



Environmental Quality Technology Program

SERDP/ESTCP Metal Finishing Workshop Background for Ground Vehicles

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Current Uses of Cr+6 and Cd

- **Approximately 300,000 vehicles in DoD fleet, mostly over 20 years old**
 - Majority low carbon steel, plain or galvanized. Other important substrates rolled homogenous armor (RHA), aluminum composites, ceramic armor, and some titanium
- **Future vehicles high strength steels, high strength aluminum alloys, lightweight composite armor, greater use of titanium and magnesium alloys**
- **Cadmium (electroplated & vacuum deposited) used on fasteners (threaded & non-threaded), small steel components, electrical connectors, and small parts (e.g. hinges and brackets)**



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Typical Ground Vehicles



One variant of the Family of Medium Tactical Vehicles (FMTV)

Photo courtesy Army Images



High Mobility Multipurpose Wheeled Vehicle (HMMWV)

Photos courtesy Army Images



Heavy Expanded Mobility Tactical Truck (HEMTT).

Photos courtesy Army Images



Current Uses of Cr+6 and Cd

- EHC used on some shock absorbers, hydraulic cylinders and rods, crankshafts, piston rings, combat vehicle turbine engines and turret races.
- Cr+6 pretreatment for both aluminum and ferrous substrates. Dichromate rinses on Cd, Zn, and Zn-Ni plated fasteners. Chromate rinses after zinc phosphating and anodizing. CCC on wide variety of electrical/electronic boxes and structural aluminum components.
- Nickel in Zn-Ni on fasteners intended to replace cadmium on fasteners.



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Current Processes

- **Automotive applications at OEMs and depots include:**
 - **Plating of chrome, cadmium, and strike solutions of copper and nickel**
 - **Anodizing and chromate conversion coating (Alodine 1200) on aluminum**
 - **Sodium dichromate sealer**
 - **Zinc phosphate pretreatments on ferrous substrates (chromium, cobalt & nickel additives both spray & dip)**
 - **Alkaline cyanide baths for cadmium plating**



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Important Performance Requirements

- **For Hard Chrome:** wear resistance, “rebuildability”, and complex non-line of sight parts
- **For Cadmium:** slight underpotential relative to UHS steels (avoid hydrogen embrittlement), lubricity, benign corrosion products
- **For Chromates:** corrosion protection, ease of use, conductivity, color identification, improved processing operational tolerances
- **Other aspects:** throughput, process robustness, coating thickness, coating uniformity, wear, metallurgical bond, fatigue life, torsion strength, tensile strength, and surface condition prior to painting and bonding



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Important Specifications and Standards

- **MIL-STD-171 (general finishing guidance)**
- **MIL-C-5541 (aluminum finishing)**
- **MIL-A-8625 (anodic coatings for Al & Al alloys)**
- **TT-C-490 (zinc phosphate)**
- **QQ-P-416 (cadmium)**
- **MIL-C-8837 (vacuum deposited cadmium)**
- **ASTM B633 (chromate conversion, zinc phosphate)**
- **ASTM B656/B689 (nickel coatings)**
- **ASTM D522/D4145 (adhesion tests)**
- **MIL-STD-1500 (cadmium, titanium)**
- **MIL-STD-810 ("environmental" testing)**
- **ASTM A153 (zinc, hot dipped)**
- **ASTM B840 (zinc-cobalt)**
- **ASTM B841 (zinc-nickel)**
- **ASTM B545 (tin-nickel)**
- **Connectors: MIL-DTL-38999; MIL-DTL-5015; MIL-PRF-24308; and MIL-C-83513**



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Change Drivers

- **High Compliance Costs**
- **New OSHA Hexavalent Chrome PEL (52 to 5 micrograms per cubic meter of air)**
- **New EU ban on Cd and Cr+6 Jul 06 on electronics/electrical components**
- **California ban on Cd coatings on automotive components**
- **Need Army approved waivers to use Cd and Cr+6 components on Stryker Family of Vehicles**



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Stryker Infantry Armored Vehicle

Photo courtesy DoD DEFENSLINK



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Replacement Priorities

- **Cadmium (high strength fasteners most prevalent)**
- **Hexavalent Chromium (electrical boxes and rinses on fasteners big concern)**



Clean Alternatives Barriers

- **Costly technical manual changes to legacy systems**
- **OEM equipment used for both commercial and DoD customers (much smaller fraction of buys). Must consider impact on both types of customers.**
- **New systems purchased to performance specifications. Army specifies outcomes, not processes. Need “buy-in” from automotive industry.**
- **Alternatives performance must be equal or better**
- **Depot concerns on capital costs and process versatility for plating multiplicity of parts.**



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Alternatives Adopted

- ***Cadmium***
 - Zn-based plating processes on low to medium strength steel fasteners
 - IVD Al plating on some (not widespread) higher strength steel substrates
- ***Chromates (Cr+6)***
 - Non-CCC (grit blasting followed by primer and topcoat) on corrosion resistant armor alloys
 - Non-CCC (Alodine 5200/5700) on aluminum roadwheels
 - DI water rinse in lieu of chromate seals on zinc phosphate during CARC application process
 - Eliminate Cr+6 Wash Primer on some high-hard steel vehicles
 - Navy and Army have achieved good success using Non-CCC coatings on Al 5083 and 7079 armor alloys



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Bradley Fighting Vehicle

Photo courtesy DoD Defenselink



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Alternatives Adopted

- ***Hard Chrome***
 - Electroless Ni, Ni-tungsten boron
 - HVOF coatings of tungsten carbide/cobalt coating on M1 Tank GTE components (e.g. compressor bearing housing)
 - Other wear resistant materials in several engine applications



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Difficult Uses to Change

- **CCC on Al electronics casings/housings (unprimed and unpainted). Must meet corrosion resistance and electrical conductivity requirements.**
- **Cr+6 chromate rinses on Cd and Zn plated fasteners on large number and variety of legacy systems. Piecemeal approach not productive and process changes need coverage identification method (color indicators provided with current Cr+6 rinses).**



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Next Targeted Changes

- **COTS non-Cr+6 pretreatments to replace CCC on non-2XXX Al alloys**
- **Elimination of chromate rinses on fasteners**
- **Adopting commercial automotive industry process changes to eliminate Cd and Cr+6 from vehicles - Need to meet DoD performance requirements and obtain commercial manufacturing equipment, licenses, and process descriptions**



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RDT&E Challenges

- **UHS steels cannot use Zn-based coatings. Al based coatings exhibit abrasive corrosion products.**
- **Uncoated steel fasteners could work, but must be affordable on life cycle basis.**
- **Stricter pretreatment process controls required for acceptable corrosion resistance to eliminate CCC for Al and steel components.**



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RDT&E Challenges

- **Capital equipment associated with zinc phosphating steel. Simple surface pretreatments (e.g. by painters) needed to reduce use of Cr6+ wash primer.**
 - Pretreatments need compatibility with broad range of MILSPEC coatings to meet upcoming NESHAP regulations.
- **Assess benefits of using Trivalent Chrome Plating (TCP) per MIL-C-5541, Type II, as fall-back post-treatment/sealer.**