

Testing Cadmium-free Coatings



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Focused Workshop on Cadmium Plating Alternatives

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Report Documentation Page

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- Department of Defense direction
- Fastener coating issues
- Past testing
- Present testing
- Future testing

- Office of the Secretary of Defense Directive
 - “Approve the use of alternatives [to hexavalent chromium (Cr^{6+})] where they can perform adequately for the intended application and operating environment.”
- Executive Order 13423
 - Ensures agency reduces toxic/hazardous chemicals and materials acquired, used, or disposed of

- Army Regulation AR 200-1
 - "Minimize the use of toxic and hazardous materials and processes in all life cycle phases of acquisition programs, logistics support, modification of existing weapons systems, and installation management."
- Compliance with environmental permits increase Army Depot's repair & waste treatment costs

- No drop-in replacement that mimics all of Cadmium's (Cd) properties
- Too many alternatives to test
- No central authority driving commonality
- Galvanic compatibility with legacy systems
- Friction and joint clamp load

➤ Metallic Platings

- Zinc (Zn)
- Nickel (Ni)
- Zinc Nickel (ZnNi)
- Tin Zinc (SnZn)

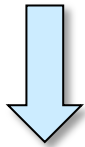
➤ "Paint-like" Coatings

- Zinc-Rich
- Magnesium-Rich
- Zinc Aluminum-Rich



***None of these match
all properties of Cd***

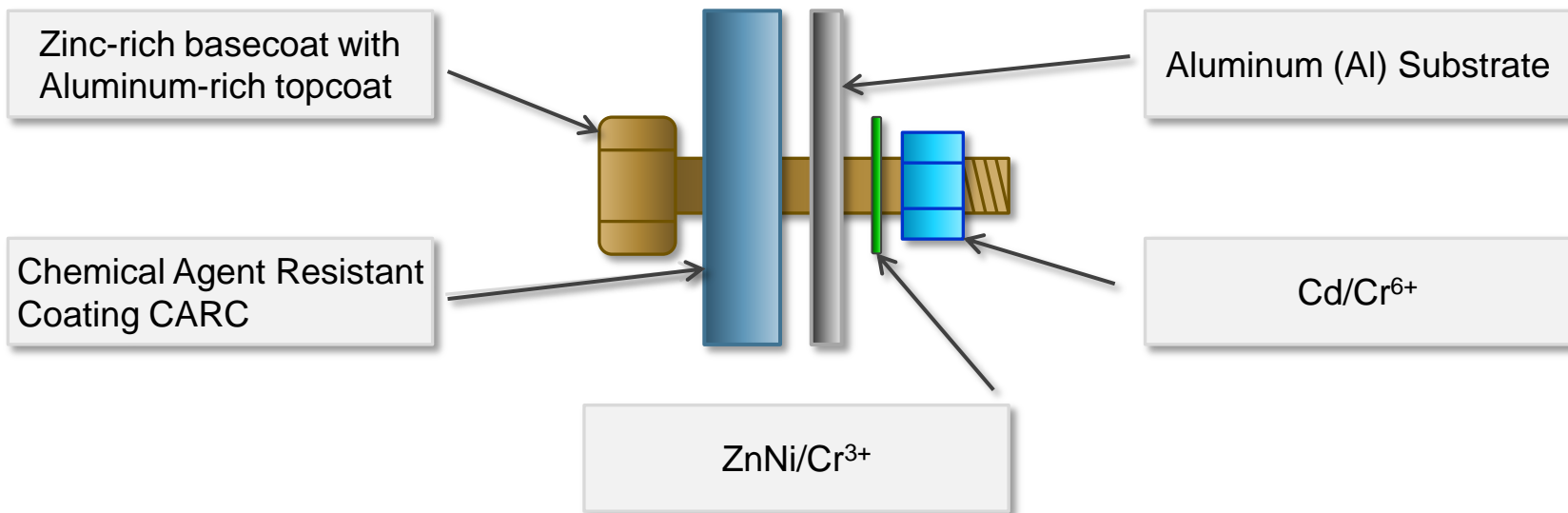
- Siloxane/Polysiloxane
- Silicate
- Polymer-based
- Zirconium-based



