NDCEE

National Defense Center for Energy and Environment

Development of Cadmium and Hexavalent Chromium Free Electrical Connectors: Test Results

Margo Neidbalson, NDCEE/*CTC*

DoD Executive Agent

Office of the Assistant Secretary of the Army (Installations and Environment)

The NDCEE is operated by: CTC *Concurrent Technologies Corporation*

Technology Transition – Supporting DoD Readiness, Sustainability, and the Warfighter

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JUN 2010		**00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE
Development of Cadmium and Hexavalent Chromium Free Electrical Connectors: Test Results

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Defense Center for Energy and Environment (NDCEE),Concurrent Technologies Corporation,100 CTC Drive,Johnstown,PA,15904

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Presented at the NDIA Environment, Energy Security & Sustainability (E2S2) Symposium & Exhibition held 14-17 June 2010 in Denver, CO. U.S. Government or Federal Rights License

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**25**	

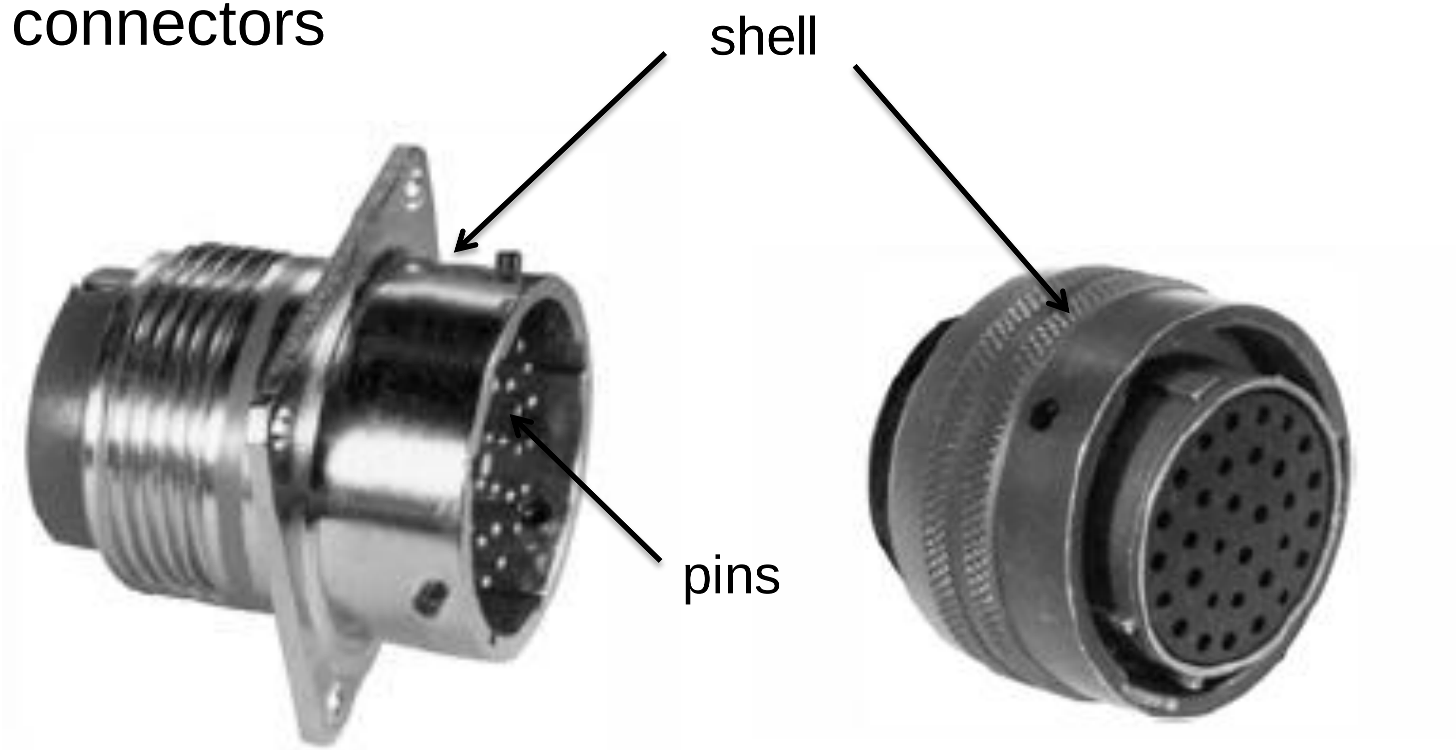
Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Presentation Outline

