May 16, 2005

Summary of Joint Hard Chrome Alternative Team (HCAT) and Joint Cadmium Alternative Team (JCAT) Conference held 15 – 17 March 2005 in Greensboro, NC

A joint HCAT and JCAT meeting was held in Greensboro, NC to discuss status of projects for chromium and cadmium alternatives. Bruce Sartwell, Naval Research Laboratory (NRL) was lead for HCAT efforts, and Erin Beck, Patuxent Naval Air Station was lead for JCAT efforts. A summary of the JCAT portion of the meeting is given below.

Joint Cadmium Alternatives Team (JCAT) Efforts

Ms. Erin Beck provided the group with an overview of JCAT efforts. The project was initiated in April 1999 per request of JG-PP and ESTCP to effectively monitor all Cadmium Alternative efforts ongoing within DoD. Efforts were to leverage from Cadmium Alternatives for Corrosion and Lubricity Application on Low Strength Steels – (BISDS) project, in which the final report is posted on JG-PP website (www.jgpp.com). Also posted to the website is the Final Report from the Air Force on their Screening of Cadmium Alternatives (which includes embrittlement and adhesion test results).

1) **Cad Alternatives JTP for High Strength Steel Landing Gear and Structural Components**

The Joint Test Protocol (JTP) was approved in July 2003 (and can be found on JG-PP website) and execution is underway. Alternatives being evaluated include: Zinc-Nickel (acid), Tin-Zinc, Aluminum Manganese, Electroplated Aluminum, Sputtered Aluminum. LHE Cadmium and IVD Aluminum as Controls. JTP testing is broken into three phases and only viable alternatives will continue to next phase of test. NOTE: JTP execution was delayed for almost 1 year due to funding/contract issues.

- Phase I testing includes hydrogen embrittlement/re-embrittlement and bend adhesion and is underway. Stakeholders agree that these are key test for high strength steel and good starting point to determine viable alternatives. An Interim Joint Test Report is planned for Spring 2005. Only viable alternatives will continue to Phase II testing.
- Phase II testing includes more common tests such as appearance, strippability, galvanic corrosion resistance, etc. Testing is scheduled to begin in Summer 2005. Again, only viable alternatives will continue to Phase III testing.
- Phase III testing includes fatigue test which are very costly and scheduled to begin in 2007.

Additional “Service specific” testing requirements have been identified and are to be completed/funded by that service. Field demonstrations on non-flight critical components are expected to begin in the Spring 2006 through 2008. Deploy coatings on flight critical components is scheduled to begin Spring 2007 thru 2008.

2) **Cad Alternative JTP on High Strength Steel Fasteners**

Mr. Tony Eng (NAVSEA) is Technical Lead for this project effort. Currently this project effort is unfunded by ESTCP due to lack of committed/interested stakeholders for transition. Mr. Eng reported that a JTP has been drafted and reviewed by current stakeholders and will be finalized when additional stakeholder and funding is provided.

Mr. Eng reported on some preliminary field demonstrations on MTVR (Marine Corp Truck) using materials supplied/on-hand. Various fasteners were bolted onto a test panel and attached to the truck for exposure to environmental elements. Results show that Zinc-Nickel and Zinc Nickel Modified coatings look promising as alternatives to cadmium.

3) **Cad Alternatives on Electrical Connectors**

Ms. Beck stated that this project effort is currently unfunded as ESTCP Board Members are seeking additional stakeholder commitment/intent to implement alternative. Mr. Michael Miller (CTC) has drafted a JTP and ready for review/comment once additional stakeholders have been identified. Ms. Beck noted that Lockheed Martin and Amphenol are working in parallel to this effort. Ms Beck added that the SAE Electrical Connector Subcommittee AE 8C1 has determined to date that no alternatives met all performance criteria of MIL-DTL-38999. As a result, a Task Team has been formulated to be more proactive in evaluating/testing more alternatives. Test data is compiled by the committee can be found in SAE document SAE AIR 5919.

Mr. Rossi (Lockheed Martin –F35 (JSF)) stated that JSF platform designed out the use of banned/restricted materials and was not allowed to use Cadmium, Chrome, Nickel on any of its components for the LRIP phase of acquisition (which is scheduled to begin by the end of 2005). To date, Alumniplate looks promising. Final testing phase began in Nov 04 and plans are to continue to investigate Alumniplate and TTH Teflon.