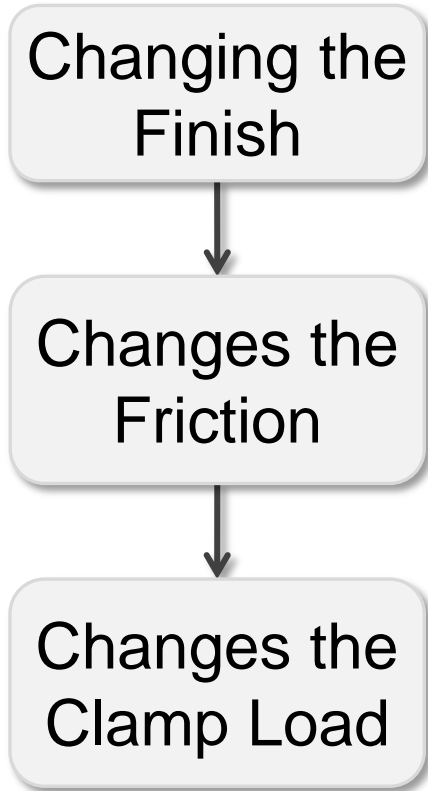
Either paint adhesion is reduced
Or
Corrosion protection is reduced

These passivation chemistries do not match all properties of Cr⁶⁺

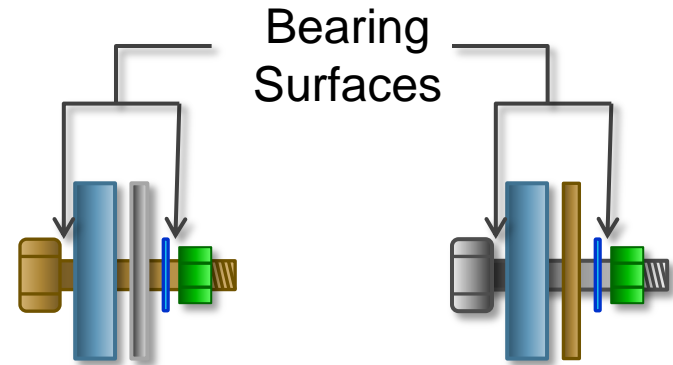
Risk of uncontrolled introduction of galvanic couples during sustainment



For the same torque...



Joint reliability



...changing finishes may result in inadequate clamp load, joint loosening, stripped threads, broken fasteners

- Threaded Fasteners
- Electrical Connectors

- Property Class Grade 8
 - 150 ksi tensile strength
 - 120 ksi min. proof load
- Sizes:
 - $3/8'' \times 3''$
 - $1/2'' \times 3''$
- Sample Size
 - Five for each test

- Six finishes evaluated for...
 - Torque at fixed clamp load (preload)
 - Effect of corrosion on rundown torque
 - Effect of corrosion on breakaway torque

