Progress on LHE Zinc-Nickel and Other Cadmium Alternatives

Steve Gaydos – Boeing – St. Louis, MO

Craig Pessetto – ES3 – Clearfield, UT

Jay Randolph – ES3 – Warner Robins, GA

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Cadmium Alternatives

- Zinc-Nickel (ES3 and Boeing)
  - Dipsol IZ-C17+ Alkaline Zinc-Nickel Plating
    - Tank Install at Hill AFB
    - Evaluation of Zn-Ni on Fasteners
- Aluminum (Boeing)
  - Sputter Aluminum
  - Cold Spray Aluminum
  - Aluminum Plating with Ionic Liquids

Dipsol Zinc-Nickel History

- 1996 – 2000 (WPAFB – ASC/ENVV)
  - Evaluated IZ-260 (In Use at DoD Plating Facilities)
    - Required Nickel Strike to be Non-Embrittling for HSS
- 2003 – 2005 (C-17 Pollution Prevention)
  - Developed IZ-C17 Alkaline Zn-Ni for HSS
    - No Ni Strike and Non-Embrittling to High Strength Steels (HSS)
- 2006 – 2007 (C-17 Pollution Prevention)
  - Conducted Qualification Tests for IZ-C17 Zn-Ni
- 2008 (ES3 – SBIR – Phase I)
  - Evaluated **IZ-C17+** Zn-Ni (Better Tank Life Than IZ-C17)
    - Also Compared TriCr CC with Hex Cr CC
- **2009 (ES3 – SBIR – Phase II)**
  - **Installed Plating Tank with IZ-C17+ Zinc-Nickel at Hill AFB**
    - **Also Installed IZ-264 Tri-Cr CC**
- **2009 (ES3 – SBIR – Phase I)**
  - **IZ-C17+ Zn-Ni Fasteners Feasibility Study**

Dipsol IZ-C17+ Zn-Ni Tank Installation at Hill AFB

April 27-28, 2009

Plating Line @ Hill AFB

Alkaline Zn-Ni Plating Tank Installation

Trivalent Cr Conversion Coating Tank Installation

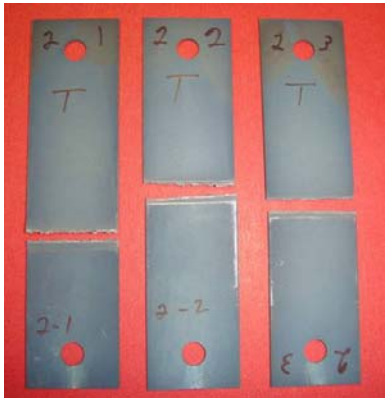
Dipsol IZ-C17+ Zn-Ni Chemicals & Rectifier

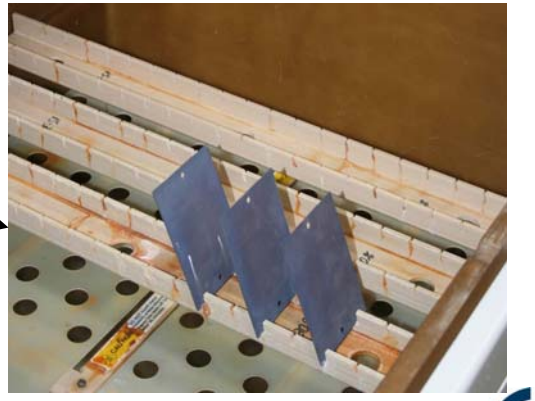
IZ-C17+ Zi-Ni Tank @ Hill AFB

IZ-264 TriCr Conversion Coat Tank @ Hill AFB

IZ-C17+ Tank Certification Tests

- Hydrogen Embrittlement
  – Pass
  - ASTM F 519 Type 1a.1
- Thickness and Adhesion
  – Pass
  - 0.3 to 0.6 mil
  - Bend-to-Break Adhesion
- Corrosion Resistance - Pass
  - 1000 hour ASTM B 117

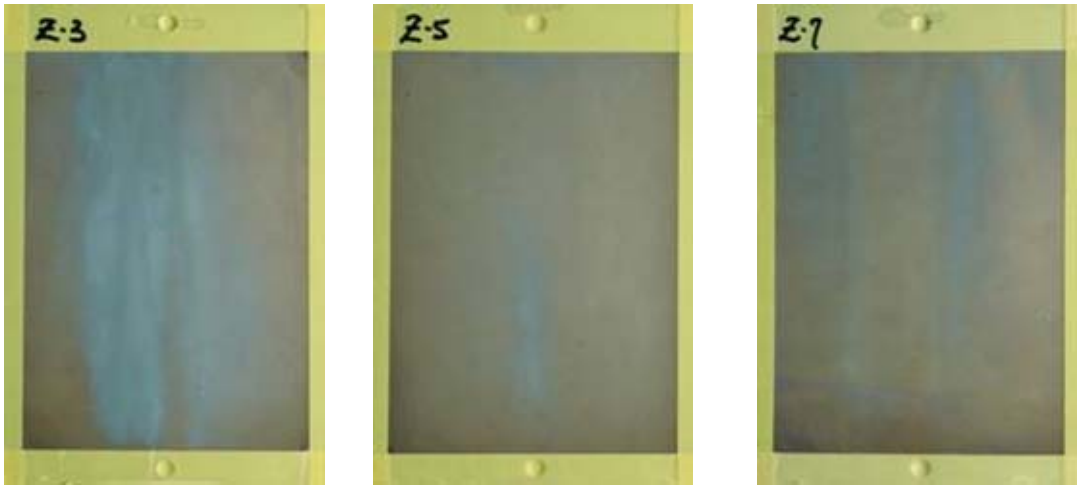




Current Testing at Hill AFB

- ASTM B 117 Corrosion Tests
- ASTM G 85 (SO_2) Corrosion Tests
- Fatigue and Hydrogen Embrittlement Testing at Different Zn and Ni Concentrations
- Develop Rapid HE Test Methods
  - Following ASTM F 1624 Guidelines
- Conduct Full Scale Plating Tests
  - Large Landing Gear Parts

