Integration of LHE alkaline Zn-Ni into NAVAIR Overhaul and Maintenance Facilities

SBIR Topic AF071-320

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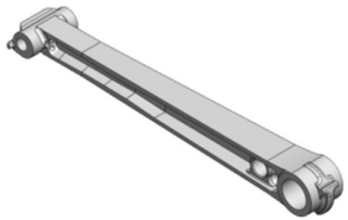
General Manager – SouthEast Operations

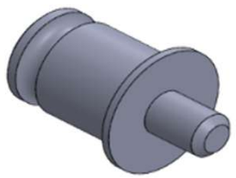
Tod Hickman
Project Manager – SouthEast Operations

NAVAIR Technical Objectives

- **Transition Zn-Ni electroplating under SBIR Topic AF071-320 as a cadmium replacement for High Strength Steel.**

  - ONR RIF (Phase III) – Implementation of LHE Alkaline Zn-Ni plating line at FRCSE - Completed
  - Phase II.5 SBIR STTP - Conduct NAVAIR certification testing with ES3 LHE Alkaline Zn-Ni process.





NAVAIR Zn-Ni SBIR Project Team

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Policy Drivers

OSH Policy Drivers: Increase Maintenance Cost & TAT
Impact: Decreased Readiness of Fleet Aircraft

- (DFARS) - 48 CFR Parts 223 and 252
- REACH - Restriction of Chemicals
- New proposed TLV-TWA: 0.2 ug/m3 Cr6+ inhalable
- Current: TLV-TWA: 5 ug/m3

AIRCRAFT FINISH SYSTEMS

- Cadmium (Cd)
  - High Strength Steel (All T/M/S Aircraft)
- Hexavalant Chromium (Cr+6)
  - Primer Coatings (All T/M/S Aircraft)
- Isocyanates
  - Topcoats (All T/M/S Aircraft)

Isocyanates

Cadmium

Cr+6

The primary and most serious adverse health effects of long-term exposure to cadmium include kidney dysfunction, lung cancer, and prostate cancer

COMFRC & FRC Policy Guidance

COMFRCINST 5100.1

- FRC Responsibilities
- Reduced Exposure
- Approve/Implement Alternatives

DEPARTMENT OF THE NAVY
FLEET READINESS CENTERS
47038 McLEOD ROAD
BLDG 448
PATUXENT RIVER, MARYLAND 20670

COMFRCINST 5100.1
Ser N00
APR 2 0 2015

COMFRC INSTRUCTION 5100.1

From: Commander, Fleet Readiness Centers

Subj: CONTROL AND MANAGEMENT OF HEAVY METALS DUST

Ref: (a) Subparts 1910.141, 1910.1025, 1910.1026, and 1910.1027 of Title 29, Code of Federal Regulations
(b) COMNAVSAFECEN MSG R 021117Z OCT 12
(c) Industrial Hygiene Field Operations Manual (Feb 2013) NEHC Technical Manual, NHC-TM6290.91-2

(16) Evaluate, approve and implement the use of viable alternative technologies to reduce or eliminate HM usage and potential HM exposure.

FRCSEINST 5103.15

- FRCSE Responsibilities
- "Do not introduce new sources of heavy metals into repair, overhaul or modification processes…"

DEPARTMENT OF THE NAVY
FLEET READINESS CENTER SOUTHEAST
NAVAL AIR STATION
JACKSONVILLE, FLORIDA 32212-0016

IN REPLY REFER TO
FRCSEINST 5103.15B
Code 65100
21 FEB 2013

FRC SOUTHEAST INSTRUCTION 5103.15B

From: Commanding Officer

Subj: HEAVY METALS CONTROL PROGRAM

Ref: (a) 29 CFR 1910 OSHA Standards for General Industry
(b) FRCSEINST 4870.1 Facility Equipment and Industrial Plant Equipment (IPE) Management Program
(c) FRCSEINST 11014.2 Preventive Maintenance and

2.4 Research and Engineering Group (code 40000)

a. Ensure that revisions to FRCSE managed technical documentation (e.g., MIMs, local engineering specifications, drawings, etc.) do not introduce new sources of heavy metals into industrial processes unless technically required.

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SBIR Phase II.5 Development Process

DIPSOL IZ-C17+ (Zn-Ni) & DIPSOL IZ-264 (Conversion Coating)

DIPSOL IZ-C17+ is an alkaline, cyanide free, Zn-Ni alloy electroplating process

- Meets requirements for a non-embrittling process per ASTM F 519 for HSS.
- Has excellent throwing/covering power
- Uniform zinc alloy deposit containing 12 – 15% Ni
- Excellent heat and corrosion resistant properties
- Plating rate: 0.8 – 1 mil/hr @ 45 ASF

DIPSOL IZ-264 is a trivalent chrome conversion coating for DIPSOL IZ-C17+.

- Can be applied prior to HE Baking
- Blue bright coating/ excellent corrosion resistance.
- Ambient Temperature Bath

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Technical Progress: ONR RIF (Phase III)

Completed September 2017

Site Installation

Final Installed Production Line at FRCSE

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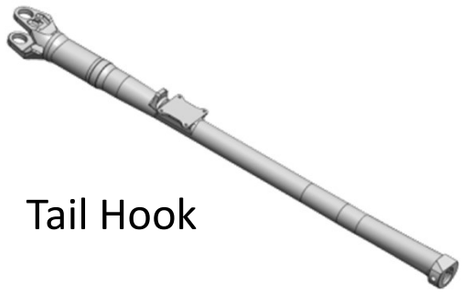
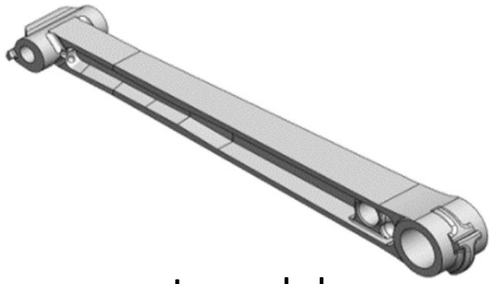
Component Plating Demonstration

