

AF Cr(VI) Minimize Roadmap

Phase 1 Results



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CURRENT STATE OF AIR FORCE HEXAVALENT CHROMIUM REDUCTION EFFORTS

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Why Minimize Cr(VI)?



- **Long Known to be a Carcinogen**
 - Inhalation causes lung cancer
 - Recognized by ACGIH, EPA, IARC
- **Increasingly Stricter OSHA regulations**
 - Revised standard February 28, 2006
- **International Pressure**
- **OSD Policy (Young Memo)**
 - April 8, 2009
 - Extraordinary action to eliminate Cr(VI)
- **DFARS Clause (final pending)**
 - Draft April 8, 2010



Why a Roadmap?



- **Develop a comprehensive approach to Cr(VI) minimization addressing all applications**
- **Avoid duplication of effort**
- **Identify opportunities to leverage scarce resources**
- **Roadmaps proven effective in the development and implementation of new technology**
 - Determining gaps
 - Assigning roles and responsibilities



Phase 1



- **Perform Literature Search**
 - ASETS Defense
 - SERDP/ESTCP Websites
 - Secondary Internet Sources
 - AFRL reports, studies, and test data
- **Research/Summarize Potential Alternatives**
- **Create an AF Cr(VI) Use Matrix**
 - By Application
 - Potential alternatives identified
 - Progress toward Cr(VI) minimization estimated



What is an Application?

- **An application is a unique use of Cr(VI), that could be classified as unique due to:**
 - Technology (hard chrome plating, primer)
 - Process (LOS plating, immersion)
 - Subsystem (landing gear, fasteners)
 - Substrate (aluminum, magnesium, high strength steel)
- **Phase 1 identified 25 unique AF Cr(VI) applications**
- **Determining applications is critical to developing alternative materials and processes**



Phase 1 Findings



- **Six AF Cr(VI) Technologies Identified**
 - Hard chrome plating
 - Conversion coating
 - Primers
 - Sealants
 - Bonding Primer
 - Wash Primer
- **Some alternatives have been implemented**
- **Tremendous opportunities for further minimization of Cr(VI)**



Hard Chrome Plating



- **Roadmap identified 6 unique applications**
- **AF uses include landing gear, engine components, housings, bracket and fasteners**
- **Existing Cr(VI) process is an immersion process**
- **Replacement efforts to date:**
 - High Velocity Oxygen-Fuel (HVOF) of Cobalt-Tungsten Carbide alloys
 - Limited to line-of-sight processes
 - Limited to high strength steel
 - Mainly landing gear and engine components



Color Coding



- **Green:** Alternative has been implemented for the application by an aircraft or at a specific location (not necessarily fully tested or to be endorsed)
- **Yellow:** Potential alternatives have been identified, and testing or evaluation is underway, or alternative shows some promise for implementation
- **Red:** Potential Alternatives have been identified, but the testing and evaluation indicated some real or potential problems, or the failure to achieve the desired results
- **Gray:** Little or no information was available or discovered concerning RDT&E activities for this application

Hard Chrome

APPLICATION	PROCESS	SUBSYSTEM	SUBSTRATE	CODE	ALT MATERIAL	ALT PROCESS	DOC #S
Hard Chrome	LOS Plating	Engine Components	High Strength Steel	HC-1	WC/CoCr, Tribaloy 400, Tribaloy 800, Cr3C2/20(80Ni-20Cr)	Thermal Spray (HVOF)	1.4, 1.5, 1.10, 1.15, 1.27, 1.39, 1.64
Hard Chrome	LOS Plating	Landing Gear	High Strength Steel	HC-1	WC/CoCr, Tribaloy 400, Cr3C2/20(80Ni-20Cr)	Thermal Spray (HVOF)	1.8, 1.46, 1.15, 1.16, 1.27, 1.39, 1.64
Hard Chrome	LOS Plating	Engine Components	Nickel Alloys (Inconel)	HC-2	WC/CoCr, Tribaloy 400, Tribaloy 800, Cr3C2/20(80Ni-20Cr)	Thermal Spray (HVOF)	1.4, 1.5
Hard Chrome	LOS Plating	Landing Gear	Titanium	HC-3	WC/17Co, Electroless Ni	Thermal Spray (HVOF)	1.5, 1.8
Hard Chrome	Non-LOS	Housings, Brackets	High Strength Steel	HC-4	Electroless Ni, nano-composite plating	Cold Spray, Immersion	1.39
Hard Chrome	Non-LOS	Fasteners	High Strength Steel	HC-5	Electroless Ni, nano-composite plating	Cold Spray, Immersion	1.24
Hard Chrome	Non-LOS	Housings, Brackets	Magnesium	HC-6	Hi-pure Al	Cold Spray, Immersion	1.17, 1.44