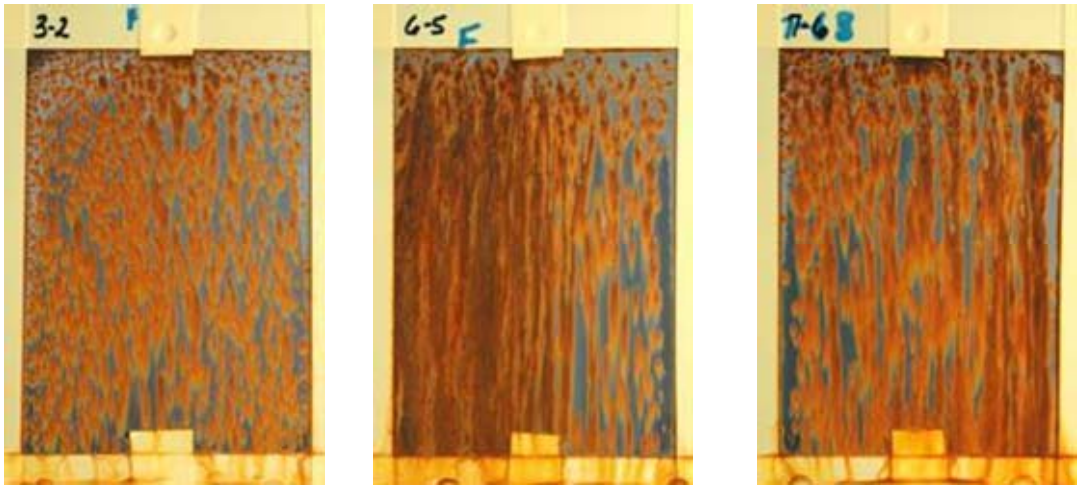
ASTM B 117 Corrosion



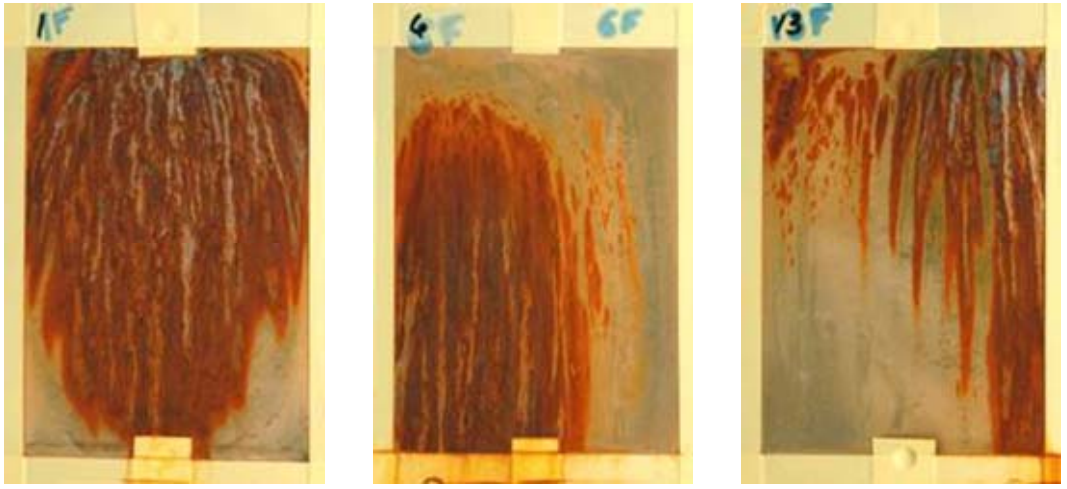
IZ-C17+ Zn-Ni – 3000 Hrs in ASTM B 117

LHE Cadmium – 500 Hrs in ASTM B 117

ASTM G 85 Corrosion

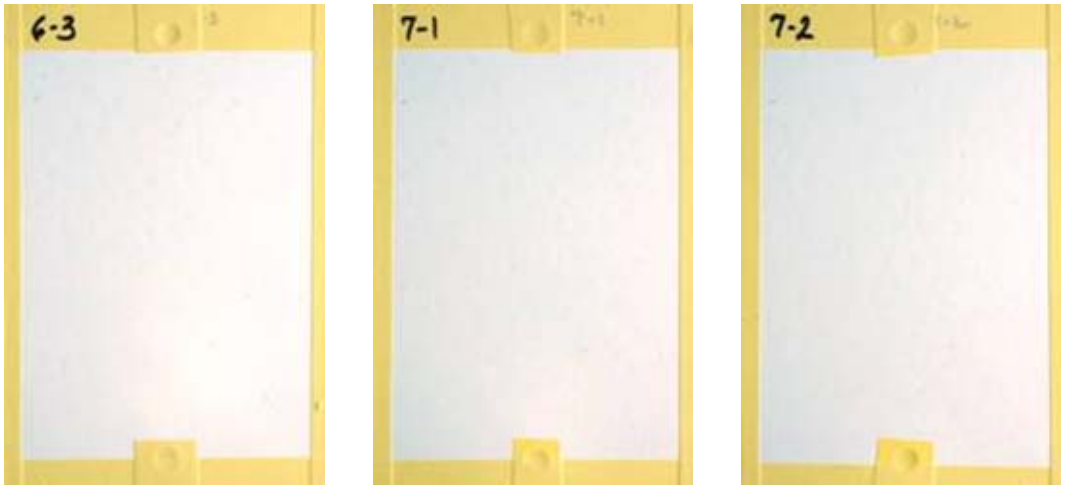


IZ-C17+ Zn-Ni – 336 Hrs in ASTM G 85 – SO_2 Salt Spray

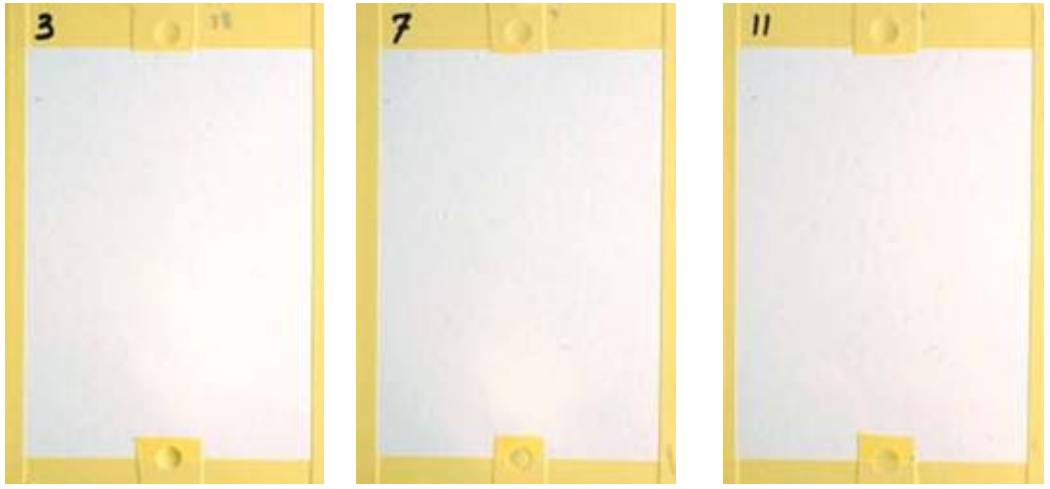


LHE Cadmium – 336 Hrs in ASTM G 85 – SO2 Salt Spray

ASTM G 85 Corrosion



Painted - IZ-C17+ Zn-Ni – 1000 Hrs in ASTM G 85 – SO_2 Salt Spray



Painted - LHE Cadmium – 1000 Hrs in ASTM G 85 – SO2 Salt Spray

Development of Cad Plating Replacement with Alkaline Zn-Ni Electroplating for Threaded Fasteners / Components