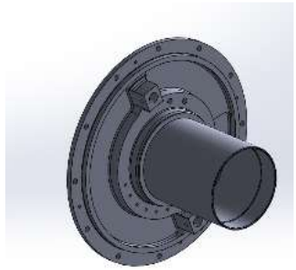
Aircraft Components & Support Equipment



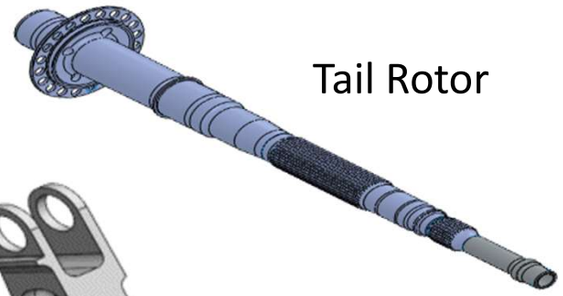
Tail Hook



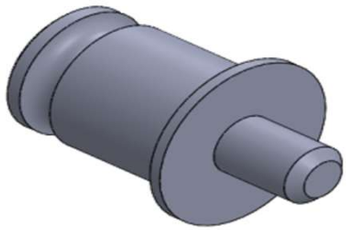
Launch bar



ARS Back Plate



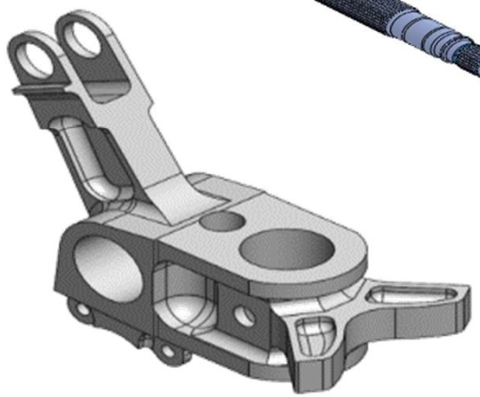
Tail Rotor



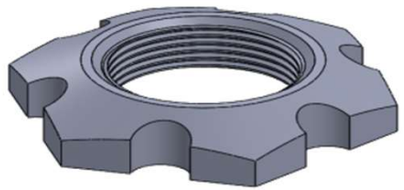
Dolly pin

Assorted bushings

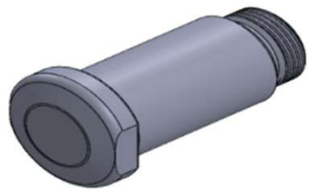
C-130 Propeller Bushing



Tail Hook Pivot



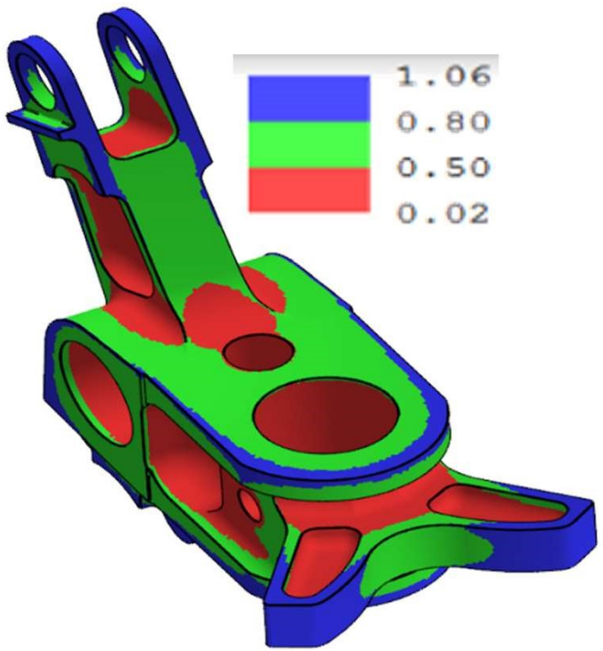
Anchor nut



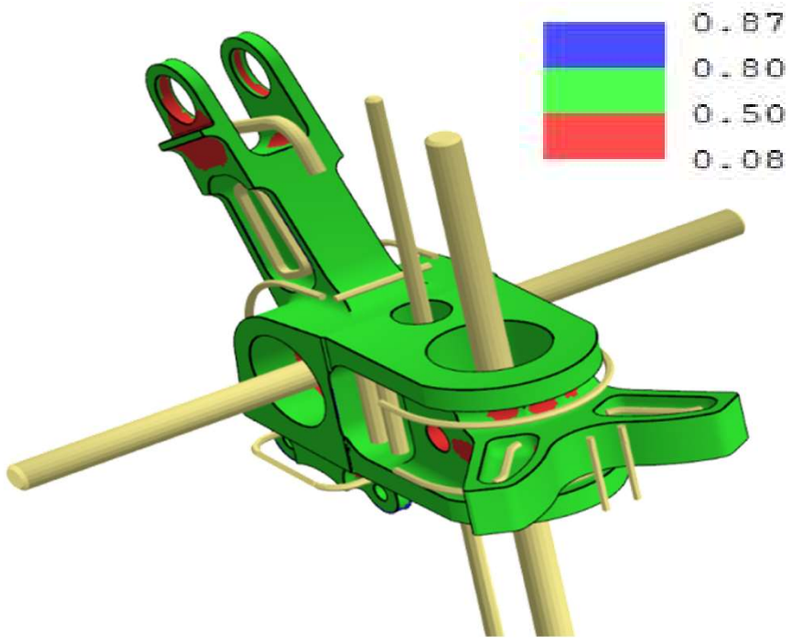
Clevis pin

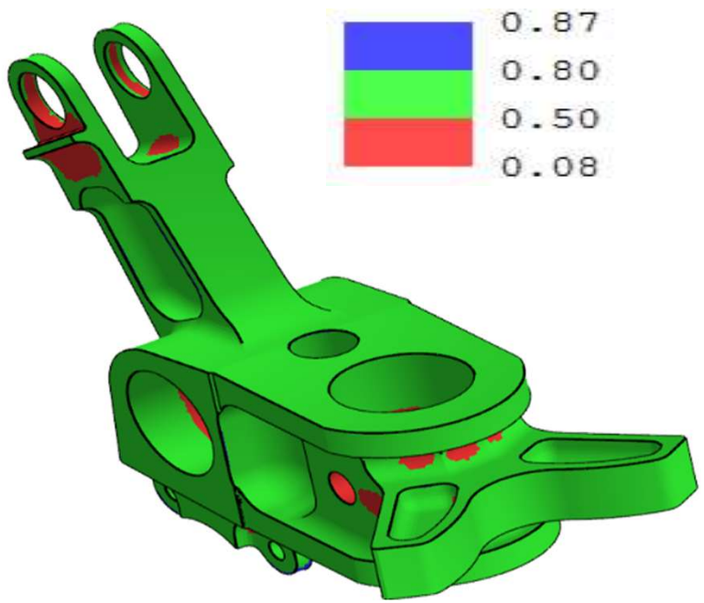
7

Technical Progress: Anode Design



Plated with no conforming anode





Plating result with conformal anode

Conformal Anode Design