Conversion Coatings



- **Roadmap identified 7 unique AF applications**
 - Includes pretreatment, sealers, anodizing and passivation
 - Includes a variety of substrates
- **Generally used as part of a paint system containing Cr(VI) primer**
- **Implemented alternatives include:**
 - Trivalent chromium process (TCP) – Navy,
 - Alodine 5200/5700
 - PreKote
- **No fully Cr(VI)-free paint system approved to date**

Conversion Coating

APPLICATION	PROCESS	SUBSYSTEM	SUBSTRATE	CODE	ALT MATERIAL	ALT PROCESS	DOC #S
Conversion Coating	Pretreatment	Plate & Sheet	Aluminum	CC-1	TCP +EPA	Conventional (immersion)	1.23
Conversion Coating	Pretreatment	Plate & Sheet	Aluminum	CC-1	PreKote, Alodine 5700, Sol-Gel, Dorado Kote 7, Low Chrome (LC) 1 and 2, Garabond X 4707	Conventional	1.1, 1.35, 1.61
Conversion Coating	Touch-up	Plate & Sheet	Aluminum	CC-2	AC-131BB, AC-X67, Alodine 871, Alodine 5700, Chemseal 100, PreKote	Conventional	1.1
Conversion Coating	Immersion, brush-on	Housings	Magnesium	CC-3	Tagnite (Si-based)	Conventional (immersion)	1.18, 1.30
Conversion Coating	Immersion, brush-on	Plate, sheet & component	Aluminum	CC-4	Alodine 5200/5700, K permanganate, fluorotitanic acid, TCP+ and Iridite	Conventional (immersion)	1.19
Conversion Coating	Immersion, brush-on	Plate, sheet & component	Aluminum	CC-4	Hi-Silicon zeolite (SiO4-AlO4)	Conventional (immersion)	1.41

Conversion Coating - continued

APPLICATION	PROCESS	SUBSYSTEM	SUBSTRATE	CODE	ALT MATERIAL	ALT PROCESS	DOC #S
Conversion Coating	Immersion, brush-on	Plate, sheet & component	Aluminum	CC-4	Electro-active polymers (EAP)	Conventional (immersion)	1.43
Conversion Coating	Immersion, brush-on	Plate & Sheet	Aluminum	CC-4	TCP+	Conventional (immersion)	1.5, 1.25
Conversion Coating	Immersion, brush-on	Plate, sheet & component	Aluminum	CC-4	TCP+	Conventional (immersion)	1.1, 1.5, 1.6, 1.23, 1.27
Conversion Coating	Immersion, brush-on	Plate, sheet & component	Aluminum	CC-4	TCP+	Conventional (immersion)	1.12, 1.23
Conversion Coating	Immersion, brush-on	Plate, sheet & component	Aluminum	CC-4	Sol-gel	Plasma Spray	1.2, 1.5, 1.7
Conversion Coating	Anodizing	Plate, sheet & component	Aluminum	CC-5	Sulfuric/TCP rinse, Boric-sulphuric anodize, Keronite/Tagnite	Conventional (immersion)	1.12
Conversion Coating	Passivation	Plate, sheet & component	Steel	CC-5	TCP+	Conventional (immersion)	1.12, 1.45
Conversion Coating	Post Treatment	Fasteners	Steel: SS, Cd-plated	CC-6	Pur Aluminum, Metal flake dip-spin	Organic topcoat	1.11
Conversion Coating	Post Treatment	PAD/CAD	Stainless Steel	CC-7	TCP over Zinc-phosphate	Conventional (immersion)	1.36



Primer



- **Single largest use of Cr(VI) by volume**
- **Roadmap identified 4 primer applications**
 - Interior v. Exterior
 - Primer removal
- **Generally used in a paint system that implements a Cr(VI) pretreatment**
- **Promising/implemented alternatives;**
 - Two Deft primers (02GN084 and 44GN098)
 - Akzo 2100 MgRP
- **No fully Cr(VI)-free paint system approved to date**

Primer Coating

APPLICATION	PROCESS	SUBSYSTEM	SUBSTRATE	CODE	ALT MATERIAL	ALT PROCESS	DOC #S
Primer	Coating	Interior/Structure	Aluminum	PR-1	Akzo 2100MgRP; Deft 44GN098; Deft 02GN084	Conventional	1.1, 1.27
Primer	Coating	Interior/Structure	Al, SS, Mg, Ti, Composite	PR-1	Magnesium-rich	Conventional	1.63
Primer	Coating	Exterior	Al, SS, Mg, Ti, Composite	PR-2	Deft 02GN083, 02GN084	Conventional	1.12
Primer	Coating	Exterior	Al, SS, Mg, Ti, Composite	PR-2	Inhibitors: RE diphenyl phosphate, IO salt/BTTSA, hydrotalcite-organidisulfide	Conventional	1.42
Primer	Coating	Exterior	Al, SS, Mg, Ti, Composite	PR-2	Epoxy-silane	Conventional	1.3
Primer	Coating	Exterior	Aluminum	PR-2	TCP+	Conventional	1.12
Primer	Coating	Exterior	Aluminum	PR-2	Akzo 10PW22-8; Deft 44GN098	Conventional	1.1
Primer	Coating	Exterior	Al, SS, Mg, Ti, Composite	PR-2	Magnesium-rich	Conventional	1.61, 1.62, 1.63
Primer	Coating	Munitions	Al, SS, Mg, Ti, Composite	PR-3		Conventional	
Primer	Removal	All	All	PR-4		Laser	



