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# Alternatives To Cadmium Plated Military Connectors and Fasteners

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# Outline

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- Undesirable Properties of Cadmium
- Desirable Properties of a Cadmium Plated Finish
- Industry Standard Connector Specifications
  - Cylindrical and Rectangular
  - Fastener specs
- Alternate Finish Reports and Industry Test Data
- Regulatory Agency Restriction of Cadmium
- Recommendations

# Undesirable Properties Of Cadmium

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- Cadmium is a Known Carcinogen
  - Inhalation of airborne cadmium dust particles is extremely hazardous
  - OSHA Personal Exposure Limit (PEL) of PEL of 5 micrograms/cubic meter in an 8 hour day
    - CA has even more stringent regulations (.005).
    - Higher PELs allowed for metal finishers, Ni-Cd battery mfgs & Cd refining operations
  
- Highly Regulated domestically and Internationally
  - Listed as a substance of very high concern (SVHC) by the EU REACH regulation
  - Additionally on NAS 411, NAVY PCCL, NAVAIR Chemicals of Concern, EPA 17, RoHS, etc
  
- Subject to Cadmium Bloom – highly toxic white corrosion product
  - Produced when cadmium is exposed to organic acids in an enclosed environment
  - shipping/storage containers. Avoid wood pallets which emit formic acid

# Undesirable Properties Of Cadmium

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- Subject to the spontaneous growth of Cadmium whiskers
- Sublimates in vacuum environments – prohibited in space applications
- Galvanically incompatible with Carbon Filled Composites
- Requires hydrogen bake out if plated on high strength steels to avoid hydrogen embrittlement metal fatigue/failure
- Poor Corrosion Resistance in Highly Acidic Environments

# Desirable Properties Of Cadmium

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- Sacrificial plating with good corrosion resistance (500-1000 hrs min neutral salt spray)
- Conductivity for EMI shielding, grounding, electrical bonding and lightning strike (2.5 milliohms max shell to shell resistance)
- Meets thermal shock, vibration, shock, humidity, EMI shielding, bending moment and other connector performance requirements
- Electroplated finish relatively thin (200-800 microinches)
  - On fine and coarse threads and complex geometries required for connectors and fasteners
  - Nickel under plate is typically used to increase wear and corrosion resistance
  - Industry electroplating specs are SAE AMS-QQ-P-416, NAS4160 and MIL-STD-870. See notes for application guidance
- Good thread lubricity (500 mating cycles min), non galling
- Predictable torque/tension on threaded fasteners, no thread lube required

# Desirable Properties Of Cadmium

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- Can meet coupling and uncoupling torque requirements after exposure to severe corrosion environments
  
- Galvanically compatibility with several other commonly used items
  - Cable shield materials (tin, silver and nickel)
  - Stainless steel coupling nut retaining rings
  - EMI spring fingers
  - EMI shielding gaskets
  - Aluminum mounting panels
  
- Non reflective finish preferable for military applications
  
- Finish can be marked with color bands for full mate indicator required on connectors, military P/N and date code, supplier mark
  - Resistance to solvents (oil, greases, fuels, aircraft de-icers, cleaners)
  - Marking remains permanent after normal use and exposure to solvents
  
- Finish provides good adhesive properties for paint, marking, and adhesives used to bond plastic inserts and silicone grommets used in connectors

# Cadmium Connector Specifications

- DLA and SAE have changed nearly every connector specification and slash sheet to add alternate finishes to cadmium:
  - MIL-DTL-38999 and associated slash sheets and MS sheets
  - MIL-PRF-28840 and associated slash sheets
  - MIL-DTL-26482 and associated MS sheets
  - MIL-DTL-83723 and associated slash sheets
  - MIL-DTL-22992 and associated MS sheets
  - MIL-PRF-83513 and associated slash sheets
  - MIL-PRF-24308 and associated slash sheets
  - MIL-DTL-83733 and associated slash sheets
  - MIL-PRF-28876
  - MIL-PRF-83513
  - SAE AS85049 and over 100 slash sheets
  - SAE AS50151. AS3400 and AS3450 sheets pending update.
- Problem. Not all connector specs have qualified sources available. Check the spec and the QPL or QPD prior to assuming availability