Mr. Shelper (Amphenol) has been working for 5 years on alternatives to cadmium for electrical connectors and provided results of Round 3 testing. They plan to continue evaluating 3 coatings: Ni-Teflon, Alumniplate, Zinc-Ni (generation #5).

4) **Cad Alternatives on Springs –**

Ms Beck reported that there are no efforts underway at this time. If interested, please contact her to discuss.

5) **Cad Alternative Conversion Coating Study**

Dr. Kate Horspool (NAVAIR PAX) provided an update on efforts to demonstrate/validate the performance of trivalent chrome process (TCP) and non-chrome process (NCP), which NAVAIR has developed as an alternative post-treatment to hexavalent chrome on cadmium replacement sacrificial coatings such as IVD Aluminum, acidic zinc-nickel, and bright zinc on high strength steels.

The benefit of TCP over Chromated Conversion Coating is that it has no hexavalent chrome (CrVI) and reduced total chrome. The benefit of NCP is the elimination of chromium to the process. With optimization, non-CrVI post treatments have been found to provide corrosion protection that surpasses specifications and equals CrVI containing post-treatment performance on various cadmium replacement coatings.

To date, optimization of activation, temperature, and immersion times have been completed. Field test components have been identified. Current efforts include demonstrating the process at NADEP Cherry Pt (Mr. Kestler is POC). The next step will be to treat actual components and field demonstrations over a two-year period. The AV-8B and H-46 platforms have been identified as good candidates for field-testing.

Plans are underway to test TCP and NCP with non-chromate primers. NAVAIR requires a "Step" approach to document changes in process and confirm integrity of component is not compromised.

6) **Atmospheric Pressure Chemical Vapor Deposition (APCVD)**

Mr. Allman (AFRL) provided update on the new SERDP 04-07 (PP-1405) to investigate the use of APVCD to produce aluminum coatings of high quality on high strength steel components. A JTP is being drafted and Dr. Kate Horspool (NAVAIR PAX) is developing test requirements and performing tests for NAVAIR.

The CVD process is well established for a wide range of coatings, high vacuum chambers are not required, it is a simple non-line of sight process, aluminum deposits are formed at a relatively low temperature, and hydrogen embrittlement is avoided.

To date, the bench-scale reactor was set up and checked out and N2 reactor flushing equipment has been installed. Work planned this quarter is to connect the precursor tank to the CVD reactor, conduct flow rate calibration for precursor, deposit aluminum on steel coupons and begin preliminary coating characterization.

7) **Magnetron Aluminum Sputtering as Alternative to Cadmium Plating**

Major Allman (AFRL) provided update on their efforts to investigate the feasibility of using PVD/magnetron sputtering to deposit improved aluminum and hard coatings as replacements for cadmium and electroplated hard chrome (EHC). Project is in four phases over a three year period using internal AF funding. Contract was initiated in June 2004. Technical and Management work plan has been approved by AFRL. Coatings being considered are Aluminum (dense, pore free), Al-Mo ($\leq$ 40%), Al-Mg ($\leq$ 44%), Al-W ($\leq$ 20%). Screen test plan has been approved. Testing, sample, and coating parameters have been defined. Plans are to obtain coated sampled and perform screen testing, analyze data and prepare a Phase I Final Report for AF review. This will be the decision point for continuing into Phase II.

Currently, Hill AFB is the only site that has a Magnetron Aluminum Sputtering process up and running in conjunction with IVD Aluminum process. This enables the coating of internal and external components in the same chamber.

NADEP Jacksonville is pursing this technology as well. However, additional funding is needed to purchase the equipment for an existing IVD Aluminum chamber and demonstrate/validate the technology on various aircraft components.

8) **Electrolytic Plasma Process (EPP) for Cleaning and Cadmium Replacement**

Mr. Bruce Sartwell (NRL) is Technical Lead for this effort. The SERDP FY05-08 project was initiated in Aug 04. Mr Cid Richards (NADEP NI) is participant and demonstration site. EPP is an aqueous process involving the electrolysis of liquid by high potential and production of plasma at or in the vicinity of the cathode (workpiece). This technology is to be used for surface cleaning and/or surface preparation for coating applications and application of coatings exhibiting properties equivalent or superior to cadmium plating on high strength steel. Project is broken out into three year technical studies approach as follows:

Year 1- Cleaning and coating study – study the deposition of Zinc-Aluminum alloy and Zinc-(Al-O/OH) composite coatings by varying process parameters to determine effects on composition and required performance characterization

Year 2 - Measure performance characterization – measure performance characterization of coatings in comparison to cadmium plating and determine effects on base high strength steel material.

