U.S. Army Toxic Metal Reduction Program: Eliminating Cr(VI) and Cd in Army Surface Finishing

For ASETSDefense

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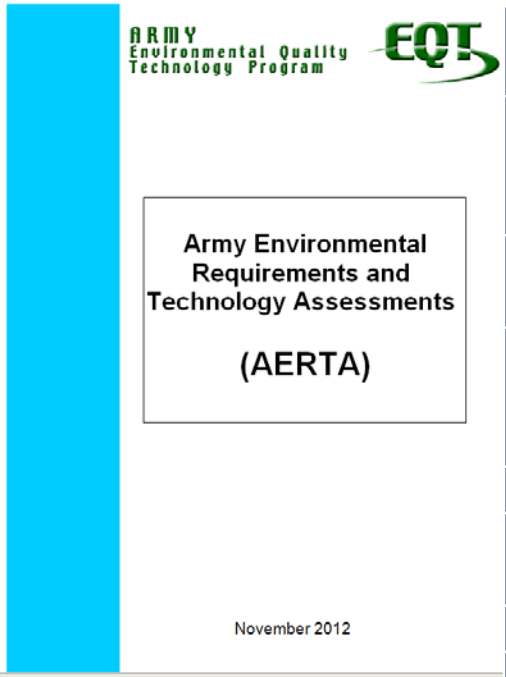
What is the TMR requirement?



#2 P2TT priority (2013)

Process	Specification	Hazardous Chemicals
Aluminum Conversion Coating	MIL-C-5541-E MIL-DTL-81706B	Sodium Dichromate
Aluminum Anodize	MIL-A-8625F Type I and IB	Chromic Acid, Sodium Dichromate, Chromium Trioxide
Cadmium Brush Plate	MIL-STD-865C	Cadmium Special, Cadmium Alkaline, Cadmium Acid
Cadmium Plating	SAE AMS-QQ-P-416B Type II	Cadmium Oxide, Sodium Cyanide, Cadmium, Nickel Chloride, Iridite
Hard Chrome Plate	SAE AMS-QQ-C-320	Chromic Acid
Copper Plating	ASTM 2418F	Copper Cyanide, Sodium Cyanide, Sodium Dichromate
Electroless Nickel	AMS2404F	Nickel Chloride
Magnesium Anodize - Conversion Coating	AMS-M-3171 Type III, IV, VI	Chromic Acid, Sodium Dichromate
Nickel Plating	SAE AMS QQ-N-290	Nickel Chloride, Nickel Sulfate, Nickel Sulfamate
Passivate	SAE AMS 2700B	Sodium Dichromate
Phosphate	MIL-DTL-16232G TT-C-490, Type I	Chromium Trioxide, Chromic Acid
Silver Plating	ASTM B700-97	Potassium Cyanide, Silver Cyanide
Wash Primer	DOD-P-15328 TT-C-490F	Zinc chromate