**Connector Manufacturer's are required to qualify alternate finishes**

# SAE AE8-C1 Connector Committee

## Recommended Alternate Finishes

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- 3 alternate military/aerospace grade connector finishes may be considered for replacement of cadmium plating on aluminum, stainless steel and composite connector bodies:

Nickel-Fluorocarbon (PTFE) - SAE AMS-2454

Zinc-Nickel (5-20% nickel) - ASTM B841, AMS2417

Pure Dense Aluminum - Mil-DTL-83488

- Connector suppliers use these 3 plating specs as a baseline. Each has their own recipe for thickness, underplate(s) to meet the performance required for connectors
- Zinc-Nickel and Aluminum connector finishes currently contain a hexavalent chromate seal – another known carcinogen
  - Non hex chrome seals are available but cannot currently meet mil spec performance
- Nickel-Fluorocarbon requires no supplementary chromate seal
- All 3 finishes are electrically conductive



# SAE AIR5919A Alternate Connector Finishes report

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- AIR5919 report was updated in July 2010
  
- Provides an alternate finish test data summary from 7 suppliers
  
- Suppliers tested their alternate finishes on connectors and accessories
  - Some alt finishes were mated to cadmium plated aluminum for galvanic compatibility after environmental testing for neutral (500-1000 hrs) and acidic (SO<sub>2</sub>, 336 hrs) salt spray corrosion tests after 500 mating cycles.
  - Shell to shell conductivity and coupling torque performance was also measured before and after environmental testing

# Alternative Connector Finishes

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- 38999 series III, class L, nickel plated stainless steel
  - Alternate finish option recently qualified by Amphenol
  - A weight, availability and cost penalty for using stainless steel connectors
  - Meets 500 hour salt spray, conductive finish
  
- Composite 38999 connectors (class J and M)
  - Available as an alternative to aluminum bodies
  - Available with nickel plating - good for severe corrosion applications which have a 2000 hour salt spray test rating
    - Compared to class W cadmium on aluminum at 500 hrs min.
  - Composites with aluminum, zinc-nickel and nickel-PTFE also available with finishes that meet 500 hrs min salt spray

# Misc Alternate Finish Reports/Papers

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- Strategic Environmental Research and Development Program (SERDP), Surface Engineering Database - ASETS Defense <http://www.asetdefense.org/databasesdescription.aspx>
- Advanced Materials, Manufacturing, and Testing Information Analysis center (AMMTIAC) <http://ammtiac.alionscience.com/>
- The Nuts & Bolts of Cadmium Plating Alternatives  
Automotive Finishing Online <http://www.afonline.com/articles/99sp01.html>
- Joint Strike Fighter report by Navair and Lockheed Martin
- Saab Bofors Dynamics report
- NDCEE/TARDEC report
- Amphenol Aerospace Operations report, SAE AEISS 2005
- Cadmium alternative papers <http://www.rowantechnology.com/technical-resources/papers-presentations/>. <http://www.asetdefense.org/Plating-Alternatives-2011.aspx>
- REACH information <http://echa.europa.eu/web/guest/regulations/reach/legislation>
- Testing Cadmium Alternatives for High Strength Steel Phase II Joint Test Report <http://www.alumiplate.com/wp-content/uploads/ST024-Testing-Cd-Alts-Phase-II-Joint-Test-Report.pdf>

# Fastener Spec Examples

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MS90353 Rivet (Aluminum alternative)

NAS18.2.1 Hex head bolt (Zinc alternative)

NAS1352 Socket head cap screw (no alts)

NAS1580 Bolt, shear (no alts)

