel is qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings must still be changed to reflect adoption of the new technology.

3.5.4 *Alternative: Other*

Testing and evaluation at Ogden Air Logistics Complex (OO-ALC) identified and validated a COTS permanganate seal as an alternative to dichromate sealers on anodized landing gear components. Additional studies have been undertaken by the Defense Logistics Agency (DLA) and Oklahoma City Air Logistics Complex (OC-ALC) on anodized components. Performance on anodized surfaces have been exceptional, but no testing on phosphated components has been completed to date.

Related Efforts

Table 21 is a list of efforts related to the research, development, testing, and evaluation of permanganate sealers to chromated sealers on anodizing or phosphate processes. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 21. Other Related Efforts

Effort	Systems	Technology	Points of Contact
AFRL/OO-ALC	All aircraft	Permanganate	Elizabeth S. Berman, Ph.D. USAF AFMC AFRL/RXSC Pollution Prevention Group Materials & Manufacturing Directorate Air Force Research Laboratory (937) 656-5700 Elizabeth.Berman@wpafb.af.mil
OC-ALC/DLA project	All aircraft	Permanganate	Van Nguyen Air Force Sustainment Center (AFSC)/ENSP Thanhvan.nguyen.1@us.af.mil 405-739-9533

Applicability

Testing to date on permanganate sealers as a non-chromated sealer has been conducted on anodized components and not phosphated parts. Initial testing would have to focus on the applicability of Boegel/Sol-Gel as a sealer for components that have gone through the phosphate process.

Barriers

Technical

To date, permanganate sealers have not been tested or evaluated as an alternative sealer to phosphated components. Testing and evaluation would be necessary to determine if the technology can be used with these components and if it meets the corrosion, adhesion, and durability standards.

Financial

The COTS permanganate sealer is a drop-in replacement, assuming technical requirements are met, and would have little capital costs associated with its implementation. There are some differences in chemical costs, but these should be offset with reductions in medical monitoring, PPE, and regulatory costs.

Acceptance

The permanganate sealer has not been tested as a sealer for phosphated components on any of the weapon systems at LEAD. However, as a drop-in replacement, the technology should gain easy acceptance assuming it meets all of the corrosion, adhesion, and durability requirements.

Logistics

Once the COTS permanganate sealer is qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings must still be changed to reflect adoption of the new technology.

3.6 Coatings Removal – Process Improvements and Alternatives

Several alternatives have been identified with the potential to reduce the Cr^{6+} waste streams associated with both physical and chemical coatings removal. These include blast booth segregation, laser coatings removal, Flashjet coatings removal, and atmospheric plasma coatings removal. In the paragraphs that follow, there is a description of each alternative, the applicability of the technology to LEAD, and known barriers to implementation.

3.6.1 *Process Improvement:* Blast Booth Segregation

Blast booth segregation is applicable only to physical coatings removal using abrasive blast media. It involves the re-engineering of the blast booths and spent media collection systems to segregate parts and components that contain Cd or Cr^{6+} to only specific booths. By doing this, only media from the segregated booths is treated as hazardous waste. Waste media from non-Cd and Cr^{6+} booths can be disposed of as non-hazardous waste. This typically has the effect of dramatically reducing Cd and Cr^{6+} waste streams and reducing disposal costs.

Related Efforts

None identified.

Applicability

To determine the applicability of this methodology at LEAD, a comprehensive study of their abrasive blasting operations needs to be initiated and completed. This study will reveal which components can be segregated into which blast booths and how the spent media collection systems can be modified. The study should also identify potential waste reductions, additional transportation requirements (and costs), and potential cost saving associated with implementation.

Barriers

Technical

There are no significant technical challenges associated with this approach.

Financial

If the study of the abrasive blasting systems suggests that implementation will result in a positive impact, significant financial investments may be required to modify the spent abrasive blast media associated with the segregated booths.

Acceptance

The challenge associated with blast booth segregation is making sure that components are processed in the appropriate booths and that components containing Cd and Cr^{6+} are not processed in non-hazardous booths. Acceptance of the methodology and training is critical to ensure success of the implementation.

Logistics

No new technology will have been introduced, so there should be no necessary changes to technical documentation. However, shop practices will have to be documented, workers trained, and processes monitored to ensure segregation of blast booths is being practiced. This could include changing the flow of components through the repair shops and possibly a system for marking components known to have Cd or Cr^{6+} containing coatings on them.

3.6.2 *Alternative:* Laser Coatings Removal

Laser Coating Removal Systems (LCRS), both robotic and operator controlled, (WP0526) and Portable hand held Nd:YAG laser systems (PLCRS) (WP0027) have been identified as a technology with the potential to supplement or replace existing coating removal operations. Laser coatings removal has shown to be non-intrusive, non-kinetic energy process that can be applied to multiple substrates, including composites, glass, metal, and plastic. Coating materials absorb high-level energy at the surface resulting in the decomposition and removal of the coating. Incorporated waste extraction systems further enhance the practicality of laser coating removal.

Related Efforts

Table 22 is a list of efforts related to the research, development, testing, and evaluation of laser coating removal technologies. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 22. Laser Coating Removal Technology Related Efforts

Effort	Systems	Technology	Points of Contact
Robotic Laser Coating Removal System (ESTCP Project WP-0526)	KC-135	Lasers	Randel Bowman OC-ALC Oklahoma City randel.bowman@tinker.af.mil (405) 736-2736
Laser Coating Removal from Helicopter Blades, Phase II	All helicopters	Lasers	Lee Patch National Center for Manufacturing Sciences leep@ncms.org (734) 995-4930
NASA Portable Laser Coating Removal Systems Field Demonstrations and Testing	M1A1 Abrams Ground support equipment Facilities, buildings	Lasers	Matthew J. Rothgeb NASA TEERM Principal Center Matthew.J.Rothgeb@nasa.gov (321) 867-8476
Naval Application of Laser Ablation Paint Removal Technology	All ships	Lasers	Concurrent Technologies Corporation (CTC) (814) 269-2610
Integration of Laser Coating Removal For Helicopter Blade Refurbishment Phase I	All helicopters H-60 Blackhawk	Lasers	Edward Reutzel Applied Research Laboratory Penn State (814) 863-9891
Sealant Removal from an A-10 Thunderbolt Center Wing Fuel Tank Using a Portable Hand-Held Nd:YAG Laser System	All aircraft A-10	Lasers	
Portable Laser Coating Removal System (PLCRS) (ESTCP Project WP-200027)	All aircraft	Lasers	

Applicability

To determine the applicability any coatings removal technologies at LEAD, a comprehensive study of their abrasive blasting, hand sanding, and chemical stripping operations needs to be initiated and completed. This study will reveal which components and/or systems can be stripped with alternative technologies and which are most applicable.