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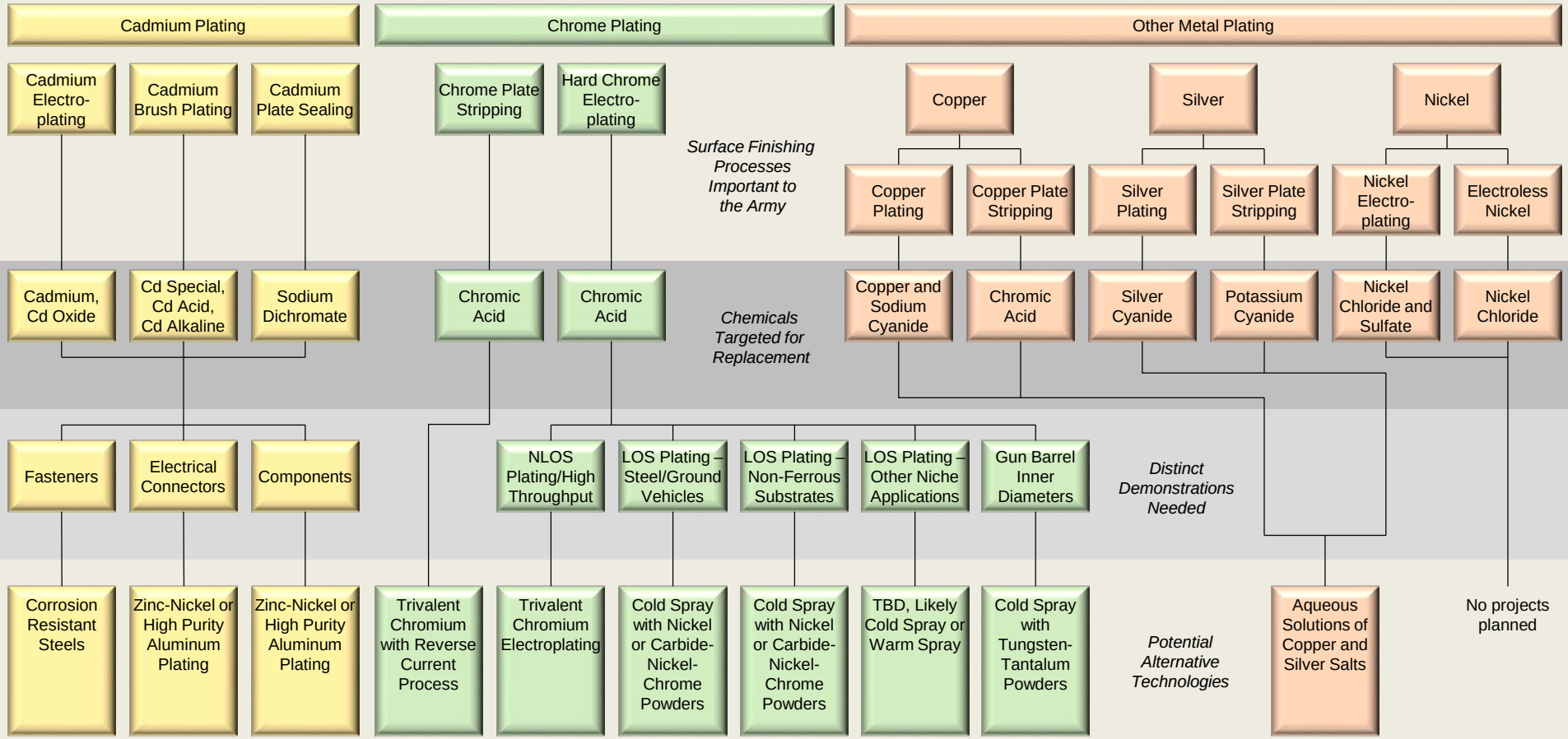
Metal Plating Projects

Total Army Usage in Plating

Total Cr(VI): 10,000 lbs/yr