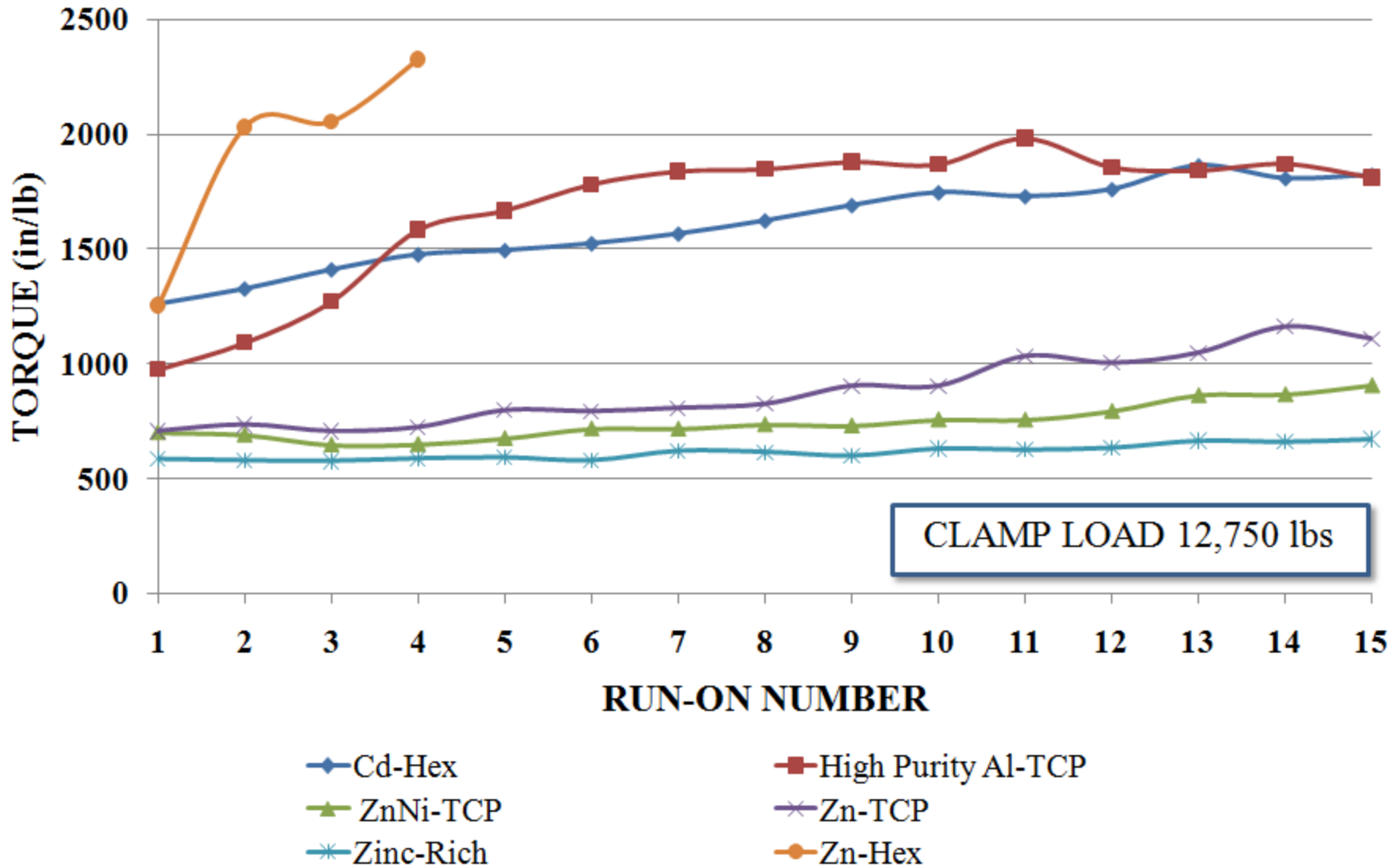
FINISH	POST-TREATMENT	LUBRICANT
Cadmium	Hexavalent Chromium (Cr ⁶⁺)	None
Zinc	Cr ⁶⁺	None
Zinc	Trivalent Chromium Process (TCP)	Enseal C22
Zinc Nickel	TCP	Enseal C22
High Purity Al	TCP	Enseal C22
Zn-rich two coat system	None	Integral to topcoate

Clamp Load 1/2" Fasteners Target vs Actual

Plating	Average Clamp Load (lb)	Target Clamp Load (lb)
Cd/Cr ⁶⁺	12,736	12,750
Zn/Cr ⁶⁺	12,759	12,750
Zn/TCP	12,737	12,750
Zn-Ni/TCP	12,749	12,750
High Purity Al/TCP	12,747	12,750
Zn-rich two coat system	12,751	12,750

Clamp Load $\frac{3}{8}$ " Fasteners Target vs Actual

Plating	Average Clamp Load (lb)	Target Clamp Load (lb)
Cd/Cr ⁶⁺	6,965	6,950
Zn/Cr ⁶⁺	6,963	6,950
Zn/TCP	6,915	6,950
Zn-Ni/TCP	6,923	6,950
High Purity Al/TCP	6,964	6,950
Zn-rich two coat system	6,965	6,950



Conclusions

- Torque value and clamp load within experimental error
- Corrosion performance equivalent or better
- Aluminum galvanic compatibility with legacy coatings
- High purity aluminum is closest to Cd

