



# *NDCEE*

National Defense Center for Energy and Environment

## Cadmium and Hexavalent Chromium Free Electrical Connectors: A Synergistic Approach



**DoD Executive Agent**

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

Robert B. Mason  
NDCEE, Johnstown, PA and Largo, FL

2009 Environment, Energy & Sustainability Symposium  
Denver, CO – May 2009

The NDCEE is operated by:  *Concurrent Technologies Corporation*

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

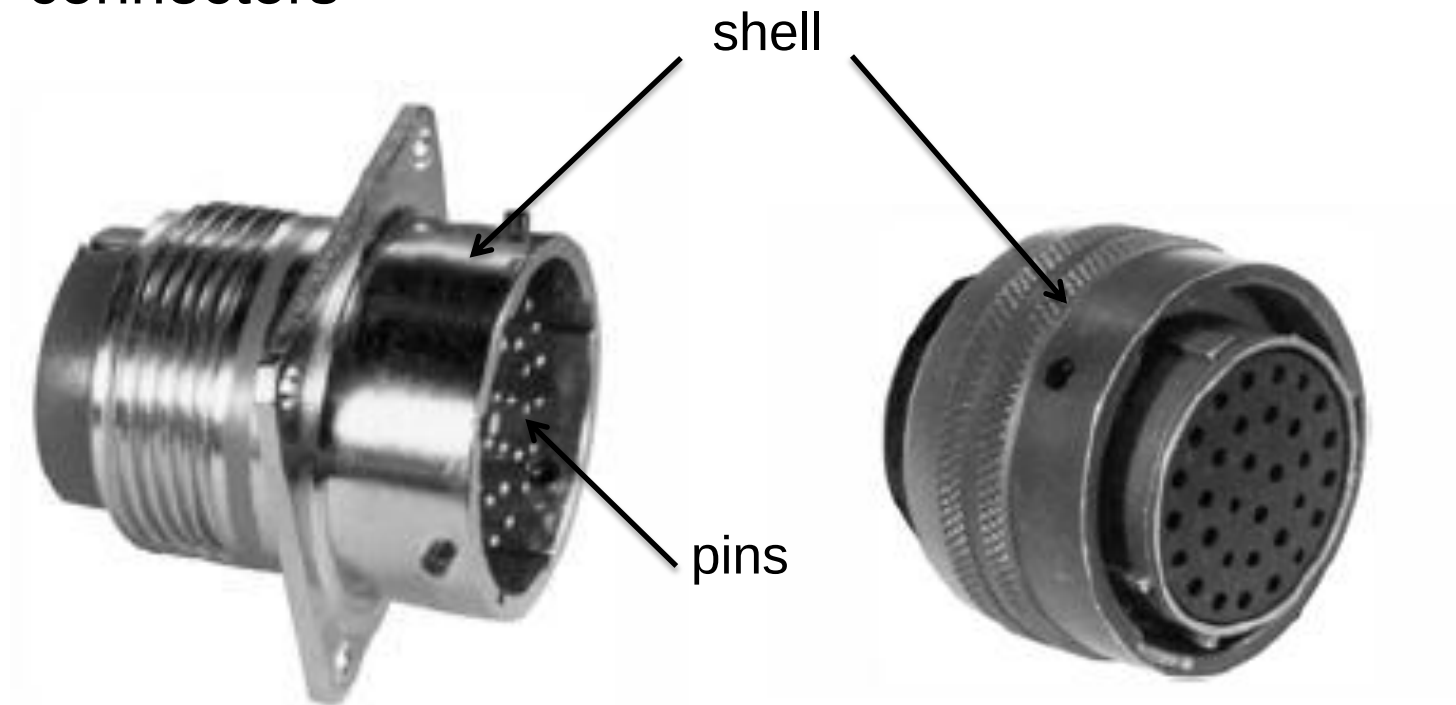
| Report Documentation Page                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |                                     |                                                           | Form Approved<br>OMB No. 0704-0188                  |                                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|-------------------------------------|-----------------------------------------------------------|-----------------------------------------------------|---------------------------------|
| Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. |                                    |                                     |                                                           |                                                     |                                 |
| 1. REPORT DATE<br><b>MAY 2009</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                    | 2. REPORT TYPE                      |                                                           | 3. DATES COVERED<br><b>00-00-2009 to 00-00-2009</b> |                                 |
| 4. TITLE AND SUBTITLE<br><b>Cadmium and Hexavalent Chromium Free Electrical Connectors: A Synergistic Approach</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                    |                                     |                                                           | 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)<br><b>National Defense Center for Energy and Environment (NDCEE), Concurrent Technologies Corporation, 100 CTC Drive, Johnstown, PA, 15904</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                    |                                     |                                                           | 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<br><b>Approved for public release; distribution unlimited</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                    |                                     |                                                           |                                                     |                                 |
| 13. SUPPLEMENTARY NOTES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                    |                                     |                                                           |                                                     |                                 |
| 14. ABSTRACT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                    |                                     |                                                           |                                                     |                                 |
| 15. SUBJECT TERMS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                    |                                     |                                                           |                                                     |                                 |
| 16. SECURITY CLASSIFICATION OF:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     | 17. LIMITATION OF ABSTRACT<br><b>Same as Report (SAR)</b> | 18. NUMBER OF PAGES<br><b>23</b>                    | 19a. NAME OF RESPONSIBLE PERSON |
| a. REPORT<br><b>unclassified</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | b. ABSTRACT<br><b>unclassified</b> | c. THIS PAGE<br><b>unclassified</b> |                                                           |                                                     |                                 |