Total Cd: 1,270 lbs/yr
Total CN: 80 lbs/yr



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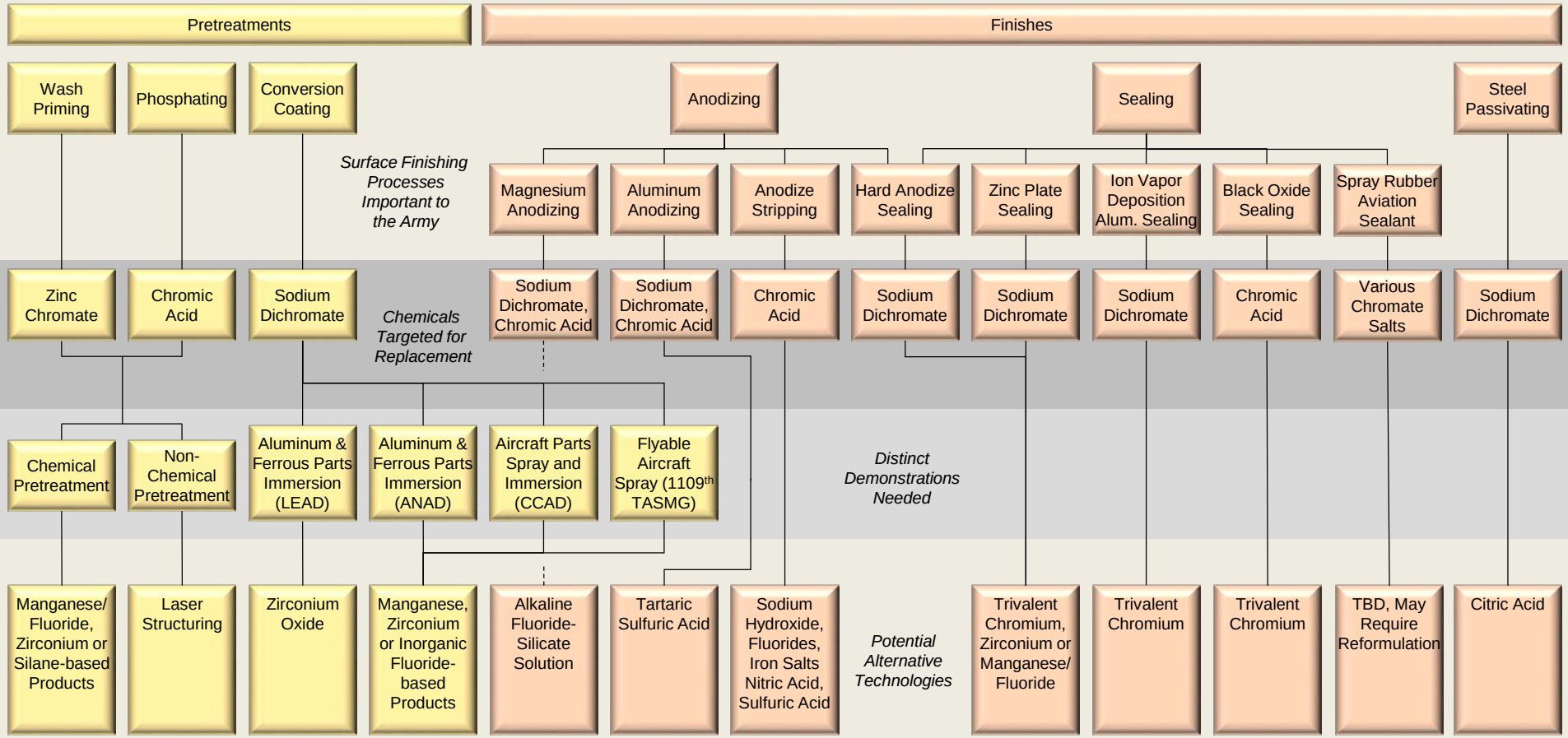
Pretreatments and Finishes