Sealants



- **Roadmap identified 4 sealant applications**
- **Used mainly to prevent dissimilar metal contact**
 - Faying surfaces
 - Installation of fasteners
- **Requires a different solution than primers in a typical coating system**
 - No topcoat
 - Inaccessible areas of the aircraft
- **Few prospective alternatives identified to date**

Sealants

APPLICATION	PROCESS	SUBSYSTEM	SUBSTRATE	CODE	ALT MATERIAL	ALT PROCESS	DOC #S
Sealant/Primer	Assembly/Post-Assy	Faying Surfaces	Al, Mg, Ti, Steel	SE-1	AC131sol-gel/23377N, Alodine5700/53022I, PreKote/AquaSur HS, PreKote/Akzo Mg-rich, Alodine5700/Akzo Mg-rich, AC-730, CS 5500CI	Conventional	1.22
Sealants	Assembly/Post-Assy	Faying Surfaces	Al, Mg, Ti, Steel	SE-2	Various PRC/DeSoto Bases/Accelerators	Conventional	1.33, 1.39
Sealants	Assembly/Post-Assy	Fastener interface	SS, Ti, Cad plating	SE-3			
Sealants	Assembly/Post-Assy	Fuel Tanks	Aluminum	SE-4			



Bonding and Wash Primers



- **Bonding Primer**
 - Critical surface prep component in adhesive structural bonding
 - Stringent and challenging requirements
 - Basic research needed to define corrosion protection requirements
- **Wash Primer**
 - Another option for pretreatment/primer prior to topcoat
 - Specification requires zinc chromate
 - Some testing of alternatives has been performed, including TCP

Bonding and Wash Primers

APPLICATION	PROCESS	SUBSYSTEM	SUBSTRATE	CODE	ALT MATERIAL	ALT PROCESS	DOC #S
Bonding	Wipe/Brush-on/Spray	Surface Prep	Metal Surfaces	BD-1		Conventional	1.66
Wash Primer	Immersion/Spray		Aluminum	WP-1	TCP+	Conventional	1.6,1.40
Wash Primer	Immersion/Spray		Magnesium	WP-2		Conventional	
Wash Primer	Immersion/Spray		Stainless Steel	WP-3		Conventional	



AFRL S&T Related Technologies



- **Cr+6 Reduction Plan**
- **Inorganic Coatings**
 - Chrome Replacement
 - Next Generation Non-Line of Sight Coatings
 - Dichromate Sealer Replacement
- **Organic Coatings**
 - Cr Free Paint Systems
 - Sicopoxy
 - Mg Rich Primer
 - UV Curable Coatings
 - Topcoats; Primer; One Coat
 - Explosion Proof UV Lamp
 - UV Paint Booth
 - Paint / Depaint Life Cycle Extension



AFRL Chrome Reduction Plan



Description

- Reduce hexavalent chromium use and waste

Approach

- Review hexavalent chromium usage in DoD to identify applications.
- Develop Strategic Implementation Plan for hexavalent chromium reduction throughout AF

Benefits

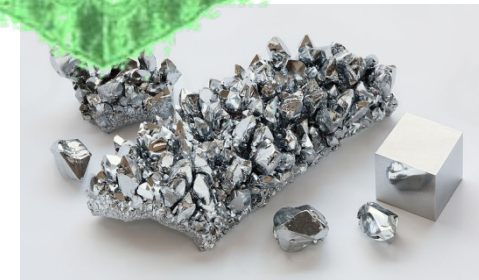
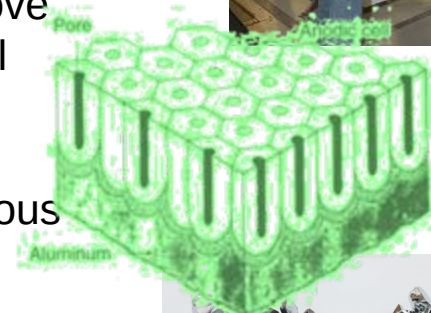
- Reduce hexavalent chromium applications in order to improve compliance to EPA, DoD, and other federal, state, and local directives.
- Addresses Executive Order 11514, CAA, CWA, RCRA, NESHAP, AFI32-7040, and AFI 32-7042, and State hazardous reduction plans