Simulated Zn-Ni Layer Thickness Distribution Over a Tail Hook Pivot

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Industrial Plating Demonstrations - (Dipsol IZ-C17+)

LHE Alkaline Zinc-Nickel (IZ-C17+)

V-22 Mast

H-1 Mast

T-45 Tail Hook

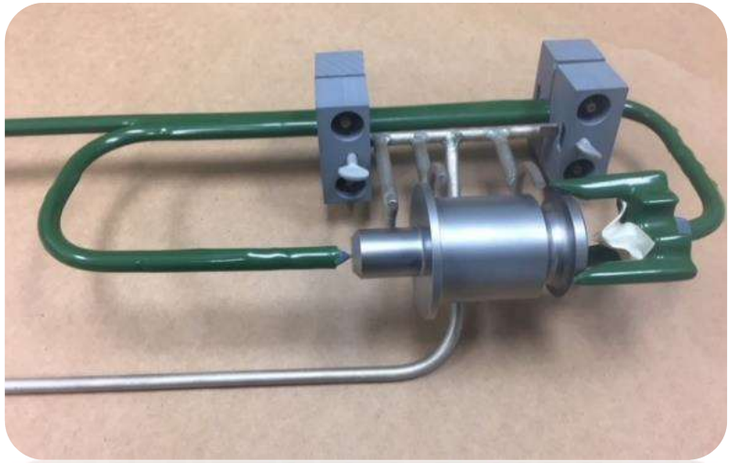
T-45 Pivot Assy

F/A-18 Launch Bar

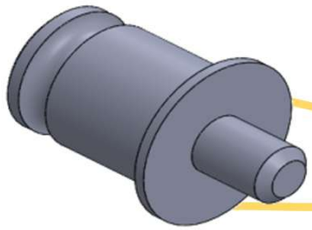
FL3

LHE Zn-Ni – Spotting Dolly Pin Dem/Val

- CVN-75 Demo with (6) Spotting Dollies.
- Direct comparison between Cd and LHE Zn-Ni
- Electroplated at FRCSE plating facility
- Installed June 2017



Plating Fixture



Dolly Pin

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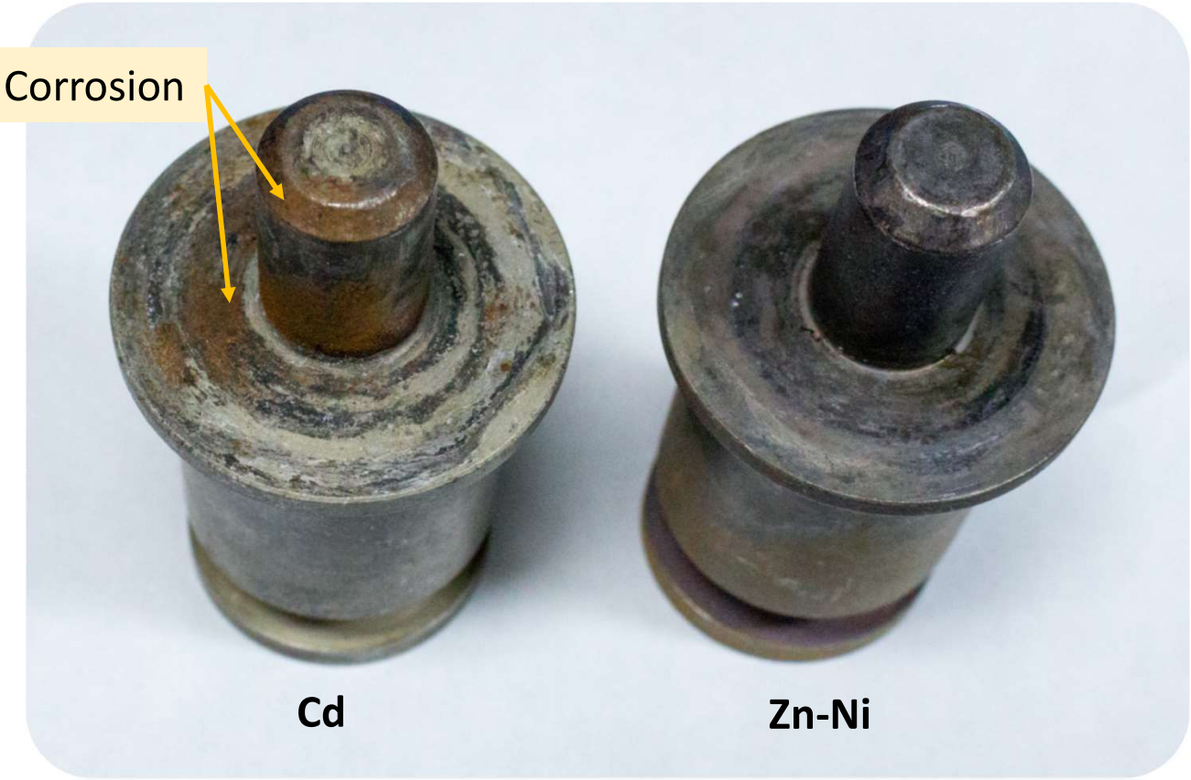
LHE Zn-Ni – Spotting Dolly Pin Dem/Val