Barriers

Technical

The most significant technical challenge associated with coatings removal at LEAD is meeting or approaching current stripping rates. Laser coating removal systems have been proven to remove the coating systems in use at LEAD, but may not match the rates at which abrasive blasting and chemical stripping accomplish it. In addition, laser coating removal systems are still being tested and operationalized for "production environment" including complete paint removal from a weapons system at a depot.

Financial

Large scale, especially robotic, laser coating removal systems are expensive, costing in the millions of dollars, so significant investment will be necessary if LEAD decided to implement. Hand-held systems are more affordable and may compare favorably with a reduction in chromated dust created by hand-sanding.

Acceptance

Laser coatings removal is a very different technology from anything currently in place at LEAD, therefore, it will take significant training to fully implement. Robotic systems require much less labor and acceptance issues could arise from that fact.

Logistics

The biggest logistical challenge to implementation is the level of training necessary to appropriate operate the laser systems. Even the hand-held systems require a significant level of training to use appropriately and safely. Once laser coatings removal is qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings must still be changed to reflect adoption of the new technology.

3.6.3 *Alternative:* FLASHJET®

The FLASHJET® system is a pulsed optical energy decoating process. It uses a combination of heat generated by a high-intensity pulsed xenon light and abrasion from a blast medium of solid carbon dioxide pellets. The paint is in effect shattered, and the residual particles are vacuumed and placed in a storage container.

The FLASHJET® process is a fully automated process that uses manipulator robotic assembly to strip the coatings from large and small components. The stripper head contains a xenon flashlamp that produces pulsed light energy to break the molecular bonds of the coating. Upon the breaking of the molecular bonds, the coating is changed into a near gaseous state through a process known as "ablation." Simultaneously, as the coating is being broken up and the ablation process is occurring, a dry ice pellet stream is sweeping away the residue while cooling and cleaning the surface. The paint that is removed is vacuumed away by an effluent capture system, which consists of high efficiency particulate air (HEPA) filters and activated charcoal. The effluent capture system separates the ash from the organic vapors by processing the ash through HEPA filters and the organic vapor through the activated charcoal. The only wastes produced by this process are the spent HEPA filters, which are tested for hazardous waste and disposed accordingly. The system has a stripping rate of approximately 270 square feet per hour, and the xenon lamp is guaranteed for 500,000 flashes, which is directly dependent on the power level at which the lamp is operated (typically, 1 million flashes are obtained.)

Related Efforts

Table 23 is a list of efforts related to the research, development, testing, and evaluation of FlashJet®. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 23. FlashJet® Technology Related Efforts

Effort	Systems	Technology	Points of Contact
Tri-Service Dem/Val of the Pulsed Optical Energy Decoating (FLASHJET) Process for Military Applications	CH-53 M113 SH-60	FLASHJET stripping	Eric Hangeland RDECOM, Aberdeen Proving Ground erik.b.hangeland.civ@mail.mil (410) 306-3184
Authorization, Doc-361: AMCOM ENGINEERING DIRECTIVE AED-A2049	All helicopters	FLASHJET stripping	Curtis Young Jr. AMCOM US Army Aviation and Missile Command
Specification, Doc-362: Requirements and procedures for stripping paint from metallic and nonmetallic substrates using the xenon/C02 process.	All helicopters	FLASHJET stripping	Boeing paul.e.rempes@boeing.com (314) 233-1541
Implementation, Doc-363: Authorization, implementation, FlashJet paint stripping	AH-64 Apache	FLASHJET stripping	Boeing paul.e.rempes@boeing.com (314) 233-1541
Technical Report, Doc-562: Aircraft Depainting Technology	All aircraft All helicopters	FLASHJET stripping	NAVAIR Patuxent River Aircraft Division 1-800-787-9804

Applicability

To determine the applicability any coatings removal technologies at LEAD, a comprehensive study of their abrasive blasting, hand sanding, and chemical stripping operations needs to be initiated and completed. This study will reveal which components and/or systems can be stripped with alternative technologies and which are most applicable.

Barriers

Technical

The most significant technical challenge associated with coatings removal at LEAD is meeting or approaching current stripping rates. FlashJet® coating removal systems have been proven to remove the coating systems in use at LEAD, but may not match the rates at which abrasive blasting and chemical stripping accomplish it.

Financial

Large scale FLashJet® systems are expensive, costing in the millions of dollars, so significant investment will be necessary if LEAD decided to implement.

Acceptance

FLashJet® coatings removal is a very different technology from anything currently in place at LEAD, therefore, it will take significant training to fully implement. Robotic systems require much less labor and acceptance issues could arise from that fact.

Logistics

The biggest logistical challenge to implementation is the level of training necessary to appropriate operate the FlashJet® systems. All of the systems require a significant level of training to use appropriately and safely. Once FlashJet® coatings removal is qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings must still be changed to reflect adoption of the new technology.