Jay Randolph
ES3
(478) 922-1460
jay.randolph@es3inc.com

Fred Laguines
ES3
(478) 922-1460
fred.laguines@es3inc.com

Don Crawford
ES3
(478) 922-1460
don.crawford@es3inc.com

Steve Gaydos
Boeing - St. Louis
(314) 233-3451
stephen.gaydos@boeing.com

Development of Cad Plating Replacement with Alkaline Zn-Ni Electroplating for Threaded Fasteners / Components

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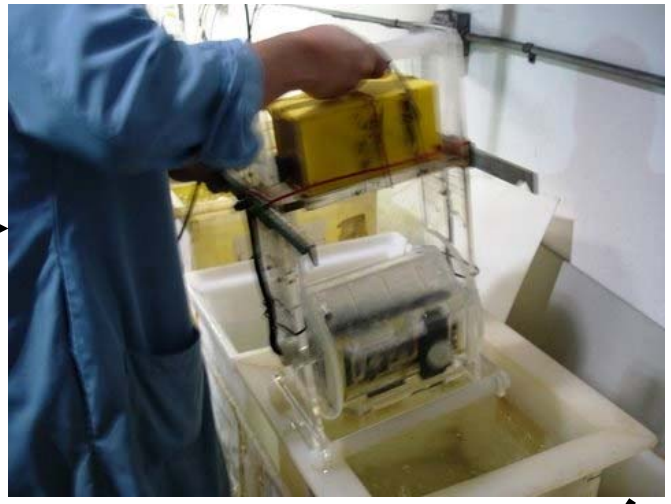
Project Summary

- Feasibility Study was completed by ES3 in April 2009.
  - Used Barrel Plating Technique on threaded steel fasteners.
  - Used Dipsol IZ-C17+ Zn-Ni
    - Excellent coverage and uniformity.
  - ASTM B 117 Corrosion Test on Fasteners
    - IZ-C17+ Zn-Ni equal to or better than Cd plated fastener baseline
  - Lubricity Tests: Run-On-Break-Away Test & Torque Tension
    - Baseline was Cd plate
    - 13 Lubricants tested
      - Zn-Ni performed as well or better than Cd plating in testing
- Phase II Test program scheduled to start in 1st Qtr FY10.
  - Qualify low alloy steel fasteners with Alkaline Zn-Ni Plating
  - Options, when funding is available, to conduct HSS 300M Steel threaded component testing with rack plating technique & qualify HSS low alloy steel fasteners.
- ES3 is working with Boeing St. Louis on this effort.
- SBIR #AF081-101 is sponsored by Robins AFB.

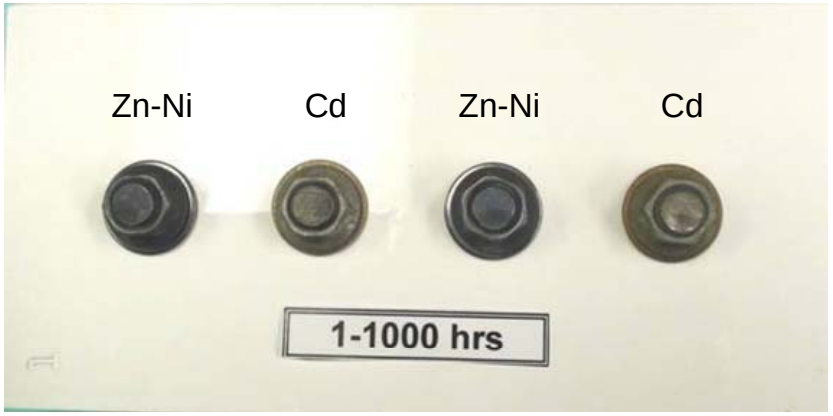
Dipsol IZ-C17+ Zn-Ni Barrel Plating of Fasteners

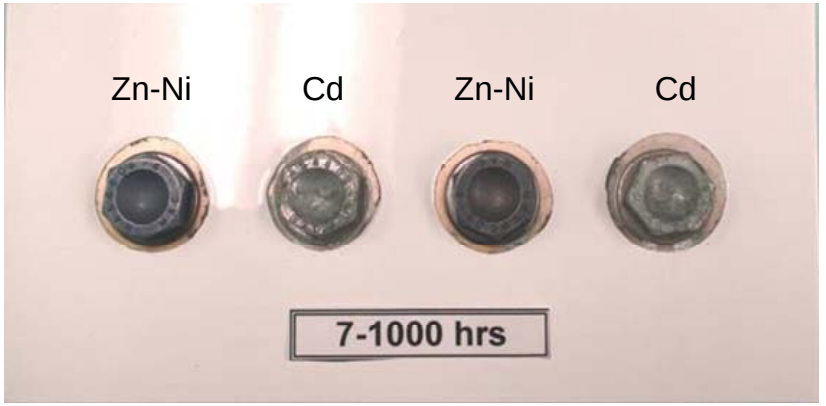


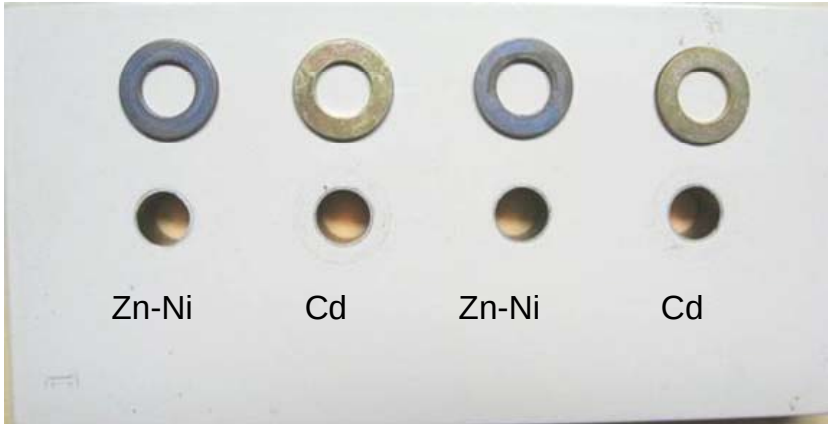
Zn-Ni and Cd Plated Fasteners

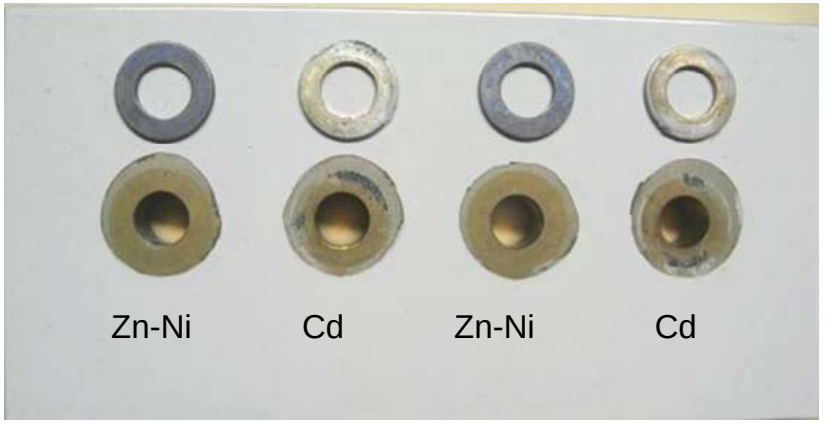
- View of:
  - Zn-Ni Plated Fasteners with Tri-Chrome Conversion Coating (top)
  - Cadmium Plated Fasteners with Hex-Chrome Conversion Coating (bottom)