180-day Inspection Results (Jun 17 - Jan 18)

NAVAIR Test Protocol

30 Core Certification Tests

Design of Experiment

- Temperature
- Composition
- Current Density

Product Quality

- Adhesion
- Thickness
- Composition

Corrosion Performance

- B117
- Cyclic
- KSC Beach

Processing & Wear

- NDI Sensitivity
- Gravelometery
- Break Away Torque

Mechanical Properties

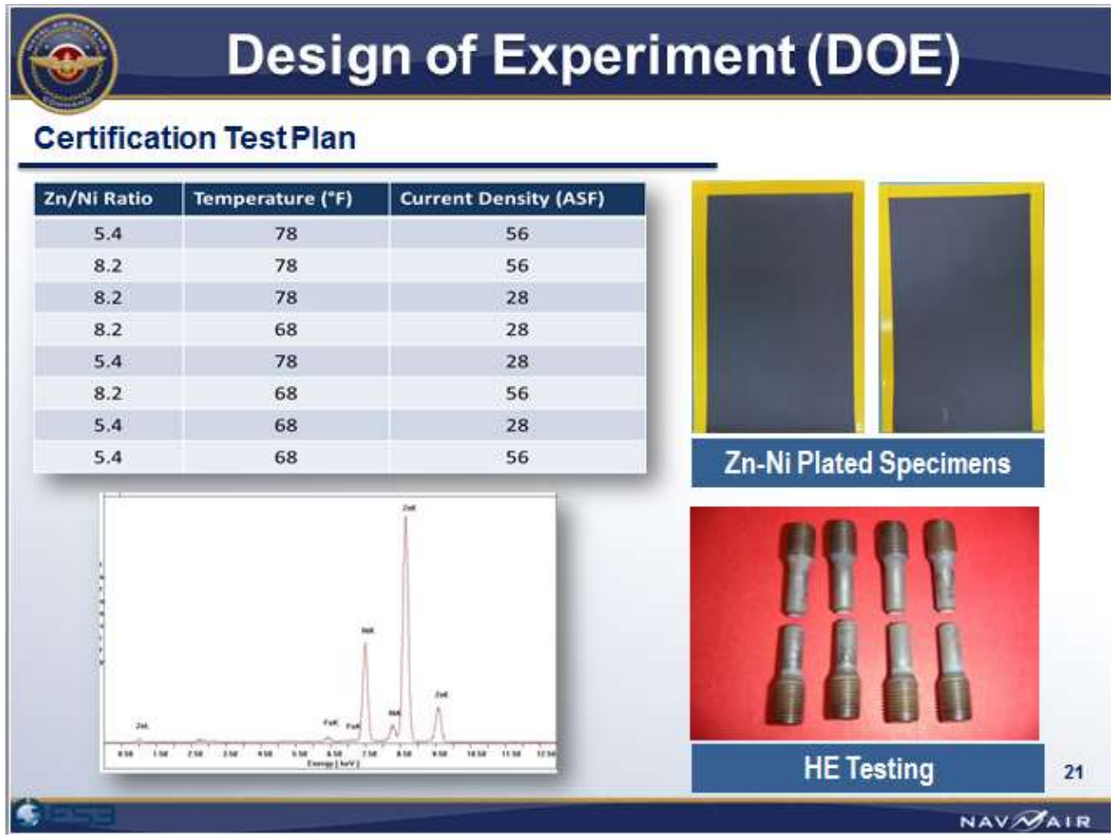
- HE
- Fatigue
- SCC
- Ti Compatibility

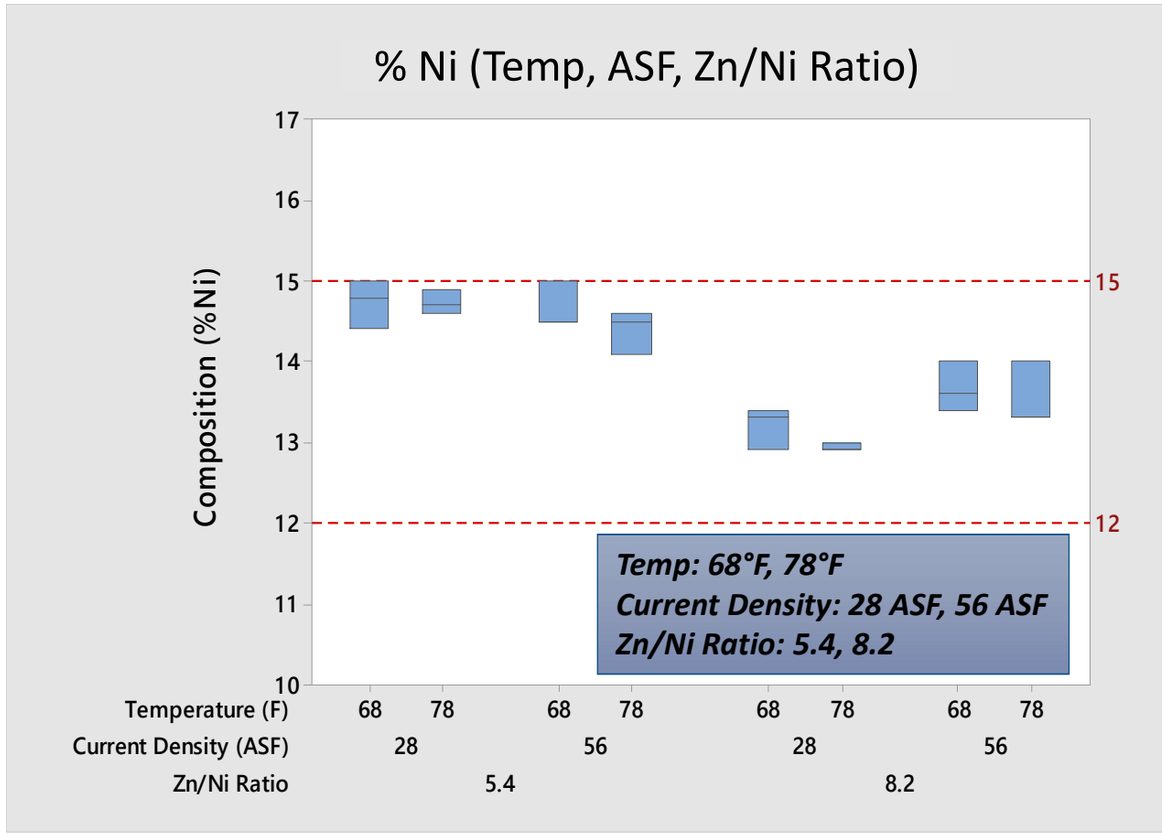
Expansion

- Low Temp HE Bake
- IWTP
- Rapid HE
- Selective Repair
- Alloy Activation
- Galling

NAVAIR HSS Certification Test Protocol – SBIR Phase II.5

Design of Experiment (DOE)





