



Materials Engineering Branch, Code 622



# Cadmium Replacements for High Strength Steel Fasteners

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## Background

- Cadmium commonly used on steel fasteners
  - easy deposition, corrosion resistance, low CoF, solderable
  - probable human carcinogen
  - can cause anemia, emphysema, and bone, kidney & liver diseases
- Chromium (VI) commonly used as a post treatment on Cd
  - enhances corrosion resistance of cadmium
  - human carcinogen
  - can cause ulcers and lung cancer
- Cd & Cr impact on life cycle costs
  - satisfactory performance
  - operator exposure, environmental emissions
  - waste related processing



# Objectives

- Eliminate the use of electroplated Cadmium in high strength steel fastener applications
- Reduce and/or eliminate the use of Chromium in high strength steel fastener applications



## JTP Tests

- General Properties
  - appearance (visual inspection)
  - coating thickness (ASTM B487)
  - max temperature (24 hr exposure-visual inspection)
- Corrosion
  - SO<sub>2</sub> salt fog w/ & w/o defect (500 hr ASTM G85-A4) [fastener & panel]
  - cyclic wet/dry corrosion w/ & w/o scribe (160 cy GM9540P) [fstnr & pnl]
  - galvanic bi-metallic (GM9540P)
  - fluid w/ & w/o scribe [coupon]
- Adhesion
  - water boil (modified ASTM D3359 - A)
  - bend (ASTM B571) [pnl]
  - paint (dry & water immersion) (ASTM D3359 - B) [pnl]



## JTP Tests (continued)

- Assembly
  - breakaway torque w/ & w/o corr expos (ASTM G85-A4 & GM9540P)
  - fastener COF (1/3 & 2/3 YS, 3 cycles)
  - torque tension (30, 40, 50, 60, 70, 80, 90% YS, 5 cycles)
- Longevity
  - fatigue (NASM 1312-11) @  $70 \pm 30$  ksi mean stress w/ & w/o corr expos
  - stress durability (ISO 15330) @ 96 hr w/ & w/o corr expos
  - slow strain rate (ASTM F606) @ 0.001"/min w/ & w/o corr expos
  - strippability (MIL-S-5002D) [fstnr & pnl]
    - bend test after coating reapplication
    - stress durability (ISO 15330) @ 96 hr before & after ctg reapplic



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Test #	Test Name	Other Samples	Coated 4"x6" plate	Uncoated Fastener Systems	Coated Fastener Systems	GM 9540 Fastener Systems	ASTM G85 A4 Fastener Systems
3.1.1	Appearance	-	-	-	10	-	-
3.1.2	Coating Thickness	-	-	-	3	-	-
3.1.3	Maximum Temp.	-	-	-	3	-	-
3.2.1 3.2.3	Unscribed Corrosion Exposure	-	6	-	20	-	-
3.2.2 3.2.4	Scribed Corrosion Exposure	-	6	-	20	-	-
3.2.5	Galvanic Bi-Metallic Corrosion	45 washers	-	-	-	-	-
3.2.6	Fluid Exposure	120 coupons	-	-	-	-	-
3.3.1	Water Boil	-	-	-	3	-	-
3.3.2	Bend Adhesion	-	3	-	-	-	-
3.3.3	Paint Adhesion	-	9	-	-	-	-
3.3.4	Water Immersion Paint Adhesion	-	27	-	-	-	-
3.4.1	Breakaway Torque	-	-	-	10	10	10
3.4.2 3.4.3	COF Torque Tension	-	-	-	10** 10**	-	-
3.5.1	Fatigue	-	-	5	5	5	5
3.5.2	Stress Durability	-	-	10	10	10	10
3.5.3	Slow Strain Rate	-	-	10	10	10	10
3.5.4	Strippability	-	-	-	10	-	-