Zn-Ni and Cd Plated Fasteners - Corrosion Testing





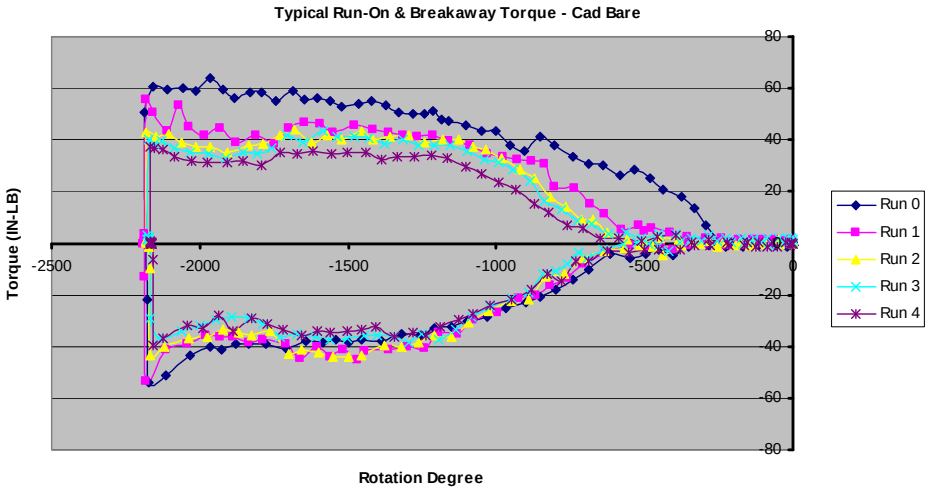


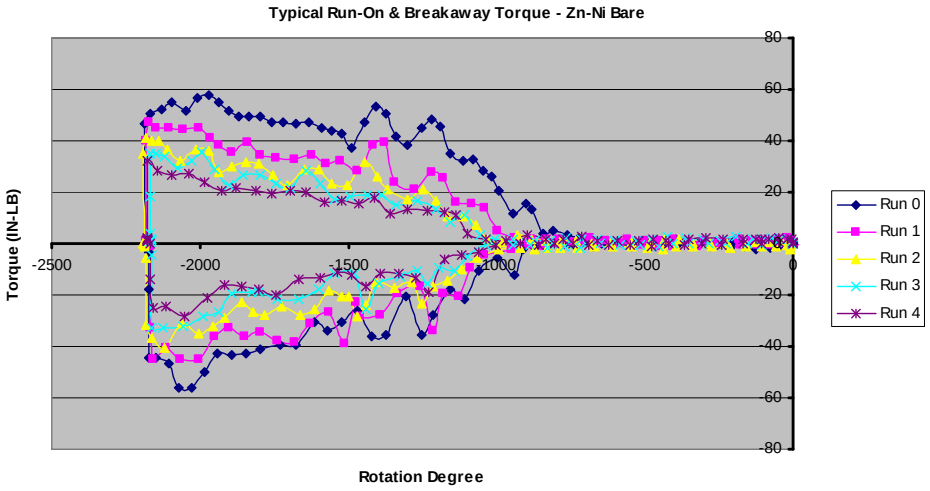


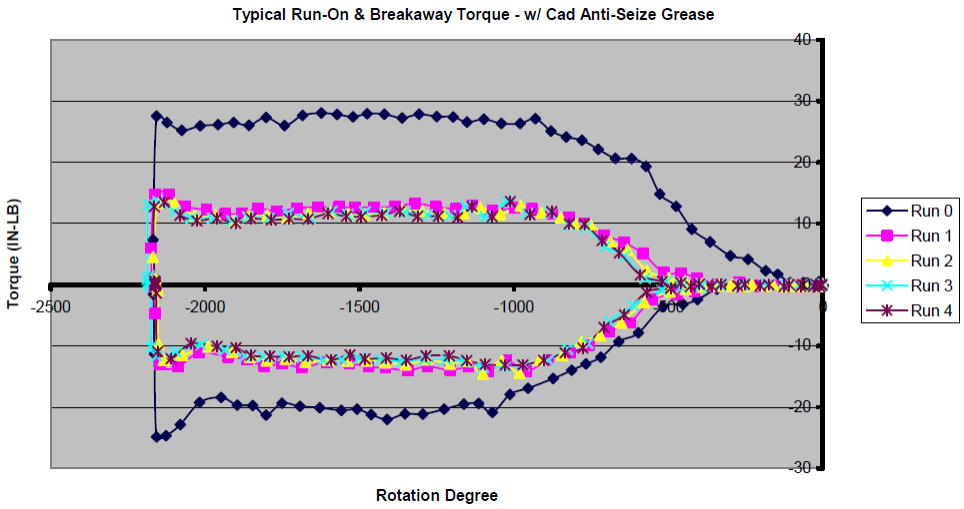
- Corrosion Photos after 1000 Hours in ASTM B 117 Salt Spray Cabinet
  - Left is Fully Painted Aluminum Test Panel with Nut
  - Right is Partially Painted Aluminum Test Panel with Bolt

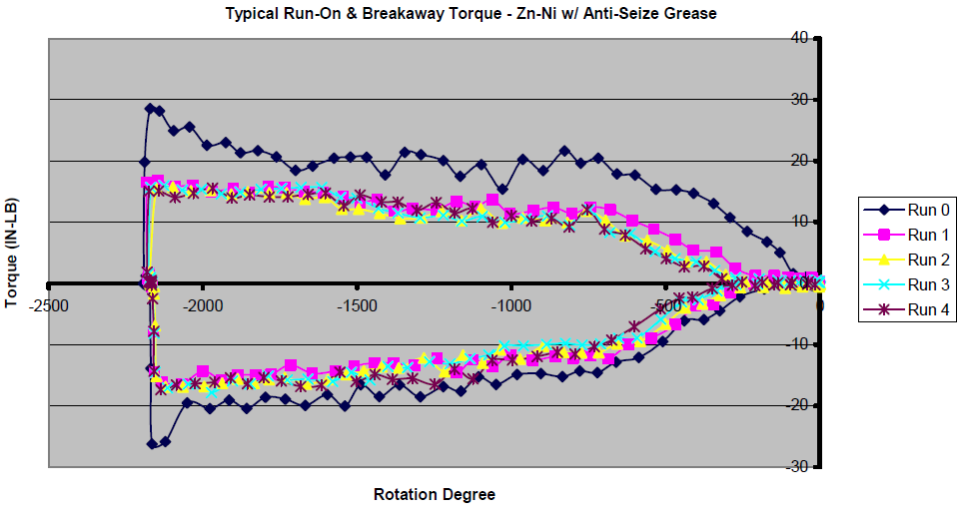
Zn-Ni and Cd Plated Fasteners – Lubricity Testing