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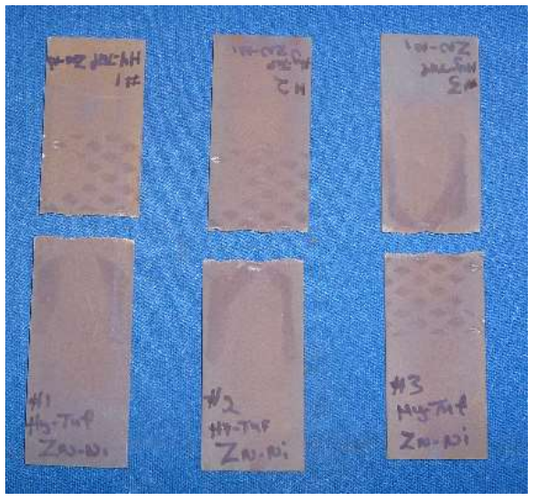
Adhesion Testing

Bend to Break Test



Zinc-Nickel on Hy-Tuf:

PASS

Cadmium on Hy-Tuf:

PASS

Bend-to-Break		
Material	**Cd**	**Zn-Ni**
4130 steel	Pass	Pass
Hy-Tuf	Pass	Pass
15-5 PH*	Pass	Pass
Al-Ni-Bronze*	Pass	Pass
Al-Bronze*	Pass	Pass
13-8*	Pass	Pass

Developed non-standard pre-plate etch using normal plating line chemicals (No nickel strike used)

Wet Tape		
Material	**Cd**	**Zn-Ni**
4130 Steel (Primer, Non-Chromated)	Pass	Pass
4130 Steel (Primer, Chromated)	Pass	Pass

** Different activation process*

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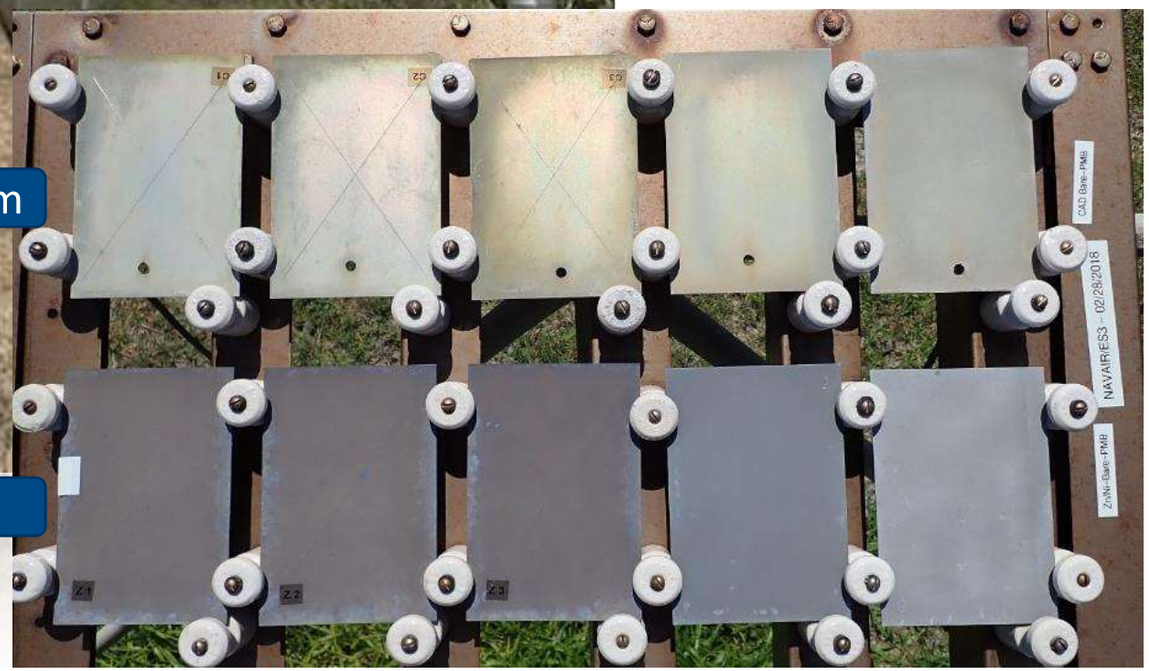
KSC Beach Initial Exposure Corrosion Testing