NAS1130 helical insert (no alts)

NAS4452 Pin (no alts)

- Alternate finishes are not readily available from fastener suppliers
- Therefore, it may be necessary to:
  - Purchase Cadmium Plated Parts
  - Strip the Cadmium Finish
  - Re-plate using Alternative Finish
    - Bake out may be required to avoid hydrogen embrittlement

# Alternative Fastener Finishes

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- Dip Spin metal loaded organic and inorganic based (may not be suitable for grounding applications)
- LHE Alkaline Zinc Nickel with dry film lube
- Aluminum, Electroplated with dry film lube
- Aluminum, IVD with dry film lube
- Hot dip and electroplated Zinc
- Alternatives to steel (Titanium, Inconel, Nitronic 60 alloy, stainless A286 alloy)
- Nanotechnology finishes?

# Regulatory Agency Restriction Of Cadmium

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- Recent pressure from domestic and international US DoD (DFAR), US Dept of Labor, EPA, RoHS and REACH policies that restricts, control permissive exposure limits or bans the use of cadmium
- Restrictions are exempted by REACH in Annex XVII for cadmium for certain aeronautical, aerospace, mining, offshore and nuclear sector applications and for electrical contacts containing cadmium in any sector of use, on account of the reliability required of the apparatus on which they are installed.
- RoHS exempts Cadmium, Lead, Mercury, Hexavalent chrome from restrictions in military, space, active medical implant devices and other tools, machinery and equipment
- For many of these regulations, cadmium and hexavalent chromium, there must be less than 0.01% and 0.1% respectively of the substance by weight at the homogeneous materials level
- Cadmium is typically coated with a hexavalent chromate finish which is also a hazardous carcinogen
- Chemical conversion coatings and passivations containing hexavalent chrome are currently exempted by DFARS Part 223 and RoHS

# Recommendations For Further Studies

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- Galvanic Compatibility
  - All alternative connector finishes must be compatible with the cable assembly system
  - Insure full compatibility with cable shield materials, accessories and mounting panels
  - More field data and galvanic testing is required to build confidence in the alt finishes
  - Connector finishes are in direct contact with tin, silver, nickel, stainless steel retaining rings, aluminum panels and various EMI shielding gasket materials (monel mesh, metal particle filled elastomers)
  - SAE AIR4789 and AIR5919 are suggested for test plans and inspection criteria for connectors
  
- Define Galvanic data (EMF) for Electroless Nickel-PTFE
  - Need to understand why it performs better than Electroless Nickel in corrosion resistance
  
- Fastener Finishes Must Be....
  - Corrosion Resistant
  - Galvanically Compatible with Aluminum and Steel Mounting Panels/Hardware
  - Non-Galling with Low Coefficient of Friction
  - Durable
  - Economical,
  - Predictable torque/tension performance
    - Preferably similar to cadmium to avoid changing recommended torques creating a field service issue
  
- Fastener industry needs to revise specs to add alternate finishes
  
- Nanotechnology Finishes for Metals

# Backup

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# Chromate Finish

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- Hexavalent chrome, a known carcinogen, was targeted by DOD for prohibition on new system designs. DFARS Case 2009-D004 document was signed into law in May 2011. DFARS part #253.223-7008 later released to clarify exemptions. Chemical film finishes were not prohibited due to lack of available drop in replacements, but this will change as alternatives become available
- Hex Chrome has a PEL of 5 micrograms/cubic meter in an 8 hour day per OSHA
- Trivalent chrome and other non-chrome alternatives are available for some paint primers and paint applications but they are not drop in replacements for hex chrome based materials
- Color options very limited for non hex chrome alternates. Yellow and Olive drab color is not available. Trivalent chromates colors are at present only available in tan or blue-ish . Marking permanency on non hex chrome alternates is unknown. The mil spec connector marking is required to meet a resistance to solvents qualification test which is harsh on marking