Total Army Usage in Pretreatments and Finishes

Total Cr(VI): 140,000+ lbs/yr



Advanced Surface Coating Plan - LEAD

Process	Contains	lbs Product	lbs Species
Chromated Primers - Wash Primers	Cr^{6+}	6735	606
Chromate Conversion Coatings - Tank	Cr^{6+}	2945	412
Cadmium Brush Plating	Cd	476	119
Specialty Coatings - CHOShield	Cr^{6+}	273	10
Chromated Primers - Other	Cr^{6+}	63	9
Chromate Sealer	Cr^{6+}	405	8
Chromate Conversion Coatings - Touch-up Pens	Cr^{6+}	60	1.8
Specialty Coatings - Silk Screen Red	Cd	0.58	0.01
Total All		10957	1166
Total Cd		477	119
Total Cr		10481	1047

Table 4. Process Cd and Cr^{6+} Usage (Noblis, 2016)

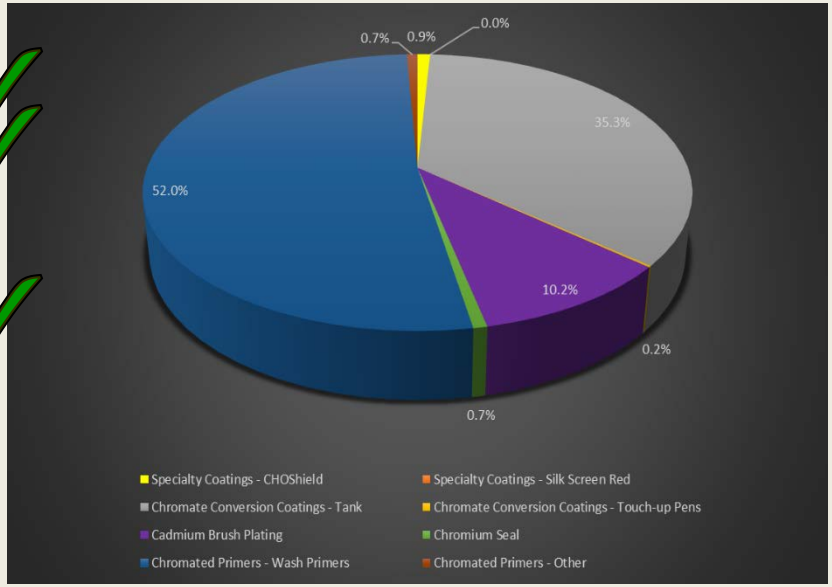


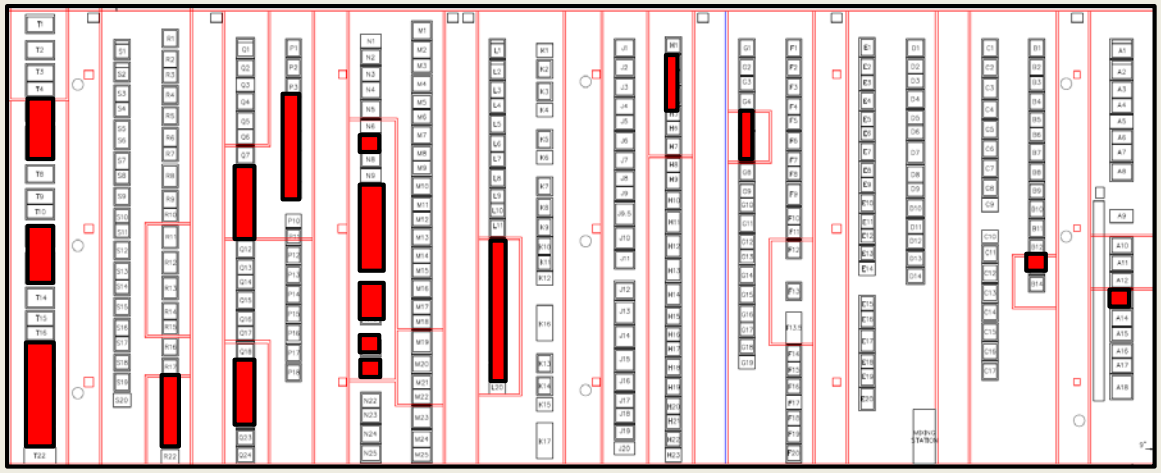
Figure 2. Process Usage at LEAD (based on pounds of Cr^{6+} and Cd species) (Noblis, 2016).

- ETAP supports SERDP/ESTCP objective to reduce Cr(VI) and Cd use and emissions at DoD Depots by 90% in 5 years
- Current TMR projects will eliminate 88% of total Cr(VI) and Cd at LEAD
  - FY18 cadmium brush plating project to eliminate another 10%
- Where to go from here?
  - Collect high resolution data at remaining Army depots
  - Partner with ESTCP to fill remaining technology gaps

Current TMR projects will eliminate 98% of Cr(VI) at LEAD

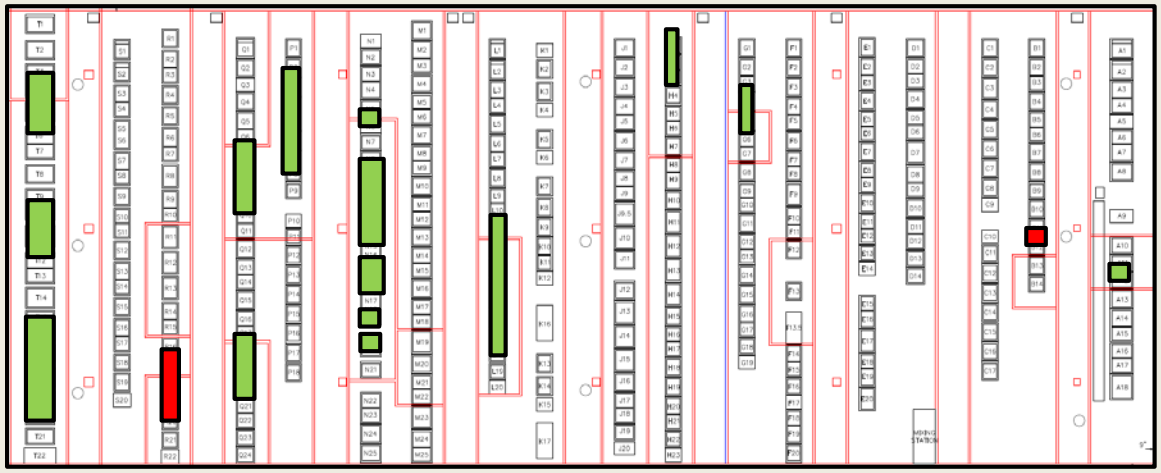
CCAD Plating Shop Cr(VI) Elimination

CCAD Plating Shop Tanks Currently Containing Cr6+



Line	Process	Num Tanks	% Tanks
A	Black Oxide Seal	1	3
B	Manganese Phosphate	1	2
G	Al Conversion Coat	3	8
H	Copper Strip	2	5
L	Stainless Steel Passivation	6	15
N-P	Chrome Plating	11	28
Q	Magnesium Conversion Coat	5	13
R	Cadmium Sealer	3	8
T	Chromic Acid Anodize	4	10
T	Anodize Strip	2	5
T	Hard Coat Anodize Seal	1	3
	Total	39	100