- Background
- Overview
- Test Plan
- Test Results – Phase I
- Test Results – Phase II
- Conclusions
- Summary

Background

- Focus on shell coatings of military grade electrical connectors



- Receptacle (wall mounting)
- Plug (straight)

Background (continued)

- Current and emerging regulations require consideration of alternative coating system
  - United States (U.S)
    - Executive Order (EO) 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*
      - Requires Government agencies to reduce quantity of toxic and hazardous chemicals and materials acquired, used, or disposed
    - Cadmium regulated as Hazardous Substance, Hazardous Air Pollutant, Hazardous Waste, Toxic Chemical, and Priority Pollutant (Clean Water Act)
    - Restrictions from
      - Occupational Safety and Health Administration
      - Environmental Protection Agency
  - European Union
    - U.S. military systems exempt BUT could govern part availability in near future
    - Restriction of Hazardous Substances Directive
    - Waste Electrical and Electronic Equipment

Overview

- Purpose
  - Selection and testing of alternative coatings for electrical connectors used in U.S. Army ground systems
- Goals
  - Compliance with EO 13423
  - Compliance with other current and emerging regulations
  - Reduction of total life cycle costs of connector shell coating systems

Test Plan

- Substrates, coatings, post-treatments
  - Candidate connector: MIL-DTL-38999 Series III Class W
    - Also test panels as available and needed
  - One substrate: 6061 aluminum
  - Control: cadmium with hexavalent chromium
  - Five cadmium alternatives
    - Electroplated aluminum (AlumiPlate®)
    - Electroplated zinc-nickel (ZnNi)
    - Electroplated tin-zinc (SnZn)
    - Composite electroless nickel (EN) - two types: Durmalon and Polymer Infused Nickel (PIN)
  - Two hexavalent chromium alternative post treatments
    - Trivalent chromium (TCP)
    - Non-chromate post-treatment (NCP)

Test Plan (continued)

- Phase I (testing as specified under MIL-DTL-38999)
  - Corrosion, Salt Spray
  - Electromagnetic Compatibility/Electromagnetic Interference Effectiveness
  - Fluid Resistance
  - High Temperature Resistance
  - Mating and Unmating Forces
  - Shell-to-Shell Conductivity

Test Plan (continued)

- Phase II (testing not specified under MIL-DTL-38999 but important to Army)
  - Corrosion, Cyclic
  - Corrosion, Scribed with Primer and Topcoat
  - Corrosion, Sulfur Dioxide
  - Durability in Humidity
  - Galvanic Corrosion Resistance
  - Lubricity (*NOTE: same as Mating and Unmating*)
  - Wear/Handling

Test Results – Phase I

- Coating Thickness

Panel Coating System	Vendor-Specified Coating Thickness Range (mils)	Average Determined Thickness (mils)
Cadmium / hex Cr	0.8 to 1.5	0.34
AlumiPlate / 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 minimum	0.33
SnZn / NCP	0.2 minimum	0.42
Durmalon	*(none provided)*	1.55
PIN	0.8 to 1.5	1.38

Test Results – Phase I (continued)

- Coating Thickness (continued)
  - Cadmium met MIL-DTL-38999 requirements
  - AlumiPlate was very low
    - Readings may not be accurate due to method used
  - Remaining candidates had acceptable coating thicknesses

Test Results – Phase I (continued)

- Corrosion, Salt Spray
  - Cadmium performed well on all specimens, met MIL-DTL-38999 requirements
  - AlumiPlate and two composite nickel candidates performed well on coated panels, similar to cadmium
  - AlumiPlate did not perform well on unmated connectors
  - Neither PIN nor AlumiPlate passed mating/unmating
  - Both versions of SnZn (TCP and NCP) failed on panels
  - Both versions of ZnNi (TCP and NCP) failed all three tests

Test Results – Phase I (continued)

Test Results – Phase I (continued)

Test Results – Phase I (continued)

Test Results – Phase I (continued)

TIN ZINC NON CHROME PANEL
ASTM B117 - 500 HOURS
RINSED AND CLEANED

TIN ZINC TCP PANEL
ASTM B117 - 500 HOURS
RINSED AND CLEANED

Test Results – Phase I (continued)