- Typical Chart for Run On - Break Away Test Showing Cad vs Alkaline Zn-Ni with and without MIL-PRF-83483 Anti-Seize Grease Lubricant



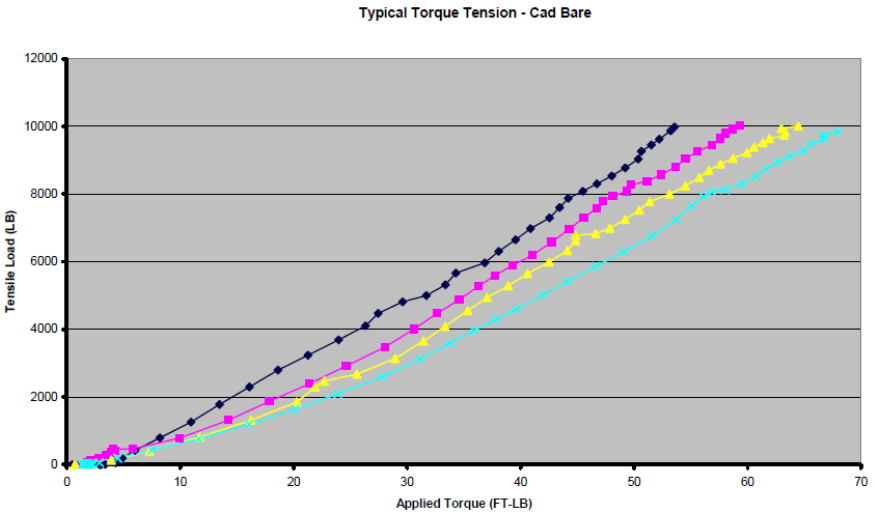


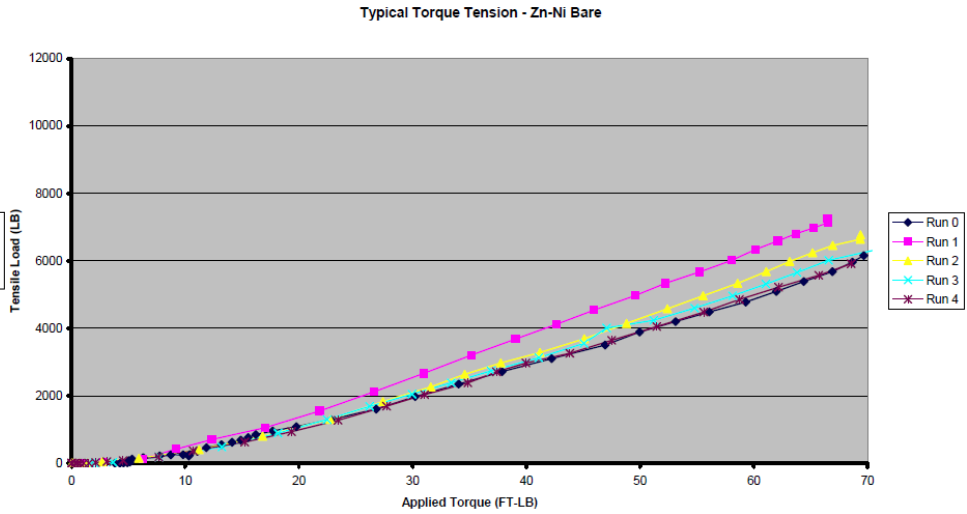


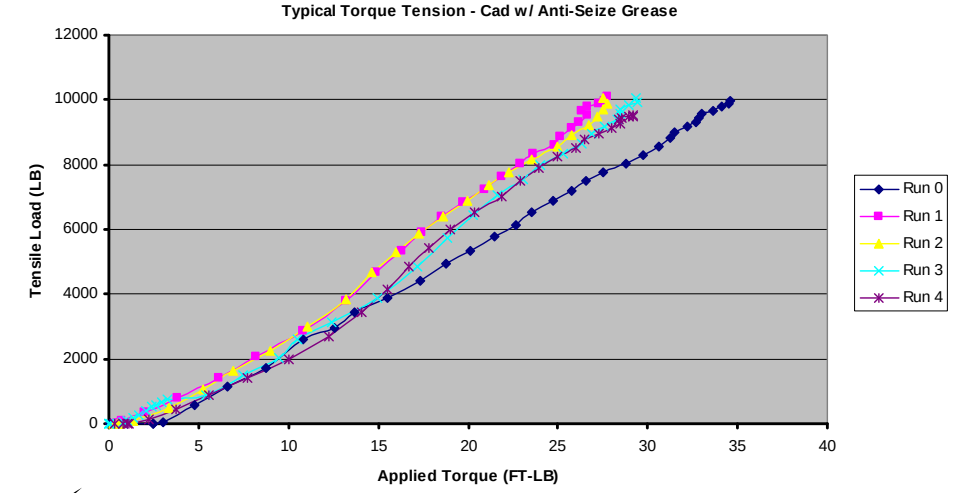


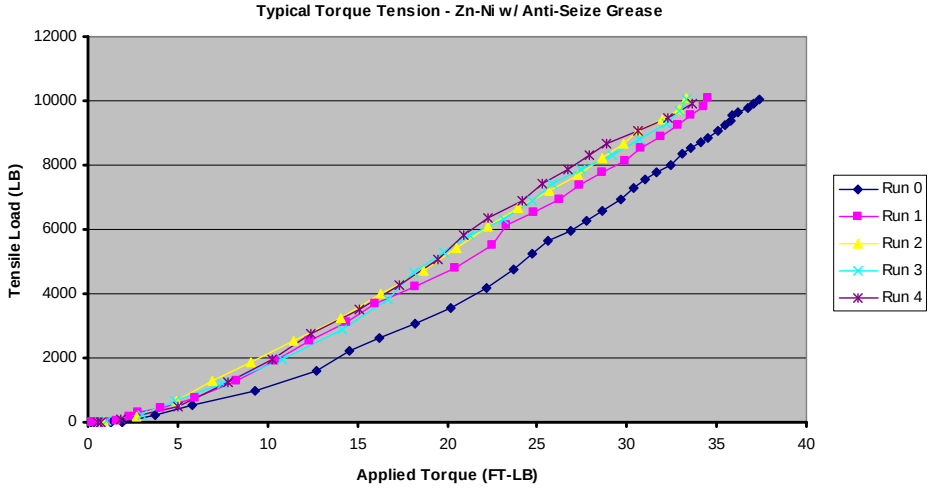
Zn-Ni and Cd Plated Fasteners – Lubricity Testing