3.6.4 *Alternative:* Other

A number of coatings removal technologies have been investigated in the past years. One of the most promising to be developed recently is atmospheric plasma. Atmospheric plasmas system uses a low pressure compressed air source and electricity to produce a special form of atmospheric pressure, air plasma, which is highly chemically activated and oxidizes the organic components of paints and other coatings. The system has been used to remove two major coating systems commonly found on Navy ships: (1) freeboard paint typically used above the waterline, and (2) antifouling paint typically used below the waterline. Initial results of this research project are promising, but significant scale-up is required before this technology is ready to use commercially.

Related Efforts

Table 24 is a list of efforts related to the research, development, testing, and evaluation of atmospheric plasma depainting technologies. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 24. Other Depainting Technology Related Efforts

Effort	Systems	Technology	Points of Contact
Atmospheric Plasma Depainting (SERDP Project WP-1762)	All aircraft	Atmospheric Plasma	Jerome Cuomo North Carolina State University (919) 515-2011

Applicability

To determine the applicability any coatings removal technologies at LEAD, a comprehensive study of their abrasive blasting, hand sanding, and chemical stripping operations needs to be initiated and completed. This study will reveal which components and/or systems can be stripped with alternative technologies and which are most applicable.

Barriers

Technical

Implementation of atmospheric plasma technology at LEAD has several technical challenges. The technology, to date, has only been tested on two Navy coatings and has not been tested on CARC systems or any other paints used at LEAD. It would have to first be demonstrated that the technology is capable of removing the coatings. In addition, the testing was done at the laboratory scale and significant scale-up would have to be accomplished to achieve commercially-acceptable stripping rates.

Financial

As the technology has not been scaled-up to commercial applications, cost data is not currently available.

Acceptance

Atmospheric plasma coatings removal is a very different technology from anything currently in place at LEAD, therefore, it will take significant training to fully implement. Robotic systems require much less labor and acceptance issues could arise from that fact.

Logistics

The biggest logistical challenge to implementation is the level of training necessary to appropriate operate the atmospheric plasma systems. All of the systems require a significant level of training to use appropriately and safely. Once atmospheric plasma coatings removal is qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings must still be changed to reflect adoption of the new technology.

3.7 Stainless Steel Welding – Process Improvements and Alternatives

Various approaches have been developed to reduce generation of or exposure to toxic fume from stainless steel welding. These include engineering controls such as changes in the welding parameters or shielding gas to limit the oxidation of metals, and compositional modification of the welding flux or electrode. For stainless steel welding, the most promising developments have been a new type of Cr-free consumable and the innovative use of silica precursor technology to modify the shielding gas. The chrome-free consumables technologies appear the most promising at this time but it is unclear if they are commercially available at this time.

Several projects are currently ongoing targeted at eliminating the release of Cr^{6+} during the welding process. Since most of the welding processes fume generated comes from the welding consumable, the filler metal employed during electric arc welding is the primary source. Chromium present in the consumables may be converted to hexavalent chromium during the welding process. The technologies below address chrome free consumables to reduce this source of fume. Some carbon steels contain recycled metals that include chromium. Even though most of the welding fume comes from the electrodes/filler wire, some of the fume does come from the metal being welded. Consequently, there is a potential for hexavalent chromium in the welding fume from these steels. This source of potential exposure is addressed through engineering controls. The best solutions are those using a combination of engineering controls and non-Cr consumables.

3.7.1 Process Improvements

Local exhaust ventilation (LEV) and personal PPE remain the most widely employed means of protecting welders' breathing zone, but they remain inconvenient and often cumbersome reducing the effectiveness of "in-the- field" welding. In a fixed facility where welding occurs in specific areas on the shop floor, local ventilation, exhaust fans, to an overhead collection systems can be effective.

3.7.2 *Alternative:* Non-Chrome Consumables

Conventional consumables for welding stainless steels have a chromium content of 16-20 percent by weight, which generates high levels of Cr^{6+} fume. New chromium free consumables have been developed as a possible replacement for standard 308 and 316 stainless steel electrodes.[11] Laboratory and field testing of an electrode alloyed with nickel (Ni), copper (Cu), and ruthenium (Ru) were found to provide almost a 100-fold reduction of Cr^{6+} in fume while producing welds with comparable corrosion resistance and mechanical properties relative to conventional methods.

Related Efforts

Table 25 is a list of efforts related to the research, development, testing, and evaluation of non-chrome consumables. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 25. Non-Chrome Consumable Related Efforts

Effort	Systems	Technology	Points of Contact
Introduction and Validation of Chromium-free Consumables for Welding stainless Steels	Stainless steels	Non-Cr^{6+} consumables	Mr. Tom Torres Naval Facilities Engineering Command (NAVFAC) Phone: 805-982-1658 tom.torres@navy.mil
Innovative Welding Technologies to Control Hazardous Air Pollutant Emissions (WP-200903)[12 13]	Stainless steels	Non-Cr^{6+} consumables – Nickel, Copper, Ruthenium	Mr. Tom Torres Naval Facilities Engineering Command (NAVFAC) Phone: 805-982-1658 tom.torres@navy.mil
Novel Approach for Welding Stainless Steel Using Chromium-Free Consumables (SEED Project)	Stainless steels	Non-Cr^{6+} consumables - Monel	Dr. Gerald Frankel The Ohio State University Phone: 614-688-4128 Fax: 614-292-9857 frankel.10@osu.edu

[11] "Introduction and Validation of Chromium-free Consumables for Welding stainless Steels", Technical Report, Naval Facilities Engineering Command, TRNAVGAC-EXWC-EV-1508, Ver. 2, April 2015.

[12] https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Surface-Engineering-and-Structural-Materials/Welding-and-Joining-Technologies/WP-200903/WP-200903/(language)/eng-US

[13] https://www.serdp-estcp.org/content/download/28598/281290/file/WP-200903-FR

Effort	Systems	Technology	Points of Contact
(WP-1346)[14]			
Development of Chrome-Free Welding Consumables for Stainless Steels (WP-1415)[15][16]	Stainless steels	Non-Cr^{6+} consumables - nickel, copper, and palladium (Ni-5Cu-1Pd); nickel, copper, ruthenium, and titanium (Ni-7.5Cu-1Ru-0.5Ti)	Dr. Gerald Frankel The Ohio State University Phone: 614-688-4128 Fax: 614-292-9857 frankel.10@osu.edu

Applicability

Non-Cr^{6+} consumable technology should be applicable to LEAD processes, however, testing would be necessary to ensure weld strengths and other requirements are met by the novel materials.