CCAD Plating Shop Tanks Containing Cr6+ if Existing Projects are 100% Successful



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Cr(VI)-Free Low VOC Alternatives for Spray-in-Place, Mixed Metal Pretreatments, TMR 12-01

- **Objective:** Eliminate Cr(VI) in multi-metal spray-on pretreatment applications (alternative to wash primer)
- **Magnitude of impact:**
  - Reduce Cr(VI) by 24K lbs/year, volatile organic compounds (VOCs) by 2.4M lbs/year
  - Violation of VOC emission limits could restrict maintenance
  - Cancellation of DOD-P-15328 planned for September 2017
- **Intended end product:** Validated Cr(VI) spray applied chemical pretreatments for multi-metal applications per TT-C-490F
- **Technology:**
  - Commercially available metal pretreatment technologies on multiple substrates and mixed metal assemblies added to QPD
    1. Bonderite 7400 (phosphoric acid, hexaflourotitanic acid, Mn)
    2. Zircobond 4200 (zirconium immersion chemistry)
    3. Oxsilan 9810/2 (organo-silane polymers)
- **Weapon systems impacted:** All systems currently using DOD-P-15328 chromated wash primer (ground vehicles, combat service support equipment and aviation/missile systems)
- **Transition Path:** TT-C-490F Qualified Product Database
- **POC:** Jack Kelley, ARL, john.v.kelley8.civ@mail.mil
  - IPT: ARL, Letterkenny Army Depot (LEAD), Anniston Army Depot (ANAD), Red River Army Depot (RRAD), Henkel, PPG

FY12	• Laboratory testing
FY13	• Down-selection/Outdoor testing
FY15	• Demo at LEAD, implementation through TT-C-490 QPD
FY17	• Demo at ANAD

Cr(VI)-Free Conversion Coatings, TMR 14-02

- **Objective:** Eliminate Cr(VI) in conversion coatings (CC)
- **Magnitude of impact:**
  - Eliminate 100K lbs/yr of Cr(VI) in Al CC, 6M pounds of CARC waste
  - Consolidated ferrous and non-ferrous pretreatment line
- **Intended end product:** Multiple approved Cr(VI)-free CCs for aircraft and Ground Support Equipment (GSE) (multi-metal and composites), application by spray and immersion
- **Technology:** Assess commercially available Al pretreatments
  - Aviation: CCAD, TASMG, Corrosion Repair Facility
    - Spray/immersion: Henkel Bonderite MN-T-5700, PPG Industries 11-TGL-27
  - GSE (immersion): ANAD, LEAD, Tobyhanna Army Depot
    - PPG X-Bond 4000 (Zr), Henkel Bonderite MN-T-5200
  - Leverage: ESTCP (LEAD) and USMC - Albany demos
- **Weapon systems impacted:** All tactical equipment that requires CARC
- **Transition Path:** TT-C-490, MIL-DTL-53072, MIL-DTL-5541, MIL-DTL-81706
- **POC:** Fred Lafferman, ARL, fred.lafferman.civ@mail.mil
  - **IPT:** AMCOM, AMRDEC, AED, TACOM, LEAD, RRAD, CCAD, TASMG, PPG Ind., Henkel

FY14	• Select candidates • Laboratory testing
FY15	• Downselect products
FY16	• Demo at CCAD (spray) • Demo at CCAD, ANAD (immersion)
FY17	• Demo at TASMG (spray) • Observe demo on end items
FY19	• Implementation