- Typical Chart for Torque Tension Test Showing Cad vs Alkaline Zn-Ni with and without MIL-PRF-83483 Anti-Seize Grease Lubricant



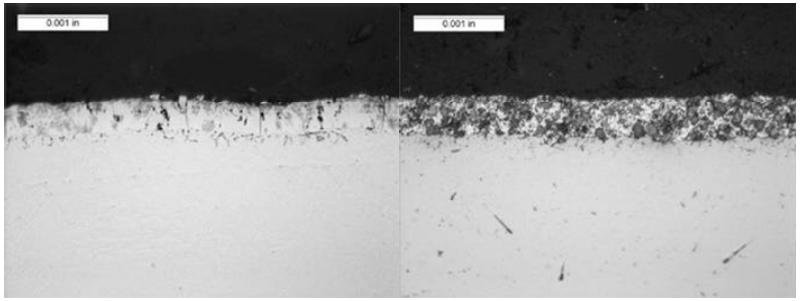




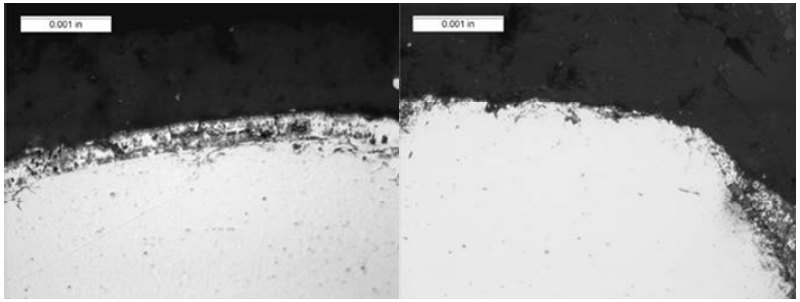


Zn-Ni and Cd Plated Fasteners – Metallography

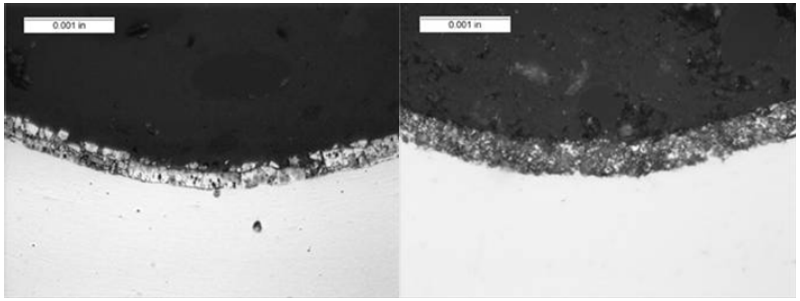
- Typical Cross Section of Zn-Ni and Cadmium Plated NAS 6606-10 Bolt.



Zn-Ni Flat Surface Cd



Zn-Ni Thread Crest Cd



Zn-Ni Thread Root Cd

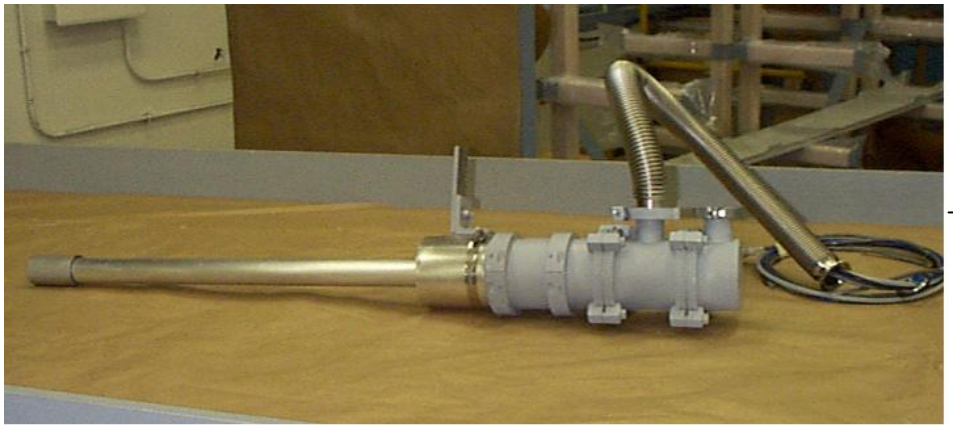
Cross-Sections of Long Bolt

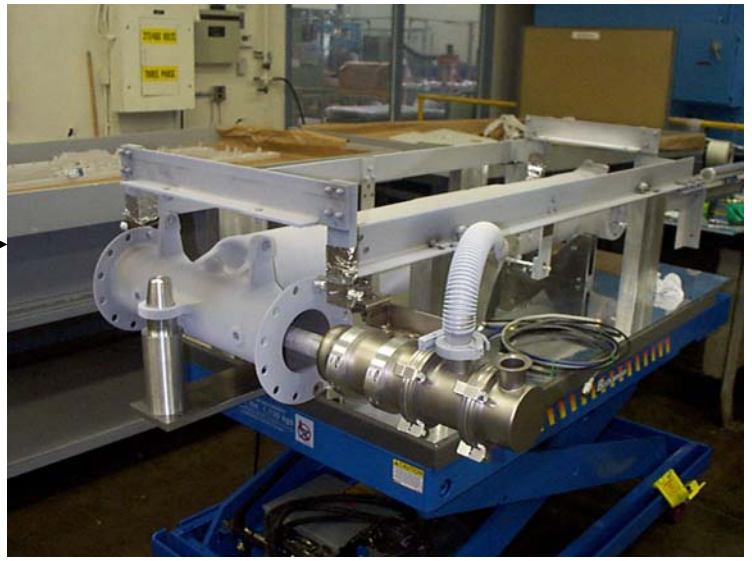
Aluminum Coatings

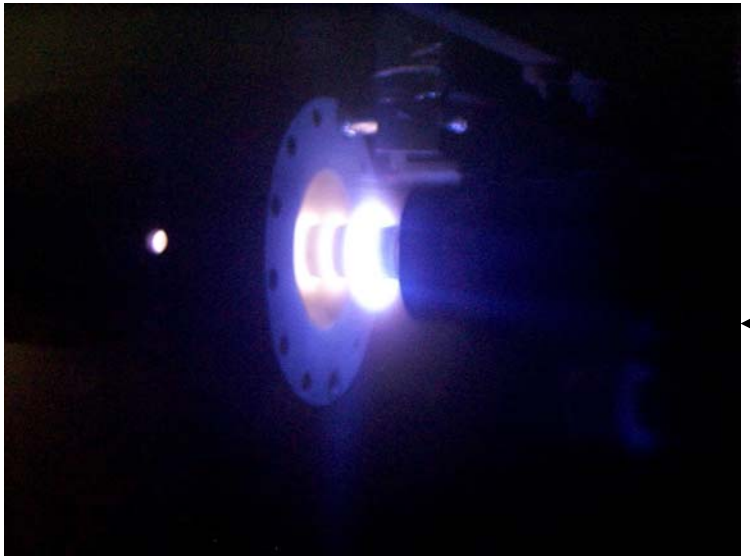
Sputter Aluminum

- Plug & Coat Sputter Probes (ID Coating)
  - Developed by Marshall Laboratories (Boulder, CO)
  - Installed in IVD Coater at Hill AFB
  - Process Certified by Boeing (DPS 9.22-1)
  - ES3 Currently Investigating New Sputter Probe Application at Hill AFB
- S-PAC (Small Parts Aluminum Coater)
  - Equipment Currently Being Built to Apply Sputter Aluminum Coating to OD of Parts
    - Update of IVD Process