Barriers

Technical

Laboratory and field testing of the non-Cr^{6+} consumables were found to provide almost a 100-fold reduction of Cr^{6+} in fume while producing welds with comparable corrosion resistance and mechanical properties relative to conventional methods. However, the consumables would have to be tested on LEAD substrates and weapon system components to ensure requirements are met.

Financial

There are no capital costs associated with this technology as they are alternative consumables used in an existing process. However, the welding rods containing palladium, ruthenium, and titanium are considerably more expensive than traditional consumables. A cost benefit analysis or life cycle analysis would have to be performed to compare existing processes to the alternatives.

Acceptance

The non-Cr^{6+} consumables have not been tested on any LEAD substrates or weapon systems, so additional testing and evaluation would be necessary to qualify the materials for use.

Logistics

Once non-Cr^{6+} consumables are qualified and accepted on weapon systems, the Technical Manuals, DMWR, and drawings must still be changed to reflect adoption of the new technology.

3.7.3 *Alterative:* Shield Gas Modification (Silica Precursor)

14 https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Surface-Engineering-and-Structural-Materials/Welding-and-Joining-Technologies/WP-1346/WP-1346/(language)/eng-US

15 https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Surface-Engineering-and-Structural-Materials/Welding-and-Joining-Technologies/WP-1415/WP-1415/(language)/eng-US

16 https://www.serdp-estcp.org/content/download/6556/86492/file/WP-1415-FR.pdf

Another approach to reducing fume generation is to modify the shield gas used in the welding process. Silica precursor technology has been developed that can limit the oxidation of chromium by quenching oxygen species and coating metal particles in welding fumes with a thin, amorphous silica layer.

The laboratory used an insulated double-shroud torch (IDST) to inject vapor-phase silica precursor tetramethylsilane (TMS) into the welding operation. This reduced Cr^{6+} exposures by over 90% and increased fume particulate sizes to 180-300 nanometers from 20 nm. Field study results further confirmed the capability of using a silica precursor to reduce Cr^{6+} exposures and encapsulate other toxic metals, Mn and Ni.

Related Efforts

Table 26 is a list of efforts related to the research, development, testing, and evaluation of shield gas modification technologies. The name of the effort, the applicable systems, the actual technology tested/evaluated, and relevant points of contact are provided. Further details are available through the POCs, the responsible organization, or through the ASETSDefense Database.

Table 26. Shield Gas Modification Technology Related Efforts

Effort	Systems	Technology	Points of Contact
Innovative Welding Technologies to Control Hazardous Air Pollutant Emissions (WP-200903)	Stainless steels	Silica precursor	Mr. Tom Torres Naval Facilities Engineering Command (NAVFAC) Phone: 805-982-1658 Fax: 805-982-4832 tom.torres@navy.mil

Applicability

Shield gas modification technologies like silica precursors should be applicable to LEAD welding operations based on the type of welding being performed. However, testing would be necessary to determine the impact (if any) of the technology on the quality of the welds and the logistics of the process. This technology is not commercially available.

Barriers

Technical

Laboratory and field testing has shown that the silica precursor technology reduced Cr^{6+} exposures by over 90% and increased the size of the fume particulates. However, testing would still need to occur with LEAD operations, substrates, and weapon systems to qualify the process. There may also be testing necessary regarding crystalline silica exposure.

Financial

There are some capital costs associated with the technology and injection of the silica precursor into the shield gas. There is also the anticipated cost of the precursor itself. A cost benefit analysis or life cycle cost analysis would be required to determine if the technology is economically feasible.

Acceptance

The silica precursor technology has not been tested at LEAD. There would have to be an evaluation of both the quality of the welds and the impact on current welding processes before acceptance could be expected.

Logistics

The base process is not changing, nor are the materials used in the welding operations. Technical Manuals, DMWR, and drawings should not require changes to reflect adoption of the new technology. However, this technology is not currently commercially available.

4 Letterkenny Army Depot Roadmap

This section of the Implementation Plan prioritizes and time-phases Cr^{6+} and Cd-alternatives initiatives at LEAD. These initiatives include ongoing projects, new starts, and research needs for those processes and materials relevant to LEAD. The methodology used to prioritize initiatives is described first followed by a brief explanation for each initiative. The time-phased roadmap to achieve Cr^{6+} and Cd reduction goals follows the explanations.

4.1 Methodology

Cr^{6+} and Cd-reduction initiatives have been prioritized using a relative scoring methodology. Four metrics were selected for analysis in the prioritization process: 1) Impact to Readiness; 2) Likelihood of Implementation; 3) Return on Investment; and 4) Impact to Goals. Each metric was qualitatively analyzed.

Impact to Readiness: This reflects the relative impact to readiness if an alternative is not implemented for the Cr^{6+} or Cd-using process. Potential impact to readiness will take into account, but not be limited to, worker exposures, regulations impacting the supply chain such as REACH, more restrictive environmental and occupational health standards, number of weapon systems impacted by the process, criticality of the process and/or weapon system to the depot, Service and DoD, and impact to the weapon system(s) if Cr^{6+} and/or Cd were unavailable for use.

Likelihood of Implementation: This relative rating is a gauge on how likely or unlikely that an alternative will be implemented for a process or process/weapon system combination. Likelihood of implementation takes into account ongoing initiatives to replace or identify alternatives for the process, the technical risk of a implementing an alternative, the logistical issues associated with implementation, cost of implementation, and other potential barriers.

Return on Investment (ROI): This metric examines the relative financial return on investment of implementing an alternative to a Cr^{6+} or Cd-using process. The ROI calculation will take into account capital costs of implementation, yearly chemical or material costs, yearly maintenance costs, energy costs, and health and safety costs. The ROI analysis will be qualitative, assigning high, medium, and low values to each of the components to reach an overall ranking.