Beach Site
4 Months

4-months Exposure

Cadmium

Zn-Ni



Unpainted/Scribed

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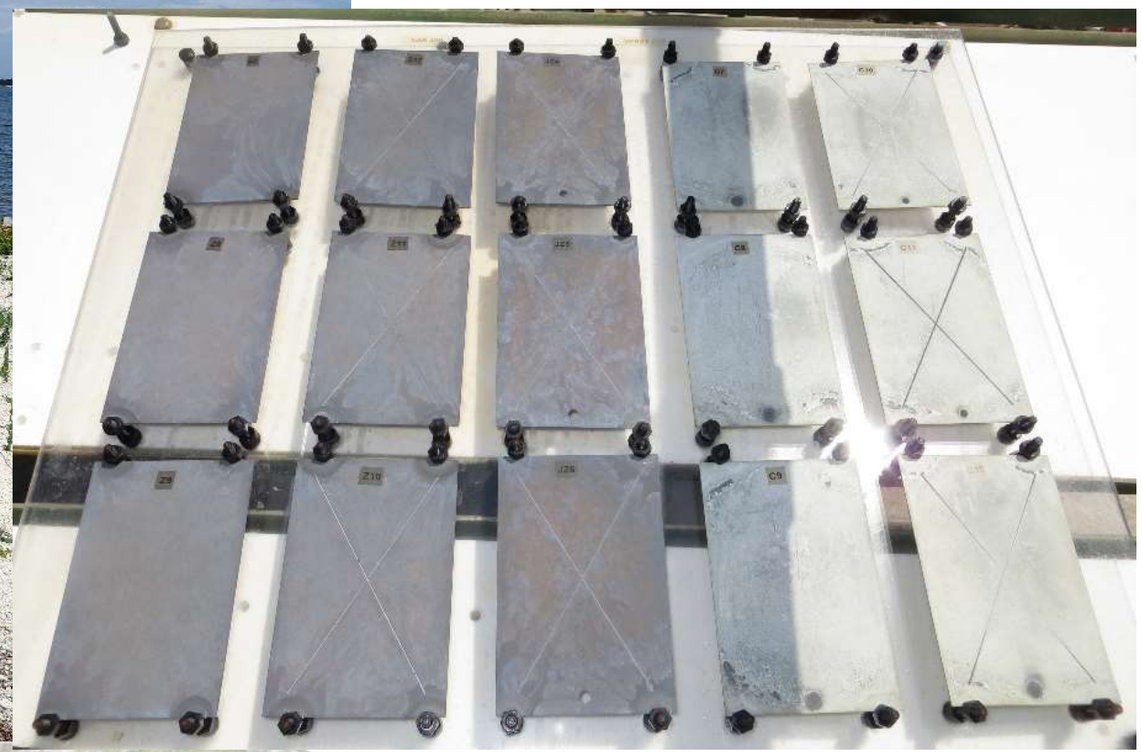
NRL Key West Exposure Corrosion Testing