Year 3 - Design (scale-up) for demonstration at Depots – If first two efforts are successful, demonstrate process for cleaning and coating of external and internal surfaces and complex geometries. Also demonstrate process on selected components obtained from the Depots, and generate conceptual design of prototype EPP cleaning/coating system that could be utilized as a demonstration unit at a repair depot.

9) **Alumiplate and Sermetel 249/273 evaluation by Goodrich**

Mr. Doug Deeken spoke about Goodrich's intention to use Alumiplate's electroplated aluminum coating on F-35 landing gear. The coating has <10% coating thickness variation. Goodrich's evaluation of Alumiplate's coating include the tests outlined in the Cd alternatives JTP for high strength steels. The issue was raised that military depots would probably not install Alumiplate equipment to rework components due to the hazardous nature of the process. Goodrich is talking with major finishing houses to encourage them to install Alumiplate process equipment.

10) **Cadmium alternatives on the C-17 program**

Ms. Mary Gilman presented information on Boeing's effort to qualify sputtered aluminum to coat the internal diameter of C-17 axles. The effort includes qualify Hill AFB to coat C-17 axles and 22 other components with IVD aluminum and sputtered aluminum. Ms. Gilman also presented screening test data on a low hydrogen embrittlement alkaline zinc-nickel coating developed by Dipsol Gumm. Boeing St. Louis is scaling up the most promising formulation.

Mr. Steve Gaydos presented test data on the sputtered aluminum coating as evaluated for the C-17 program. The sputtered aluminum coating passed all MIL-DTL-83488 Class 2 Type 2 requirements. For hydrogen embrittlement: needs coat of epoxy primer to pass DI water re-embrittlement test, needs primer and topcoat to pass re-embrittlement salt water test. Brush tin-zinc looks promising as a repair alternative due to good corrosion and hydrogen embrittlement results.

11) **High-strength corrosion resistant steel**

Mr. Craig Edwards presented information on ESTCP project PP-0304, which is to demonstrate/validate a high strength stainless steel for landing gear as a replacement for 300M. The steel manufacturer is Questek and the alloy designation is S-53. March 2007 is target date to have a qualified landing gear part. The part would be passivated, primed and painted. There is a JTP they are using to evaluate the alloy. A goal is to get S-53 into MIL-HBK-5, they are working with DARPA to fastrack.

12) **Cadmium alternatives Joint Test Report for low strength steel lubricity and threaded components**

Dr. Joe Osborne reviewed the test results from the cadmium alternatives JTP executed for low strength steel for lubricity and threaded component applications. The JTP was intended as a sort of screening test in preparation for the high strength steel effort. Both the JTP and JTR can be downloaded from the JGPP website (www.jgpp.com).

13) **Zinc-Nickel coating development at Boeing Seattle**

Dr. Joe Osborne presented work that Boeing Seattle has been doing to develop a low hydrogen embrittlement alkaline zinc nickel process. This process is different from the Dipsol Gumm process reported on above that Boeing St. Louis is working on. The Boeing Seattle process is in early development and has scaled-up to an 85-gallon tank. Boeing qualification tests will include hydrogen embrittlement and re-embrittlement.

Boeing Seattle's acidic zinc-nickel process is currently undergoing an aging study and has been scaled-up to 1000 gallons. The coating does not pass the DI water re-embrittlement test consistently.

Boeing Seattle is looking at zinc-nickel on fasteners and gearbox splines, and development of low hydrogen embrittlement brush zinc-nickel. The Boeing 787 will be a green aircraft.

14) **Cadmium replacement on steel using ZnCoFe coatings**

Dr. Göran Holmbom presented work from the Garteur project in which Saab Aerospace evaluated cadmium replacement coatings. Evaluated coatings included acid ZnNi (Corroban), ZnCoFe, ZnNi, plated and IVD Al, sputtered AlMg. Overall ZnCoFe (Zincrolyte NCZ 191) performed best, but failed stress corrosion cracking test and is therefore not used on high strength steel > 180 ksi. The ZnCoFe coating has been used on the JAS39 Gripen fighter aircraft for over 10 years with no problems; the process is drop-in and less expensive than Cd. 72% of the sacrificially protected steel components on the Gripen are ZnCoFe coated. The remaining 28% are Cd plated.