Cr(VI)-Free Aluminum Anodizing, TMR 15-01

- **Objective:** Eliminate Cr(VI) in aluminum anodizing, stripping and sealing
- **Magnitude of impact:**
  - CCAD anodize and anodize stripping baths use:
    - Anodize: 2300 gallon tank with 1500 lbs. chromic acid, added as needed (500 lbs. added in 2010-2011)
    - Stripping: 1 process line, 2050 lbs of dry chromic acid
  - International regulation impact on supply chain (REACH)
- **Intended end product:** 1) Validated Cr(VI)-free anodizing process in production environment, 2) validated Cr(VI) free chemical stripper for all forms of anodized aluminum
- **Technology:** Two anodize technologies, Cr(VI)-free strippers
  1. Sikorsky: Tartaric Sulfuric Acid Anodizing
  2. NAVAIR: Thin Film Sulfuric Acid Anodizing process
  3. Cr(VI)-free strippers for legacy, alternative anodize (ARL)
- **Weapon systems impacted:** All aircraft maintained at CCAD, including other Service aircraft
- **Transition Path:** CCAD process standard, MIL-A-8625, MEO added to DMWRs
- **POC:** Scott Howison, AMCOM, stephen.s.howison.civ@mail.mil
  - **IPT:** AMCOM, ARL, Sikorsky, AMRDEC-AED, CCAD, UH-60 Project Office (PO), AH-64E Apache PO, CH-47 PO

- **FY15** • Initiate laboratory testing with Sikorsky
- **FY16** • Evaluation of TSAA and anodic coating stripper
- **FY18** • Demo at CCAD
- **FY19** • Implementation through MEO

Cr(VI)-Free Surface Activation and Preparation for Metal Plating, TMR 13-03

- **Objective:** Eliminate chromic acid (Cr(VI)) used in stripping anodized coatings from aluminum
- **Magnitude of impact:**
  - Eliminate 1,400 lbs/yr of chromic acid at Corpus Christi Army Depot (CCAD) in anodize stripping processes
- **Intended end product:** Validated Cr(VI) free chemical stripper for anodized coating on aluminum (Type I, Type III and alternative processes)
- **Technology:** Commercially available chemical strippers
  - NaOH Stripper/Deoxidizer
  - LNC Deoxidizer (ferric sulfate, nitric acid, HF)
  - Sikorsky (proprietary)
  - Stripol ANO
  - Metalast ADS 1000 (sulfuric acid)
- **Weapon systems impacted:** All systems that use anodized aluminum, including ground tactical and support equipment and aviation systems
- **Transition Path:** Revision to MIL-A-8625
- **POC:** Jack Kelley, ARL, john.v.kelley8.civ@mail.mil
  - **IPT:** ARL, AMCOM, AMRDEC, ANAD, CCAD, PEO-Stryker Brigade Combat Team, Hubbard Hall, Henkel, Chemetall, AMZ Manufacturing, PPI Aerospace

FY14
- Develop testing protocol
- Laboratory testing

FY16
- Down-select

FY17
- Demonstration at ANAD/CCAD

FY18
- Specification revision and implementation

Cr(VI)-Free Hard Chrome Electroplating, TMR 14-01

- **Objective:** Eliminate Cr(VI) from electroplated hard chrome (EHC) processes
- **Magnitude of impact:**
  - Eliminate 5 tons of chromic acid used in EHC in Army depot operations (ANAD, CCAD, Rock Island Arsenal (RIA))
- **Intended end product:** Cr(VI)-free Non-Line of Sight (NLOS) plating process that results in a hard chrome plate that meets AMS 2460 performance requirements
- **Technology:** Faraday Technologies developed process
  - Trivalent chromium (Cr(III)) bath chemistry
  - Pulsed, reverse waveform rectifiers/power supply
  - Non-lead anodes
  - Leverage: SBIR for stripping chrome plating
- **Weapon systems impacted:** All aircraft maintained at CCAD; ground vehicles at ANAD and specific processes at RIA
- **Transition Path:** Individual MEOs, CCAD process standard
- **POC:** Michael Johnson, AMCOM, michael.l.johnson17.ctr@mail.mil
  - **IPT:** AMCOM, TACOM, AED, ARL, PEO Aviation, CCAD, Faraday Technologies

FY14
- Laboratory testing (130 gallon)