Impact to Goals: This metric examines the impact to Cr^{6+} and Cd reduction goals at the depot. Reduction goals are based on pounds of Cr^{6+} or Cd used in depot processes. Therefore, initiatives that target high-usage processes have a greater impact on reduction goals than those with relatively low usage. The Advanced Coatings 5-Year Strategy and Roadmap establishes goals for Cr^{6+} and Cd usage and emissions/exposures/waste streams reductions. In all cases, the reduction goals are >90% over the next 5 years. To achieve these reduction goals at LEAD, several initiatives (both ongoing and new-start) are recommended and included here as part of the depot-specific implementation plan.

4.1.1 Tier 1 Priority Initiatives

Tier 1 priority initiatives are critical to achieving Cr^{6+} and Cd reduction goals. If these initiatives are not successfully implemented, the reduction goals cannot be achieved. These initiatives will typically have far reaching impact to other depots, addressing similar critical usages, emissions, exposures, and/or waste streams. Tier 1 priority processes typically have high impacts to readiness, though this is not always the case. Four of the recommended initiatives are considered Tier 1 priorities and, therefore, critical to achieving reduction goals at LEAD. Each is described in greater detail below.

4.1.1.1 HAP-Free, Non-Cr(VI) Wash Primer

Qualitative Assessment

Chromated wash primers have a very high impact to readiness as they are applied to just about every weapon system maintained at LEAD, including several critical systems. Inability to use chromated wash primers without an alternative identified and implemented would be catastrophic. Zn-rich primers have already been in production use by the USMC for a few years. Evaluation information should be coming available that would indicate how well it has served USMC in the field. This appears to be a very good alternative for LEAD.

Army Research Laboratory (ARL) and the Research, Development, and Engineering Command (RDECOM) Toxic Metals Reduction (TMR) program have an ongoing initiative to identify and implement an alternative to chromated wash primers[17]. In addition, Aviation and Missile Command (AMCOM) has initiated a Technology Transfer Agreement (TTA) to facilitate adoption of successful technologies. The technology being investigated by ARL, Bonderite 7400, has passed initial testing and the chances of implementation at LEAD is high if it is approved for aviation and missile ground support systems. Bonderite 7400 is a drop-in replacement for the existing chromated wash primers. Cost differences in the product would be offset by saving on medical monitoring and relaxed regulations. Application of wash primers is, by far, the single largest use of Cr^{6+} at LEAD- making up 64.26% by weight of all chromate species used at LEAD, according to 2014 hazardous materials usage data. The reduction goal of >90% Cr^{6+} cannot be achieved without identifying and implementing a non-chrome alternative to the current wash primers.

Description

The intended product of ARL is to identify and qualify an approved non-hexavalent chrome alternative to replace DOD-P-15328 wash primer. The alternative must be spray applied with

[17] Toxic Metal Reduction IPR Cr (VI)-Free Conversion Coatings (TMR 14-02), Fred Lafferman' Research Chemist, Army Research Laboratory, 410-306-1520, Fred.lafferman.civ@mail.mil, 3 February 2015. http://www.asetsdefense.org/documents/Workshops/2014/1/5%20Lieb%202014.pdf

similar process parameters, effective on multi-metal assemblies, and qualify to TT-C-490. The approach is to identify technologies to fill the technology gap created by impending cancellation of DOD-P-15328 through:

- Laboratory validation to downselect to best performers for demonstrations
- Mid scale demonstration of 3 candidates to assess process parameters
- Full scale production demonstration to validate process and performance
- Qualify candidate (s) and add to TT-C-490 QPD
- Work with PHC, who are writing toxicology assessments for each of the final candidates

The product will transition to all weapons systems that currently use DOD-P-15328 in rework and new manufacture, most likely ground vehicles and support equipment (BFV, HMMWV, trailers, shelters, containers, tactical vehicles)..The initiative addresses AERTA PP-2-02-04 by eliminating Cr^{6+} in wash primer (pretreatments), OSD Policy, DFARS 2009-D004 and local and Federal regulations limiting VOC emissions, and cancellation of DOD-P-15328. The initiative will eliminate DOD-P-15328 wash primer, reducing Cr^{6+} by 24K lbs/year and VOCs by 2.4M lbs/year.

4.1.1.2 Non-Chromate Conversion Coatings for Aluminum

Qualitative Assessment

Chromate conversion coatings have a high impact to readiness as they are applied to almost every weapon system maintained at LEAD. Inability to use a chromated conversion coating without identifying an alternative would compromise a number of missile and ground combat systems. Likelihood of implementation at LEAD is above average. The ARL effort identified above is a current effort to identify an alternative for both aircraft and ground support equipment, but technical challenges remain to be overcome before implementation of a new alternative. ROI is strong, with differences in product and material costs offset by savings on medical monitoring and protective equipment. The use of chromate conversion coatings is the second largest use of Cr^{6+} at LEAD-28.10% according to 2014 hazardous materials usage data. The reduction goal of >90% Cr^{6+} cannot be achieved without identifying and implementing a non-chrome alternative to the current conversion coating process.