- Electromagnetic Compatibility/Electromagnetic Interference Effectiveness
  - Not conducted under this effort
- Fluid Resistance
  - All specimens passed
- High Temperature Resistance
  - All specimens passed except ZnNi with TCP
    - Shell-to-shell readings varied widely before and after exposure
    - Coating flaked off after high temperature exposure

Test Results – Phase I (continued)

- Mating and Unmating
  - All specimens met MIL-DTL-38999 requirements
  - AlumiPlate and ZnNi with TCP demonstrated characteristics closest to cadmium
- Shell-to-Shell Conductivity
  - All specimens passed except ZnNi with TCP
    - Readings varied widely, usually greater than 5 millivolt limit

Test Results – Phase II

- Corrosion, Cyclic
  - Shell-to-shell conductivity
    - All specimens passed before and after exposure
  - Coupling torque
    - AlumiPlate, ZnNi, and PIN specimens did not pass mating/ unmating requirements on mated connectors

Test Results – Phase II (continued)

- Corrosion, Scribed with Primer and Topcoat
  - AlumiPlate, ZnNi with TCP, both types of SnZn specimens (TCP and NCP) exhibited performance similar to cadmium
  - Durmalon, PIN, and ZnNi with NCP specimens exhibited failure with total coating delamination
    - Non-aggressive pretreatment employed (acetone wipe) to ensure TCP/ NCP post-treatments would not be degraded
    - Pretreatment likely insufficient to remove tenacious oxide that tends to form on surface of nickel coatings

Test Results – Phase II (continued)

- Corrosion, Sulfur Dioxide
  - Appearance - cadmium was best performer, followed by ZnNi with TCP
  - Shell-to-shell – all specimens passed
  - Note: fluid gets into connector, increases conductivity
- Durability in Humidity
  - All specimens passed

Test Results – Phase II (continued)

- Galvanic Corrosion Resistance
  - Test methodology was revised due to material availability - candidate receptacles were mated to a cadmium plug
  - All specimens passed shell-to-shell conductivity
  - All specimens exhibited very minimal corrosion after 168 hours of exposure, except ZnNi with NCP
- Wear/ Handling
  - All candidates passed except two SnZn coatings (TCP and NCP) which failed (total loss of adhesion)

Conclusions

- Performance ranked vs. cadmium
- Key findings
  - No candidates demonstrated performance as good as or better than cadmium in all tests
  - AlumiPlate, two composite nickels (Durmalon and PIN), and ZnNi with NCP generated highest ratings
    - Dry film lubricant required for AlumiPlate to meet the torque tension requirements
    - Durmalon and PIN coatings require more aggressive pretreatment for painting applications
- Note: One of the composite nickels (Durmalon) approved for 38999 in March 2010

Conclusions (continued)

- Key findings (continued)
  - ZnNi with TCP demonstrated unusually poor and inconsistent performance, particularly with respect to coating adhesion and shell-to-shell characteristics
  - Both SnZn (TCP and NCP) demonstrated unusually poor and inconsistent performance, failed nearly all tests
- Evaluation of alternative coatings should include testing that correlates to field conditions
- Note: Team is confirming that none of the alternative coatings received supplemental post-treatments

Summary

- Current and future environmental regulations will restrict the use of cadmium and hexavalent chromium on electrical connector shells
- To meet this need, this effort has
  - Identified the most commonly used electrical connector design in the inventory (based on data sets provided)
  - Identified five promising candidates to replace cadmium
  - Identified two promising candidates to replace hexavalent chromium
  - Developed a test plan to assess candidate performance for this application
  - Conducted testing to identify best candidates

National Defense Center for Energy and Environment

DoD Executive Agent

Office of the Assistant Secretary of the Army (Installations and Environment)

www.ndcee.ctc.com

Points of Contact

NDCEE Technical Monitor

Name: Ms. Pam Khabra
Organization: U.S. Army TARDEC
E-mail: parminder.khabra@us.army.mil
Phone Number: (586) 282-5954

NDCEE Project Contact

Name: Ms. Margo Neidbalson
Organization: *CTC*
E-mail: neidbalm@ctc.com
Phone Number: (814) 269-6402

This work was funded through the Office of the Assistant Secretary of the Army (Installations and Environment) and conducted under contract W74V8H-04-D-0005 Task 0470. The views, opinions, and/or findings contained in this paper are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision unless so designated by other official documentation.