FY16
- Process validation and characterization

FY18
- Establish Pilot Process (400 gallon)
- Demonstration at CCAD

FY20
- Implementation through MEOs

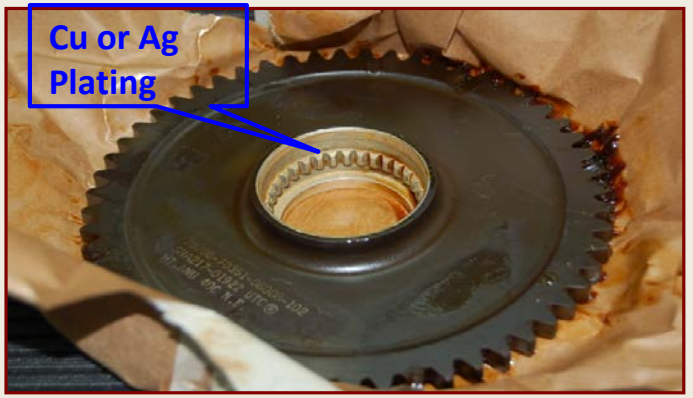
Cold Spray – Demonstration of Portable System, as Hard Chrome Alternative, TMR 16-03

- **Objective:** Eliminate Cr(VI) in electroplated hard chrome
- **Magnitude of impact:**
  - Potential to eliminate Cr(VI) in all Line-of-Sight (LOS) hard chrome applications (and Ni plating)
  - Increase throughput for dimensional restoration
  - Mobile repair processes
- **Intended end product:** Cr(VI)-free portable CS system for field repair, production process for inner diameter applications at ANAD, LEAD and CCAD.
- **Technology:**
  - Portable CS equipment with optimized ID nozzle with amorphous iron, Cr, Ni, and CrC-NiCr powders
  - Transition powders developed by SERDP WP-2607
  - Dimensional restoration of hard (HRC 45+) surface
  - Coordinated path forward for LOS applications
- **Weapon systems impacted:** All LOS hard chrome surfaces at ANAD, LEAD and CCAD.
- **POC:** Vic Champagne, ARL, victor.k.champagne.civ@mail.mil

- **FY16** • Design and set-up CS process, robotic pathways
- **FY18** • Demo at ANAD to establish CS capability
- **FY19** • Demo at LEAD to establish CS capability
- **FY20** • Demo at CCAD to establish CS capability

Cyanide-Free Copper and Silver Electroplating, TMR 15-02

- **Objective:** Eliminate cyanide from copper and silver electroplating at CCAD
- **Magnitude of impact:**
  - Cyanide alarm requirement: Up to 1 hr evacuation per alarm
  - 80 lbs/yr of cyanide used at CCAD
- **Intended end product:**
  - Non-cyanide products and processes for copper and silver plating/strike demonstrated at CCAD
  - Non-chromic acid and non-cyanide stripping methods to remove copper and silver plating/strike demonstrated at CCAD
- **Technology:**
  - Leverage DoD, commercially available plating chemistry
    - E-Brite 30/30 and E-Brite Ultra Cu (Copper)
    - E-Brite 50/50 (Silver), Silver Cyless II
  - Cold spray for LOS Cu or Ag deposition
  - Cyanide, Cr(VI)-free stripping process for copper and silver
- **Transition:** MEOs at CCAD
- **Weapon systems impacted:** All aircraft maintained at CCAD
- **POC:** Sheree York, AMCOM, sheree.t.york.civ@mail.mil
  - **IPT:** AMCOM G-4, CCAD, EPI, AED, ARL, AH-64 PO, UH-60 PO, CH-47 PO



Small Spur Gear, P/N 70351-08088-102

FY15
- Establish Pilot Process at CCAD
- Evaluate CS

FY16
- Demonstrate Plating/Strike
- Laboratory testing

FY17
- Implement Plating/Strike
- Demonstrate Stripping

FY18
- Implement Cr(VI)-Free Stripping

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Non-Chromate Alternative Sealing for MIL-DTL-13924D Black Oxide Coatings for Ferrous Metals, TMR 16-01

- **Objective:** Eliminate Cr(VI) in sealers for MIL-DTL-13924
- **Magnitude of impact:**
  - Reduce the estimated 1.4M gallons chromic acid solution used in 2011 at ANAD
- **Intended end product:** Cr(VI)-free technologies for sealing MIL-DTL-13924 on ferrous substrates on all classes within specification and chromic acid sealers mandated in MIL-DTL-16232
- **Technology:**
  - TCP (SurTec 580) already demonstrated as TRL-8 on Zn Phosphate, but considered TRL-6 until demonstrated on black oxide
  - Provide the non-Cr(VI) options via a revision of MIL-DTL-13924 and MIL-DTL-16232
  - Perform demonstration at ANAD on misc and small arms parts
- **Weapon systems impacted:** Small arms and related accessories at ANAD
- **POC:** Jack Kelley, ARL, john.v.kelley8.civ@mail.mil