- Tested to MIL-DTL-38999
 - Corrosion, Salt Spray
 - Electromagnetic Compatibility (EMC) / Electromagnetic Interference (EMI)
 - Fluid Resistance
 - High Temperature Resistance
 - Mating and Un-mating Forces
 - Shell to Shell Conductivity
- Additional Tests
 - Corrosion, Cyclic
 - Corrosion, Scribed with Primer and Topcoat
 - Corrosion, Sulfur Dioxide
 - Durability in Humidity
 - Galvanic Corrosion Resistance (Compatibility)
 - Lubricity
 - Wear/Handling

Coatings

- Al / TCP
- ZnNi / TCP
- ZnNi / Non-Chrome Passivation (NCP)
- Ni-PTFE 1
- Ni-PTFE 2
- Note: SnZn tested on flat panels

Coated Coupons Run with Electrical Connectors	Vendor-Provided Coating Thickness Range (mils)	Average Measured Thickness (mils)
Cadmium / hex Cr	0.8 to 1.5	0.34
Al / TCP	0.6 to 1.0	0.03
ZnNi / TCP	0.8 to 1.5	0.93
ZnNi / NCP	0.7 to 1.2	0.89
SnZn / TCP	0.2 min.	0.33
SnZn / NCP	0.2 min.	0.42
Ni-PTFE*	(none provided)	1.55
PIN	0.8 to 1.5	1.38

*PTFE = Polytetrafluoroethylene

Coupons Run with Electrical Connectors	Vendor-Provided Coating Thickness (mils)	Average Measured Thickness (mils)
Cd/Cr ⁶⁺	0.8 to 1.5	0.34
Al / TCP	0.6 to 1.0	0.03
ZnNi / TCP	0.8 to 1.5	0.93
ZnNi / NCP	0.7 to 1.2	0.89
Ni-PTFE	(none provided)	1.55
PIN	0.8 to 1.5 per side	1.38
SnZn / TCP	0.2 minimum	0.33
SnZn / NCP	0.2 minimum	0.42

- High purity aluminum plated fasteners with TCP and electrocoat
 - Fluid resistance
 - Outdoor exposure
 - Torque-Tension testing
 - Lab cyclic corrosion test
- High purity Al coating on Stryker wheel stud and lugnut field exposure ongoing – threaded fastener

- Field testing confirms that electrodeposited, high purity Al outperforms zinc-rich coating
- HAZMAT reduced; performance improved
- Recommended single Cd replacement

Socket scuffing does not affect performance

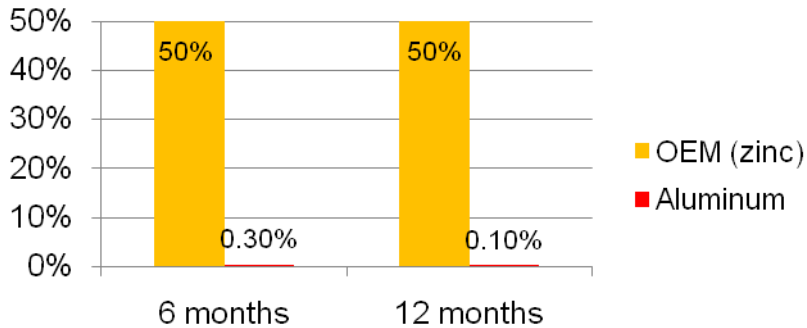


Aluminum-Plated Lugs



OEM Zinc-Rich

Max % Surface Area Covered by Corrosion



Aluminum-Plated Lugs
1 Year – RV-0259-05



OEM Zinc Lugs Nuts
1 Year – RV-0259-05

- Cyclic corrosion
 - Lab cyclic corrosion testing
 - Outdoor exposure at Army test site
 - Un-scribed and Scribed connectors?
 - Galvanic - all coating combinations
- EMC / EMI
- Shell-to-Shell Conductivity

- Fluid Resistance
- High Temperature Resistance
- Mating and Un-mating Forces
- Durability in Humidity
- Wear/Handling

- Coatings
 - Cadmium
 - Zinc-Nickel
 - High Purity Aluminum
 - Nickel/Composite Nickel
- Statistically significant sample sizes

- Significant body of work testing coatings for electrical connectors
- Receptive to adjusting this new work plan to avoid duplication

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