Description

The intended end-product is a Cr^{6+} free pretreatment conversion coating for aviation and GSE with application for multi-metal. The goal is qualification and approval for transition to MIL-DTL-5541 and TT-C-490. The aviation demo sites will be CCAD, TASM-G, Ft. Campbell, Wheeler AAF and the GSE demo sites LEAD, RRAD, ANAD, and MDMC. The technical approach includes full scale demonstrations of commercially available products and verification of performance to baseline technologies for transition by PMs and PEOs in 3 years. Current state of the art for pretreatment of metallic substrates is hexavalent or trivalent chromium containing materials for aluminum and zinc phosphate for ferrous substrates. Alternative technologies are currently at a TRL level of 7 and at project completion will be at an 8. The technology technologies being tested include:

- Aircraft assets/Aluminum/Spray and Immersion
    - 11-TGL-27 (Zirconium oxide)—PPG Industries

- Bonderite 5700/5200 (Zirconium oxide)—Henkel Corp
- Iridite NCP (Aluminum fluoride)—MacDermid Industrial Solutions
- Recc 3021 (Rare earth/Cerium)—Deft/PPG
- Recc 3024 (Rare earth/Cerium)—Deft/PPG
- PreKoat (Solgel/Silanes)—Pantheon Enterprises, Inc
- AC-131(Zirconium/Silane)—3M Industries

- GSE assets/Multi-metal/Immersion only
  - X-Bond 4000 (Zirconium oxide)—PPG Industries
  - Recc 3012 (Rare earth/Cerium)—Deft/PPG
  - Bonderite/Oxsilan—Henkel/Chemetal

Successful technologies will be transitioned to the following weapon systems:

- Army Aircraft—UH-60, AH-64 and CH-47
- Tactical GSE equipment—FMTV, MRAP, HMMWV
- Missile Systems Support Equipment—Patriot Trailers

The initiative addresses elimination of Cr^{6+} in military surface finishing processes, AERTA requirement PP-2-02-04 by eliminating Cr^{6+} in pretreatments, Defense Federal Acquisition Regulation Supplement: Prohibition (223.7302), and OSHA Regulation 1910.1026. Other benefits of the initiative include reduction of over 100K pounds of Cr^{6+} generated from aluminum conversion coatings each year and over 6M pounds of stripped CARC waste that must be treated as toxic waste. Success would eliminate at least 90% of Cr^{6+} from conversion coating operations, reduce corrosion costs to military for multi-services, manage risks of exposure by being accountable for material used, amount of emissions, and waste generated and disposed, and avoid fines, penalties and house-keeping costs for non-compliance with occupational regulation.

4.1.1.3 Alternative to Cadmium Brush Plating

Qualitative Assessment

Cadmium brush plating has a moderate impact to readiness based on the number of weapon systems impacted by the process at LEAD. Inability to use cadmium brush plating without an identified alternative would compromise several weapon systems maintained at LEAD. Likelihood of implementation is high based on current efforts in the Air Force and Navy to identify cadmium brush plating alternatives on mild steel. The technology is established and initial testing has been positive. The ROI is moderate based on the capital cost of the plating equipment, but alternative plating solutions costs are decreasing. Cadmium brush plating is, by far, the largest usage of Cd on LEAD. It is impossible to reach the cadmium reduction goals at LEAD without implementing an alternative to cadmium brush plating.

Description

This project (ESTCP WP-201412) focuses on elimination of toxic and carcinogenic cadmium (Cd) material for brush plating repair operations, and reduction of solid waste associated with adsorbents used to contain solution leakage attributed with traditional brush plating repair processes. The technical objectives are to:

3. Demonstrate the commercial off-the-shelf (COTS) brush plating tool Dalistick® Station for selective plating, ensuring its safety and cost effectiveness for Department of Defense (DoD) maintenance, repair, and overhaul operations.
4. Test and evaluate the COTS Zinidal Aero (code 11040) zinc-nickel (Zn-Ni) brush plated coating as a Cd replacement on high strength steels (HSS) for repair applications on weapon systems parts and components (landing gear, terminal assemblies, landing gear doors, bushings, etc.

Low hydrogen embrittlement (LHE) Zn (14-16) Ni electroplates are now being used in the commercial aircraft industry to replace LHE Cd plating. Hill AFB is in the process of moving all of their LHE Cd plating production to this material. Brush plated ZnNi is an industry-recognized prepare for this material. WP-201412 will evaluate the ability of a novel brush plating tool, the Dalistick® Station to plate the COTS product Zinidal Zn-Ni coating on HSS. The Dalistick® Station is a mobile electroplating system that enables selective electrochemical treatments without generating any leakage of electrolyte during the plating process. The Dalistick® Station recovers residual brush plating solution and recycles it for reuse in a closed-loop process at the point of contact with the part. It is designed to perform plating and surface finishing operations on steels or light alloys on site, at depots, or in the field. It performs these treatments on curved, horizontal, and/or vertical surfaces and edges without any leakage of electrolyte and minimal generation of solid waste. The Zinidal coating is a promising candidate to replace Cd plating. The Zinidal Aero Zn-Ni solution deposits a coating with 10-14% weight Ni and 86-90% weight Zn at varying thicknesses. The coating provides sacrificial corrosion protection to steels, and the process does not require hydrogen embrittlement relief baking when plated on HSS.

The elimination of Cd brush plating with the use of the Dalistick® Station and Zinidal solution will offer the following cost, regulatory, and environmental, health, and safety benefits:

- Avoidance of compliance issues in military repair operations.
- Environmental and operations impacts, such as the ability to perform selective electrochemical treatments (rust removal, coating removal, spot anodizing) and plating, using one unit-station without electrolyte/hazardous chemical solution leakage during processing on curved, horizontal, or vertical surfaces and edges either in the field or at the Air Logistic Complexes/Depots.
- Cost savings due to recycle and reuse of plating solution in the closed-loop process.
- Reduction of solid waste that is generated from using absorbents (estimated at 60-70%).
- Reduction of worker exposure to hazardous materials and to residual brush plating solutions.
- Reduction of monitoring, use of personal protective equipment, permitting, and record keeping.
- Reduction of transportation/energy costs due to in-field repair capability.
- Reduction of fielding time and flow time at the Air Logistic Complexes/Depots.