# Presentation Outline

- Background
- Overview
- Identification of Army's Electrical Connector Requirements
- Review of Previous Efforts to Identify Cadmium/Hexavalent Chromium Alternatives
- Development of Test Plan
- Status and Future Activities
- Summary

# Background

- Focus on shell coatings of military grade electrical connectors

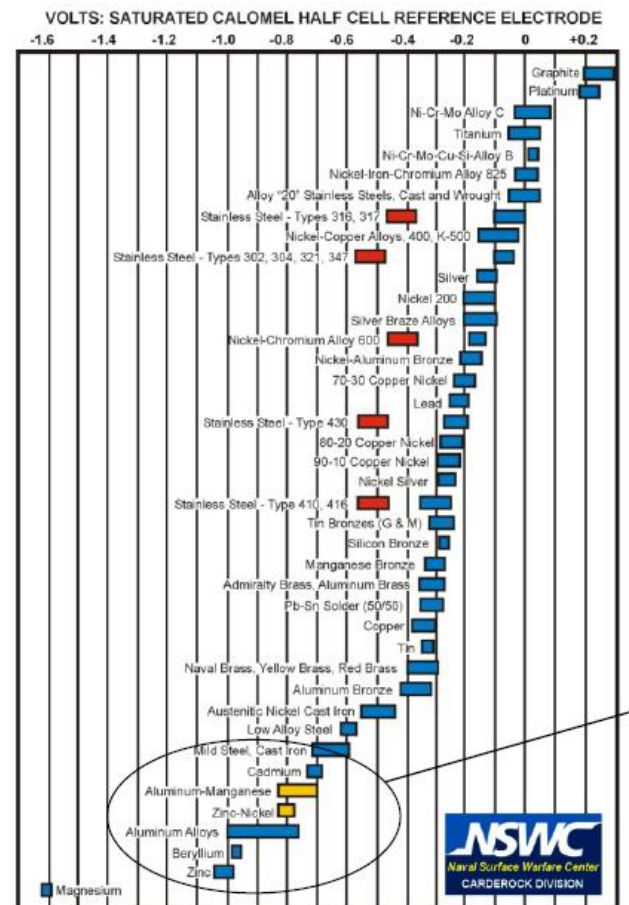


- Receptacle (wall mounting)

- Plug (straight)

# Background (continued)

- Shells currently coated with cadmium plating and hexavalent chromium topcoat
  - Imparts numerous engineering properties in synergistic fashion
    - Corrosion resistance
    - Ease of manufacturability
    - Electrical conductivity
    - Electromagnetic compatibility
    - Inhibition of algae growth
    - Lubricity
    - Repairability
    - Shock resistance
    - Solderability
    - Temperature resistance
    - Vibration resistance



# 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

# Identification of Army's Electrical Connector Requirements

- Part numbers provided by TARDEC for four weapons systems
- Databases employed to obtain
  - Drawings (as available)
  - Procurement specification (as available)
  - Shell coating (cadmium, electroless nickel [EN], etc.)
  - Quantities procured (and dates)



# Identification of Army's Electrical Connector Requirements (continued)

- Analysis – most commonly used connector types, by spec



CHAMPION: MIL-DTL-38999/26, class W  
connectors

# Review of Previous Efforts to Identify Cadmium/Hexavalent Chromium Alternatives

- Past Work to Demonstrate Alternatives
  - NDCEE
  - Strategic Environmental Research and Development Program (SERDP)
  - Environmental Security Technology Certification Program (ESTCP)
  - Joint Group on Pollution Prevention (JG-PP)
  - Joint Cadmium Alternatives Team (JCAT)
  - Defense Logistics Agency (DLA)
  - Concurrent Technologies Corporation (CTC)
  - Electrical Connector Manufacturers