Weapon Systems

- Various aircraft components - especially landing gear, wheels, hydraulic components, fasteners; vehicles; ground support equipment

Stakeholders

- USAF (e.g., B-1, F-16, F-18, F-22, F-35, C-5, C-17 POs, Space); ANG; Army aircraft, TACOM; NAVAIR; Coast Guard, NASA, DSCC, OEMs

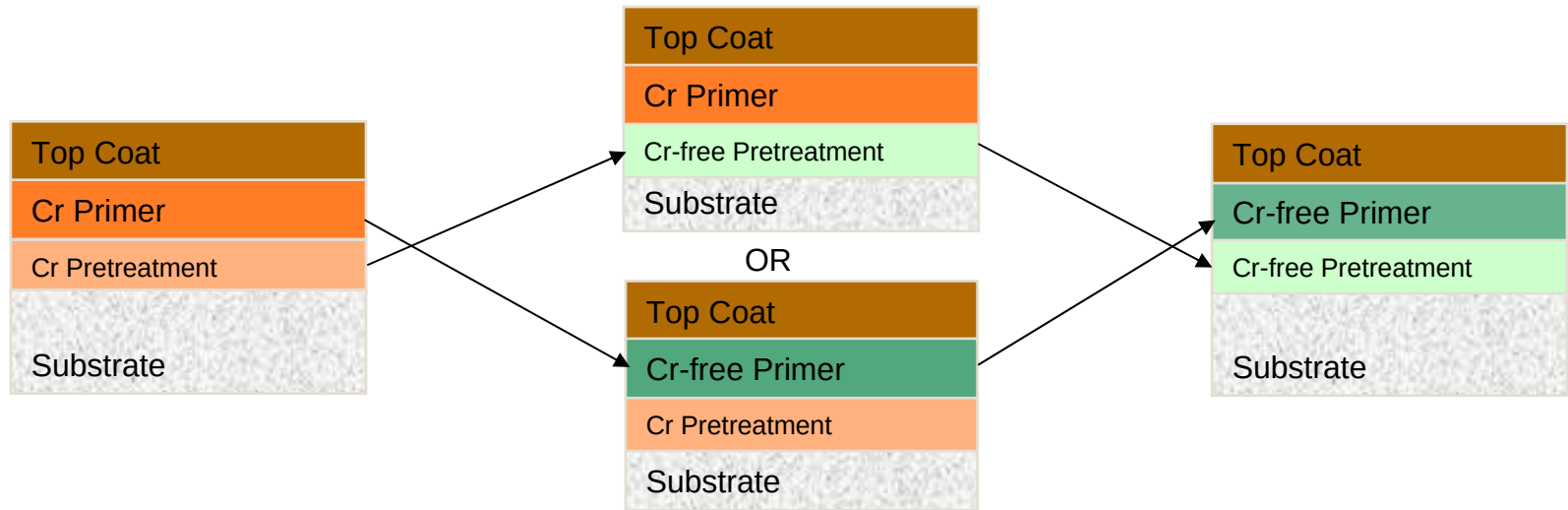




AFRL Chromium-free Coating Systems Integration Plan



No qualified, completely chromium-free system yet ...



← Yesterday

Today

Tomorrow →

- Some individual chromium-free components cannot be combined with some MIL SPEC or other components; e.g., PreKote with Deft 02-GN-084
- AFRL currently testing two chromium-free coating systems that show most promise based on screening/performance testing



PreKote / Mg Rich (AeroDur 2100)



- **Pretreatment Manufacturer – Pantheon Chemical**
 - Approved for use in T.O. 1-1-8 with a chrome primer
 - PreKote used on F-16, T- Jets (AETC) since mid '90s, Hill AFB since '05, C-5 & C-130's @ Robins AFB
- **Primer Manufacturer – Akzo Nobel**
 - Corrosion Inhibitor – Mg particles
 - Galvanic Corrosion protection
 - New formulation best lab corrosion test performance to date
- **System Performs as well as chrome in outdoor exposure on corrosion sensors on aircraft**
 - Parts flying on CG HH-60 rescue aircraft
- **Field testing on full aircraft in planning stages (HH-60, C-130, F-16)**
- **System in testing for qualification to MIL-PRF-32239**
- **CTIO's choice to meet USD, Mr. Young letter**



The Road Ahead...Phase 2



- **Phase 1 has:**
 - Established the applications to use as a starting point
 - Identified much of the existing RDT&E data
- **Phase 2 will:**
 - Develop technology roadmaps
 - Identify technology gaps for each application
 - Identify intermediate steps needed
 - Identify RDT&E projects
 - Estimate funding levels and timeframes needed
 - Document Cr(VI) use and alternative implementation by weapon system