Plug & Coat Sputter Probe Operation



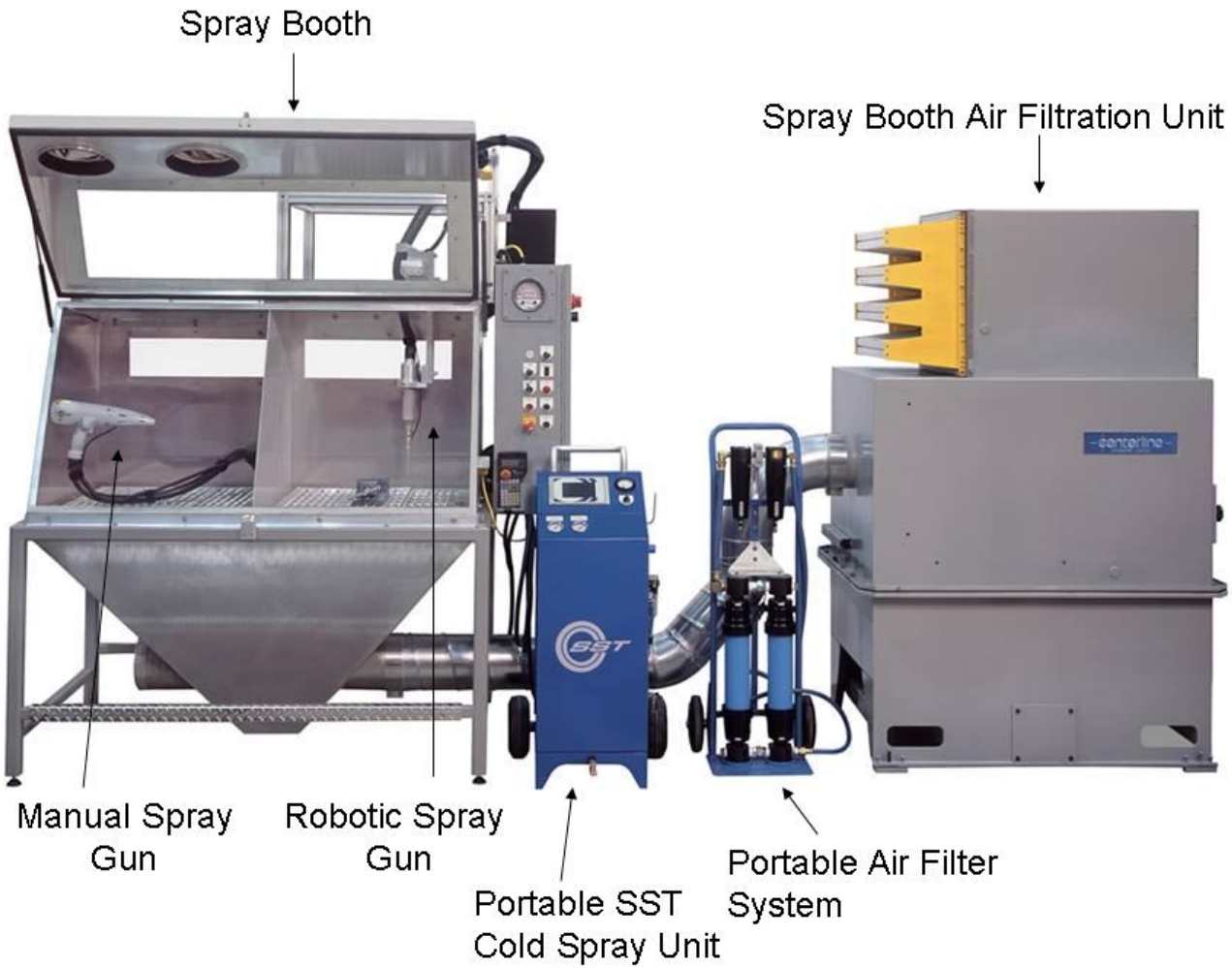




Cold Spray Aluminum

- Centerline SST Cold Spray Equipment
  - Installed at Boeing – July 2008
  - Procedures Developed to Apply Cold Spray Aluminum Coating (1 - 2 mils)
    - Repair Damaged MIL-DTL-83488 Aluminum Coatings (IVD, Sputter, CVD, Alumiplate, etc.)
  - Demonstration of Cold Spray Technology Held at Boeing on August 13, 2009