Atmospheric Rack at 3 Months

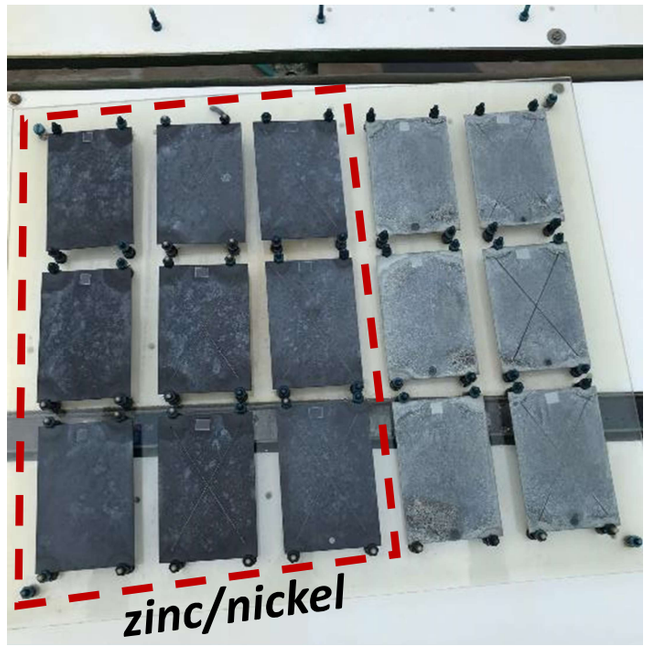


Unpainted/Scribed

NRL Key West Exposure Corrosion Testing

Seawater Spray Exposure Rack

Spray Rack at 12 Months



Unpainted cadmium, IVD-Al, zinc/nickel

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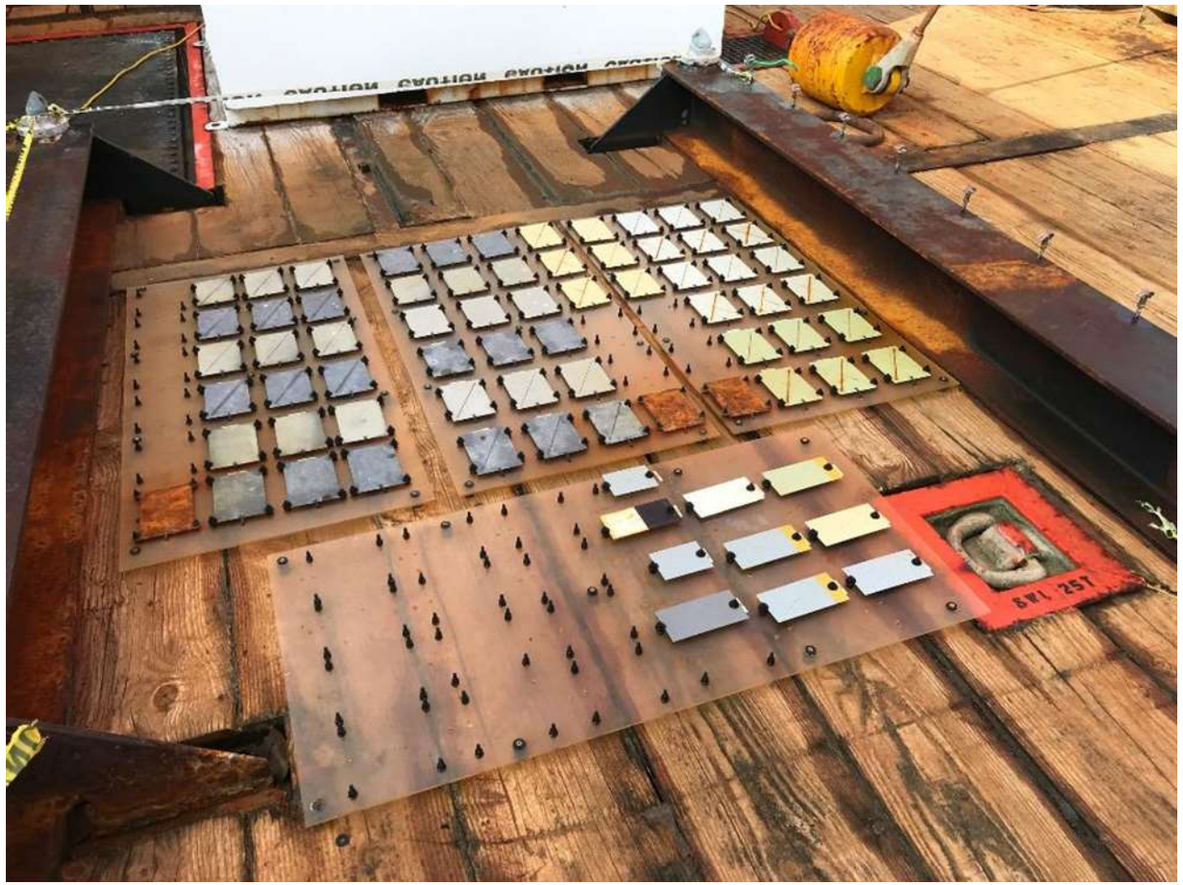
NRL Key West HOS Mystique



Shipboard Exposure
3 Months

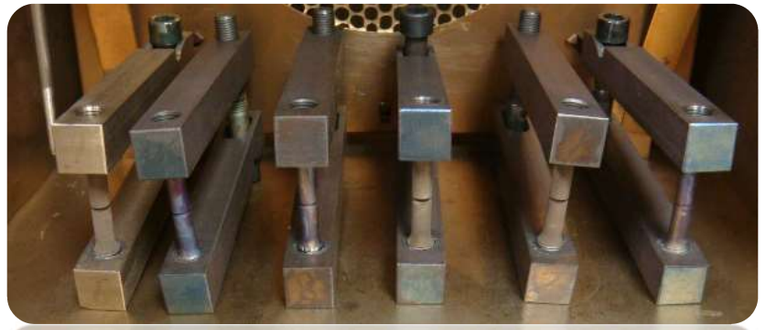
Unpainted/Scribed

Embrittlement Testing

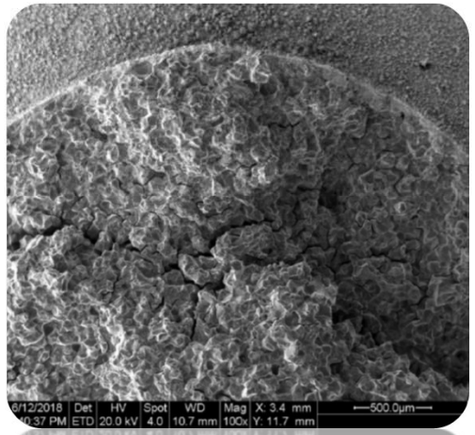
Coating	Tested	Pass	Fail
Bare	5	5	0
Cd	5	5	0
Zn-Ni	5	5	0

ASTM F519 Hydrogen Embrittlement 200-hr test

Solid Metal Embrittlement Fixture



Solid Metal Embrittlement Coupons Mounted in Test Fixtures



SEM view of Cd coupons failure

Coating	Hours at 75% NFS	Result
Cd	8	Fail
Cd	8	Fail
Cd	8	Fail
Zn-Ni	200	Pass
Zn-Ni	200	Pass
Zn-Ni	200	Pass