FY16
- Laboratory evaluation of black oxide and heavy zinc phosphate sealer alternatives

FY17
- Demonstrate at ANAD on current process line

FY18
- Implement alternatives through changes to MIL-DTL-13924 and MIL-DTL-16232

Cr(VI)-Free Post-Treatment Sealers for Legacy Coatings, TMR 16-02

- **Objective:** Eliminate Cr(VI) in post-treatment sealers
- **Magnitude of impact:**
  - Reduce the overall usage of chromic acid solution at ANAD, CCAD, RRAD, RIA
- **Intended end product:** Qualified Cr(VI)-free post-treatment sealers for zinc plating, IVD aluminum, and hard coat aluminum anodize processes
- **Technology:**
  - Zinc plating: Corrosil 501 (BG)
  - Hard coat aluminum anodize: Potassium permanganate
  - Surveying other services and vendors for alternatives
  - Demonstrate the new materials in a production environment (CCAD and TACOM depot)
- **Weapon systems impacted:**
  - ANAD: Ground vehicles and towed artillery
  - CCAD: All aircraft
  - RRAD: Ground vehicles and other heavy equipment
  - RIA: Wide variety of equipment
- **POC:** Lisa Maddox, AMCOM, lisa.j.maddox.civ@mail.mil

- **FY16** • Develop test protocol
- **FY17** • Evaluate sealers in laboratory
- **FY18** • Demonstrate in production environment (3 demos)
- **FY19** • Implement through new process standards and specifications

Cadmium Path Forward

- ETAP established Cadmium IPT in 2016
- Surveyed depots to collect annual Cd plating and brush plating usage
  - CCAD: Internal active plating shop plates 550+ parts, does not include connectors and fasteners (purchased through DLA)
  - LEAD: 476 lbs/yr in cadmium brush plating, <1 lb used in Silk Screen Red paint
  - Tobyhanna Army Depot: Usage quantity TBD
  - ANAD, RRAD, RIA: No cadmium plating reported at facility
  - Watervliet Arsenal: Eliminated Cd from most applications eliminated - estimated 3 systems continue to use Cd plating for gun barrels (e.g., bore evacuator)
- Group parts into categories based on similar performance requirements
  - Gears, bushings, miscellaneous parts plated in-house at Army depots
  - Brush plating repair
  - Common fasteners, electrical connectors purchased through DLA
- Identify Army-specific performance requirements from users, if applicable
- Collect performance data for alternatives from the Air Force, Navy (ES3)
- Evaluate maturity of alternative technologies (e.g., ZnNi, high purity Al) for all applications
  - May require independent study to compile data and compare to requirements
- Develop demonstration project plans for FY18-19 start

Are the Alternatives More Sustainable?

- U.S. Army Public Health Center evaluates all proposed alternatives using Toxicology Assessment (TA) Process
  - Literature review
  - Computational modeling
  - Data collection
  - Toxicity Testing, if necessary
- TA review concurrent with project maturity
- Data will inform acquisition documentation and occupational exposure requirements
  - Toxicity Clearance, Health Hazard Assessment
  - Occupational Exposure Limits, Industrial Hygiene Plan
  - Programmatic Environment, Safety and Occupational Health Evaluation
  - Life Cycle Environmental Assessment

Developmental Environment, Safety and Occupational Health Evaluation (DESHE)

- DESHE is a process and not a report or document
- Purpose: Develop and document a baseline level of ESOH performance data for each level of research in order to support risk-based decisions
  - Should include human toxicity (mammalian), fate and transport, eco-toxicity and safety data
- Phased approach to gather, develop and document ESOH performance data for materials, processes and technologies during all phases of RDT&E
  - Data requirements determined by Budget Activity (BA) level or TRL
  - Early stages – qualitative data
  - Higher maturity technologies – more robust, quantitative data
  - Data should be collected using regulatory-approved methods (ASTM, OECD) and consistent with Good Laboratory Practices

Summary

- Army EQT P2 TMR Program will conduct demonstrations of more sustainable surface finishing processes at Army depots and installations from FY15-23
- P2 Technology Team will support transition through document changes, maintenance orders and updates to QPD
- Goal: Eliminate 100% of Cr(VI), Cd or toxic constituents in select processes (with Army-wide goals consistent with SERDP/ESTCP 90% reduction)
- Seeking leveraging opportunities, data sharing, support for specification changes and promising technologies for future demonstrations