# Review of Previous Efforts to Identify Cadmium/Hexavalent Chromium Alternatives (continued)

- Findings - Viable Alternatives to Cadmium
  - Advanced Materials
  - Aluminum-Manganese Molten Salt Bath
  - Aluminum Deposited Through Chemical Vapor Deposition
  - Electrodeposited Aluminum (AlumiPlate®)
  - Electroplated Tin-Zinc (SnZn)
  - Electroplated Zinc-Cobalt (ZnCo)
  - Electroplated Zinc-Nickel (ZnNi)
  - Aluminum Deposited Through Ion Vapor Deposition
  - Metal-Filled Paints and Ceramics
  - Sputtered Aluminum

# Review of Previous Efforts to Identify Cadmium/Hexavalent Chromium Alternatives (continued)

- Findings - Viable Alternatives to Hexavalent Chromium Topcoats
  - Trivalent chromium processes
  - Non-chromate processes
- *INITIAL* most promising cadmium alternatives for electrical connector applications
  - Electrodeposited Aluminum (AlumiPlate®)
  - Electroplated ZnCo
  - Electroplated ZnNi
- All three already approved for use on MIL-DTL-38999 connectors (*at least at first.....*)

# Review of Previous Efforts to Identify Cadmium/Hexavalent Chromium Alternatives (continued)

- ZnCo removed from consideration
  - Questionable corrosion resistance, especially at high temperatures
  - Removed from MIL-DTL-38999
- SnZn added
  - Based on some previous promising results
  - Client requested non-nickel candidate
- Also added two types of EN-polytetrafluoroethylene (PTFE) processes
  - Already approved for use on MIL-DTL-38999 connectors
  - Do not require topcoat

# Review of Previous Efforts to Identify Cadmium/Hexavalent Chromium Alternatives (continued)

- Data Gap Analysis
  - Electrodeposited Aluminum (AlumiPlate®)
    - Approved for MIL-DTL-38999 (and MIL-DTL-5015)
    - Cyclic corrosion testing not done
    - Some further durability testing would be useful
    - Other gaps identified but may be filled with 38999 qualification testing

# Review of Previous Efforts to Identify Cadmium/Hexavalent Chromium Alternatives (continued)

- Data Gap Analysis (cont.)
  - Electroplated ZnNi
    - Approved for MIL-DTL-38999 (and MIL-DTL-5015)
    - Relatively mature process – lots of general data exists
    - Cyclic corrosion, durability, electrical and mechanical data are gaps
    - Dezincification has been an issue in past studies
  - Electroplated SnZn
    - *No approval for MIL-DTL-38999*
    - Prior data somewhat inconsistent
      - Older formulations did not yield consistent alloy composition
      - Newer formulations may have alleviated issue

# Review of Previous Efforts to Identify Cadmium/Hexavalent Chromium Alternatives (continued)

- Data Gap Analysis (cont.)
  - Composite EN (with PTFE)
    - Approved for MIL-DTL-38999
    - Currently undergoing qualification testing (manufacturers)
    - Cyclic testing, other important parameters outside of 38999 testing not being considered
    - Galvanic corrosion resistance questionable



# Development of 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 ZnNi
    - Electroplated SnZn
    - Composite EN (two types)
  - Two hexavalent chromium alternative post treatments
    - Trivalent chromium
    - Non-chromate post-treatment (as available)

# Development of Test Plan (continued)

- Proposed tests – Phase 1 (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

# Development of Test Plan (continued)

- Proposed tests - Phase 2 (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
  - Wear/Handling

# Status and Future Activities

- |                                       |                   |
|---------------------------------------|-------------------|
| ■ <b>Procure test specimens</b>       | <b>April 2009</b> |
| ■ <b>Initiate testing</b>             | <b>April 2009</b> |
| ■ <b>Draft test report and submit</b> | <b>March 2010</b> |
| ■ <b>Final report</b>                 | <b>May 2010</b>   |

# 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
- Specimen procurement and testing is currently underway

# Acknowledgements

- **NDCEE Executive Agent** Mr. Tad Davis, DASA (ESOH)
- **NDCEE Program Director** Mr. Hew Wolfe, ODASA (ESOH)
- **NDCEE Program Manager** Mr. Tom Guinivan, ODASA (ESOH)
- **NDCEE Contracting Officer's Representative** Mr. Tom Moran, ODASA (ESOH)
- **Government Technical Monitor** Ms. Parminder Khabra, TARDEC-RDECOM
- **Government Technical Advisor** Mr. Carl Handsy, TARDEC-RDECOM
- **NDCEE Project Manager** Ms. Margo Neidbalson, NDCEE

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

# For Further Information

Pam Khabra  
U.S. Army TARDEC  
[Parminder.khabra@us.army.mil](mailto:Parminder.khabra@us.army.mil)

Robert Mason  
Concurrent Technologies Corporation  
7995 114<sup>th</sup> Avenue  
Largo, FL 33773  
Phone: (727) 549-7246  
[masonr@ctc.com](mailto:masonr@ctc.com)

NDCEE website:  
<http://www.ndcee.ctc.com>

# Thank you for your attention!



## Questions?