- Reduction of occupational and environmental hazards will benefit warfighter readiness

4.1.1.4 Reduction of Cr^{6+} and Cd Spent Blast Media

Qualitative Assessment

Abrasive blasting has a moderate impact to readiness as there is little risk that the technology would become unavailable for any reason. However, almost every weapon system maintained LEAD is impacted by this process. The likelihood of implementation is also considered moderate as there has, to date, been no studies of alternatives nor testing performed to qualify an alternative to abrasive media blasting. The return on investment is high as a large reduction in the amount of hazardous and overall waste would save LEAD significant amounts of money. Impact to goals is very high as this is the single largest Cr^{6+} and Cd waste stream on LEAD, total 1.3 million pounds of spend media in 2014. All of this was disposed of as hazardous waste. It is not possible to reach waste stream reduction goals for Cr^{6+} and Cd at LEAD without addressing the spent blast media.

Description

This initiative should be implemented in phases. The first phase is an in-depth study of the abrasive media blasting processes at LEAD. This study should identify, in great detail, the components being processed through the blast media cabinets. This detail should include the components, substrate, coatings being removed, and the number of components. In addition, details on the blast media cabinets should be gathered including the type of media used, the purpose of the blasting, the type of cabinet, the recycle ratios, and the configuration of the cyclone systems, filters, and pressure systems.

Where possible, components containing Cr^{6+} or Cd should be segregated into specific cabinets connected to separate filters, cyclones, and pressure systems. Where this is not possible, investigation of coating removal technologies such as hand-held lasers, robotic lasers, Flashjet®, and atmospheric plasma can be considered. Each of these technologies result in a dramatic reduction in the amount of waste from the stripping operations.

4.1.2 Tier 2 Priority Initiatives

Tier 2 Priority Initiatives are those not critical to achieving Cr^{6+} and Cd reduction goals at LEAD, but address significant usages, emissions, exposures, and/or waste streams. These initiatives may impact similar processes at other depots, therefore, increasing the legitimacy of expending resources to identify and implement alternatives. These initiatives typically have moderate impact to readiness, but may exhibit strong ROIs. Two initiatives are considered Tier 2 priorities at LEAD. These are described in greater detail below.

4.1.2.1 Non-Chrome Conductive EMI Coating

Qualitative Assessment

The impact to readiness of this process is moderate as it impacts only a few systems maintained at LEAD. However, these systems are critical and the inability to use Cho-Shield would result in a significant gap in capability. The likelihood of implementing an alternative to the existing process is high. There are commercially available Cho-Shield products that do not contain Cr^{6+} that can be tested and implemented. The ROI is moderate as the cost of the products are very similar, but there will be some savings from eliminate medical monitoring and protective equipment. Impact to goals is moderate as identifying and implementing an alternative to the Cho-Shield coating is not necessary for meeting Cr^{6+} usage reduction goals at LEAD.

Description

Cho-Shield is a three-part, copper-filled urethane coating system which has been formulated with special additives and stabilizers to maintain electrical conductivity, even at elevated temperatures, which prevent aluminum surfaces from corroding in high humidity and/or marine environments. In particular, Cho-Shield 2003 contains soluble chromates to minimize the effects of galvanic corrosion of the aluminum substrate, even in the event of a coating scratch. Cho-Shield 2002 is a non-chromate version of the coating and, with the total stack-up, may be a drop-in replacement for Cho-Shield 2003. In addition, there are other formulations that use silver versus copper as the conductive additive. These formulations do not use chromates for corrosion inhibitors and should be tested as part of the coating stack-up as an alternative. In addition to the alternative Cho-Shield formulations, several other coatings companies produce non-chromate EMI shielding coatings, including MG Chemicals and Central Coating.

4.1.2.2 Non-Chrome Sealer for Phosphate Coatings

Qualitative Assessment

Chromated sealers have only a moderate impact to readiness as only those systems with phosphated parts are processed. However, these system are critical and the inability to effectively seal the phosphate parts would compromise them. The likelihood of implementing a solution is good. Ogden Air Logistics Complex (OO-ALC) has tested, validated and implemented a Permanganate Seal as an alternative to the chromate product. There is also existing work going on at for the Defense Logistics Agency (DLA) at Oklahoma City Air Logistics Complex (OC-ALC) focused on finding a non-chrome alternative to dichromate sealers. OC-ALC is evaluating similar technologies as those implemented at OO-ALC. In addition, there is the ESTCP project WP-200906 [18]that has demonstrated Surtec 580 for sealing phosphate coatings. On cost analysis it was found cost saving quite large from energy saving as trivalent works at ambient temperature while chromate requires elevated temperatures. The ROI would be driven by the decrease in energy requirements, medical monitoring, and relaxed regulations. The impact to goals is moderate and it is not necessary to find an alternative to chromate sealers for LEAD to reach their Cr^{6+} usage reduction goals at this time.

Description

The objective of the projects at OO-ALC and OC-ALC was to identify, demonstrate/validate and transition alternatives to sodium dichromate sealer. The technical approach included: determining OO-ALC and OC-ALC sealing requirements; Identifying alternatives to sodium dichromate seal; evaluating alternative sealers through screening and performance tests; conducting a cost-benefit analysis; conducting additional testing; and conducting technology transfer activities. Alternatives were expected to meet the following:

[18] https://www.serdp-estcp.org/content/download/35499/340712/file/WP-200906-FR%20Non-Chromate%20Sealers.pdf

- Performance requirements in MIL-A-8625F
- Must be applicable to 2024-T3 and 7075-T6
- Reduce/eliminate environmental safety and occupational health (ESOH) concerns
- Easy to use process
- Prefer a “drop-in” replacement
- Must be cost-effective

The Air Force selected 2 of the most-promising COTS candidates for laboratory testing along with three baselines and one benchmark and ultimately received OO-ALC Engineering Review Board approval to use the permanganate seal.

4.1.3 Tier 3 Priority Initiatives

Tier 3 priority initiatives are not critical to achieving Cr^{6+} and Cd reduction goals and address usages, emissions, exposures, and/or waste streams minor enough to call into question the merit of expending resources to identify alternatives. These processes are typically localized, impacting only a single depot or shop and have little impact to readiness. One (1) initiative is considered a Tier 3 priority for LEAD and is described in greater detail below.