Centerline SST Portable Cold Spray Equipment



Centerline Ultra-Portable Cold Spray Equipment

Trained Cold Spray Operators

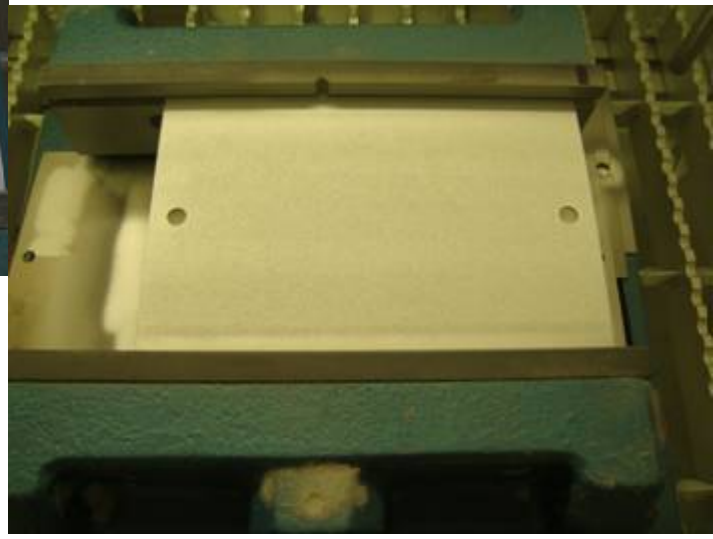
Best Dressed Cold Spray Operator

Oldest Cold Spray Operator

IVD Al Repaired with Cold Spray Al

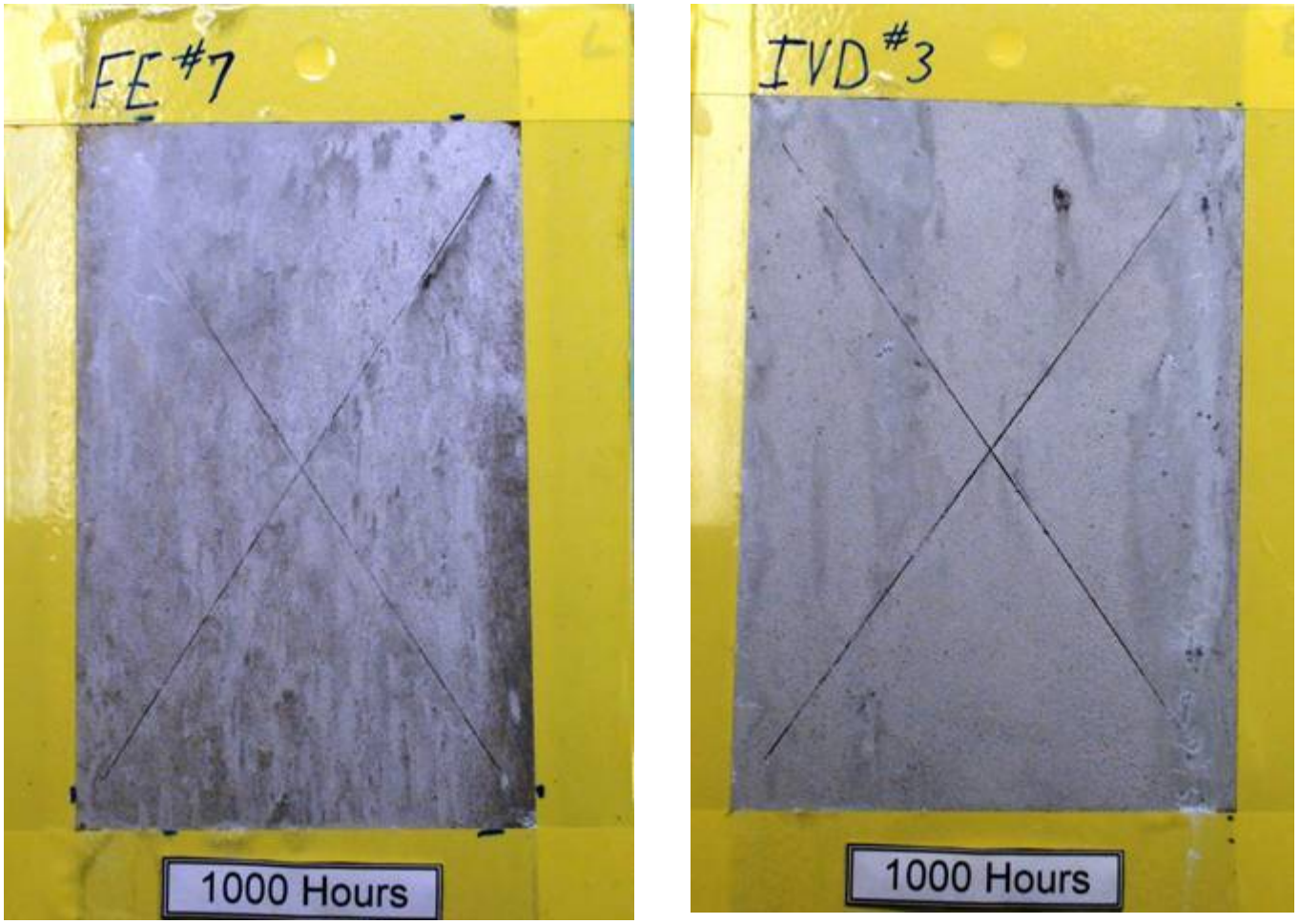
Damaged IVD Al

Damaged Area Prepared



Cold Spray Al Repaired IVD Al

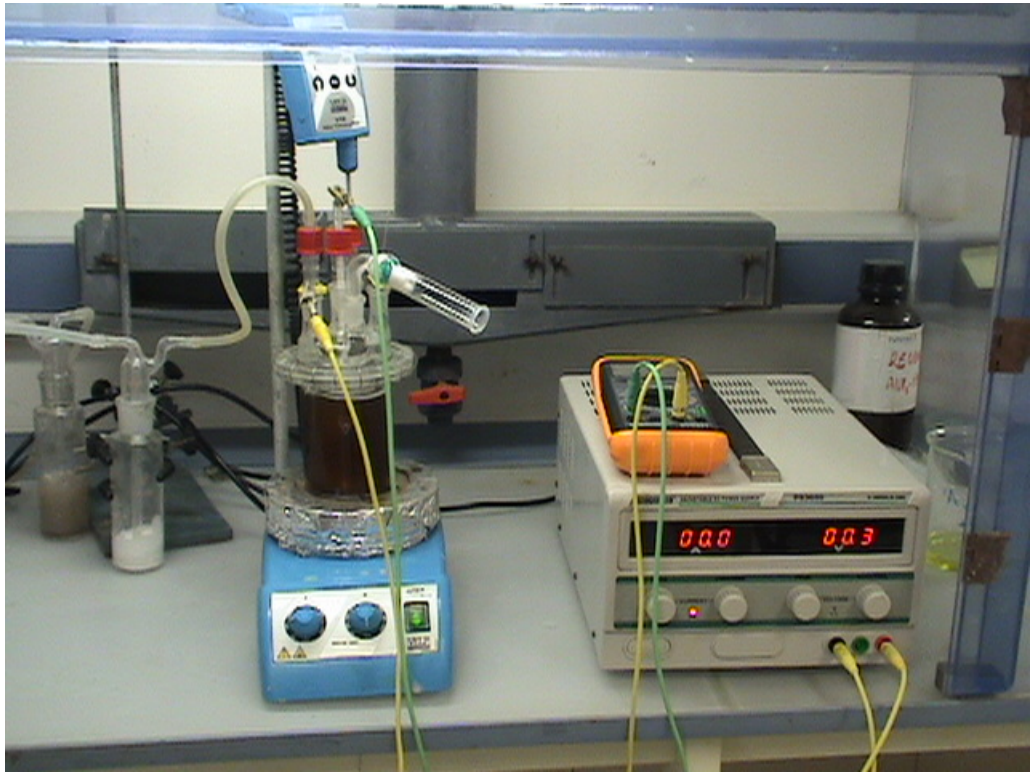
Cold Spray Aluminum – Corrosion Resistance



1000 Hours in ASTM B 117 (Scribed Corrosion Test) –
Cold Spray Al on Steel (Left) and Cold Spray Al on Damaged IVD Al (Right)

Aluminum Plating in Ionic Liquids

- Boeing Research & Technology – Europe
  Evaluating Ionic Liquids for Aluminum Plating



Questions?