## JTP Status

- Draft issued 17 Mar 2004 and sent to 39 technical stakeholders/contributors
- 291 comments received and adjudicated
  - Eric Brooman (AFRL)
  - Joe Osborne (Boeing)
  - Harry Archer (NSWCIHD)
  - Ralph Adler (ARL)
  - Tim Tenopir (PHD NSWC)
  - Michael Kane (AMCOM)
  - Patrick Doyle (NAWCADLKE)
- Selected Issues
  - Zn vs Cad as control
  - Grade 8 (150 ksi) vs 180 ksi or 220 ksi fasteners
  - Use of dry film lubricants
  - Mandatory and service specific tests/requirements



## Preliminary Field Demo

- Fastener: 1.25” (length), 3/8” - 16 UNC grade 8, hex head cap screw
- Nuts installed/removed 5 times
- Fasteners torqued to 90% YS on 4142 plate
- 1 hr dwell, torque reapplication
- Installed on MTRV (Lejeune, NC; Kaneohe Bay, HI; Okinawa, Japan)



## Candidate Coating Systems

- Zn with Cr post treatment
- Zn with proprietary non Cr treatment
  - Cd originally planned
- Zn/Al Flake in inorganic binder with friction control TC
- Zn/Al Flake with Cr in inorganic binder with friction control TC
- ZnNi per SAE AMS2417E
- ZnNi with silicate surface conversion and black UV TC



KB #205



OK #201



KB #100



CL#118





## Torque Data

	<b>DFT (mils)</b>	<b>COF</b>	<b>Initial Torque (ft-lb)</b>	<b>Unexpos BA Torque (ft-lb)</b>	<b>1 Yr Fld Expos BA Torque (ft-lb)</b>	<b>BA Torque % Change</b>
<b>Zn w/Cr</b>	<b>~0.3</b>	<b>0.11</b>	<b>46</b>	<b>38</b>	<b>60</b>	<b>159</b>
<b>Zn w/NC</b>	<b>~0.3</b>	<b>&gt;0.08</b>	<b>50</b>	<b>41</b>	<b>47</b>	<b>113</b>
<b>Zn/Al</b>	<b>0.4-0.6</b>	<b>0.11</b>	<b>46</b>	<b>21</b>	<b>28</b>	<b>137</b>
<b>Zn/Al/Cr</b>	<b>0.2-0.5</b>	<b>0.11</b>	<b>46</b>	<b>22</b>	<b>28</b>	<b>125</b>
<b>ZnNi</b>	<b>0.3-0.5</b>	<b>0.08</b>	<b>70</b>	<b>62</b>	<b>58</b>	<b>94</b>
<b>Modified ZnNi</b>	<b>0.25</b>	<b>0.13</b>	<b>53</b>	<b>32</b>	<b>30</b>	<b>96</b>



## Slow Strain Rate Data

	DFT (mils)	Initial Unexposed UTS (ksi)	1 Yr Field Exposure UTS (ksi)	UTS % Change
Zn w/Cr	~0.3	166	164	98.4
Zn w/NC	~0.3	164	162	98.9
Zn/Al	0.4-0.6	170	169	99.3
Zn/Al/Cr	0.2-0.5	166	165	99.6
ZnNi	0.3-0.5	170	167	98.6
Mod ZnNi	0.25	170	161	94.6

Note: thread stress area based on ASTM F606,  $A_s=0.7854 [D-0.9743/n]^2$



## Conclusions

- Draft JTP issued
- Draft JTP reviewed by technical stakeholders
- Draft JTP comments adjudicated
- Field exposure test on operational USMC vehicles initiated
- 1 yr field exposure samples collected (analysis ongoing)
- Based on data collected to date:
  - ZnNi and modified ZnNi coatings appear to maintain lubricity
  - Zn w/NC and Zn/Al coatings are displaying the most surface corrosion
  - Hydrogen embrittlement has not been detected wrt coating application nor during field service
- Further JTP coordination on hold until endorsement by DOD