4.1.3.1 Non-Cadmium Silk Screen Red

Qualitative Assessment

Use of the silk screen red epoxy ink has a low impact to readiness. The particular ink is used primarily based on preference as it is the “right” color. It is used for marking and stenciling on a few systems and the inability to use the existing product would have little impact on the functionality of the system. Likelihood of implementation is moderate as there has been no identified alternative to the Cd-containing ink and no initiatives to identify one. ROI is moderate to low as there would be little cost savings or negative impact to implementing an alternative. Impact to goals is low based on the small amount of product used annually-accounts for less than 1% of Cd usage.

Description

The preferred approach would be to identify a commercially available epoxy ink that meets the color requirements with a Cd-free formulation. If this proves to be impossible, then a research effort will be required to identify non-Cd pigment additives to achieve the required color and maintain consistent properties.

4.2 LEAD Initiatives Timeline

As evidenced by the descriptions above, most of LEAD’s Cr^{6+} and Cd usage, emissions, exposure, and waste stream reduction goals can likely be met by leveraging ongoing or past initiatives. In fact, 90% Cr^{6+} and Cd usage reduction can be achieved through three initiatives all leveraging ongoing work either within the Army or, in the case of cadmium brush plating, the Air Force. Only three new starts are recommended and only one of those is a Tier 1 priority initiative, critical to achieving LEAD reduction goals. Figure 14 illustrates the recommended timeline of initiatives to achieve reduction goals. Ongoing initiatives follow the timeline established by the organization leading the effort. For these initiatives, LEAD involvement is indicated according to the priorities outlined in the paragraphs above. New start timelines are hypothetical projections intended to meet Cr^{6+} and Cd reduction goals. At the end of each initiative, a two-year implementation phase has been added to allow time for specification and technical manual changes, capital purchases, and full qualification of the alternative technology.

Some risk to this timeline exists as (1) ARL has not communicated the plan and timeline to sunset the wash primer specification to all of the affected PEO/PMs and this could delay the wash primer implementation and (2) The cadmium brush plating project timing is dependent on funding and contracting lead times and (3) alternative technologies to blast media may be available sooner than FY19 even due to funding and contract lead times.

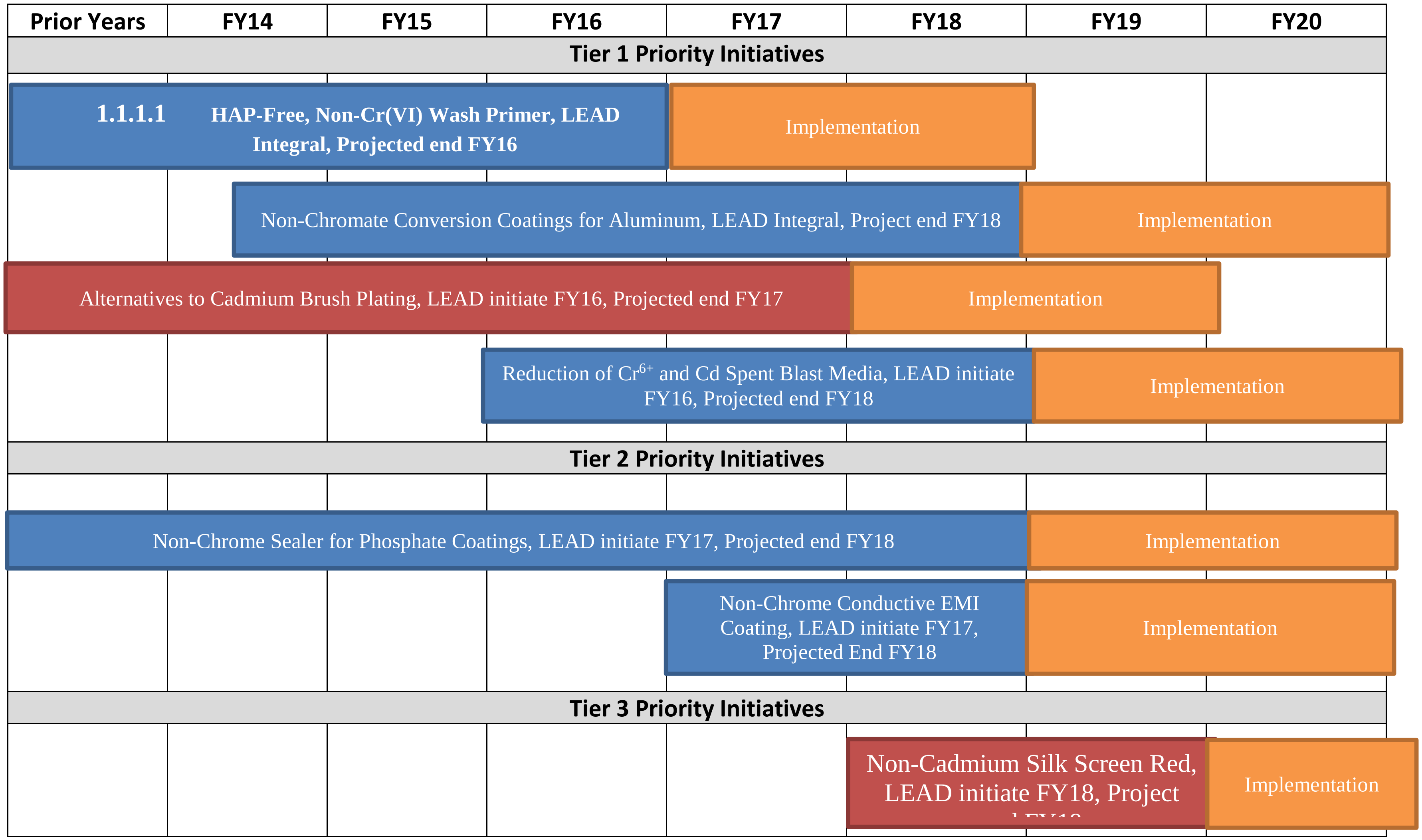

Figure 11. LEAD Timeline