Solid Metal Embrittlement 300M Coupons 200-hr test @ 500°F

Titanium Embrittlement Coupons

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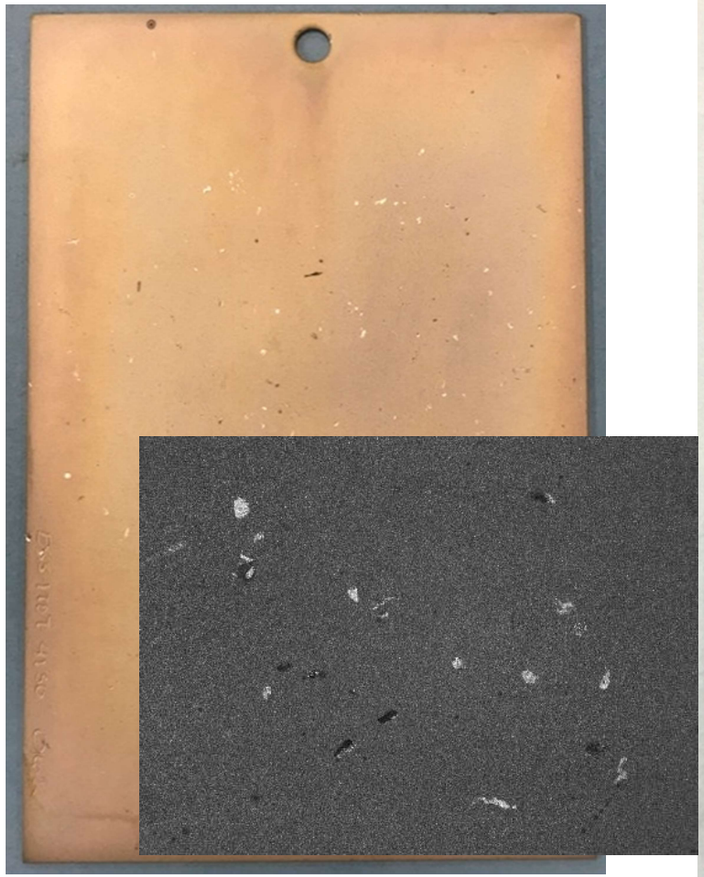
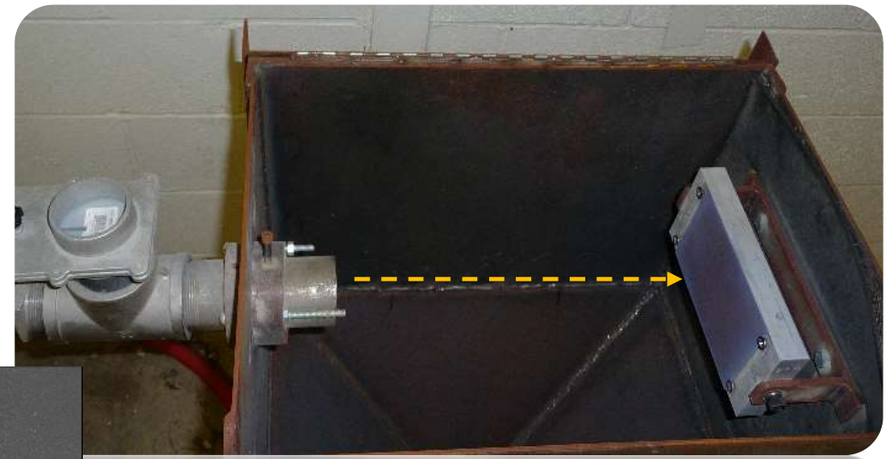
Gravelometry Testing



Cadmium Post-test

Zinc-Nickel Post-test



Zn-Ni coupon mounted in Test Apparatus

Gravelometry Test Apparatus (IAW ASTM D3170)

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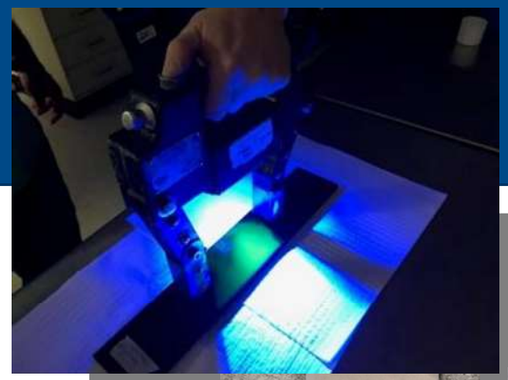
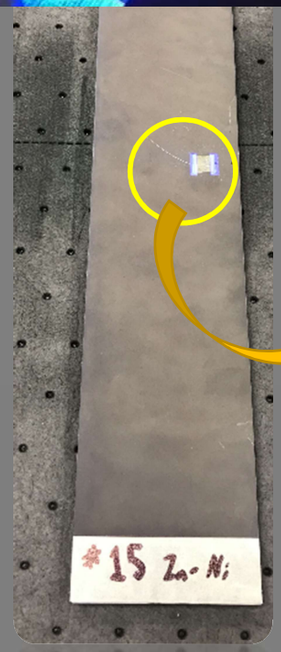
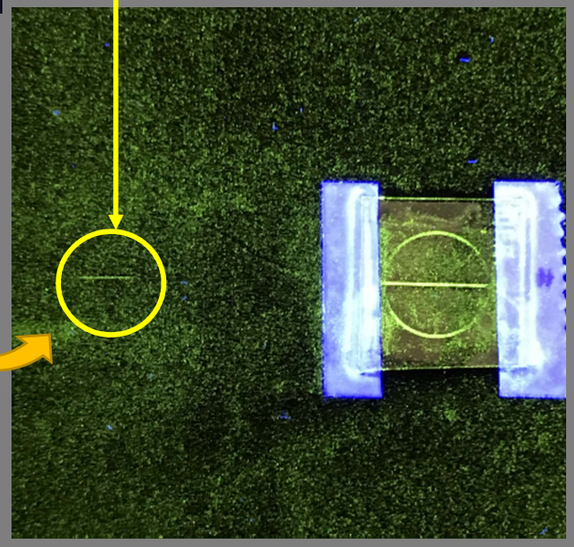
Non-Destructive Testing





Zinc-Nickel

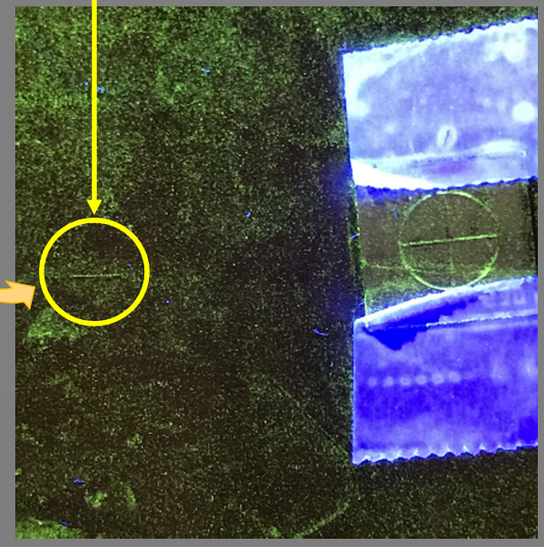
Crack Location



MPI Image

Cadmium

Crack Location



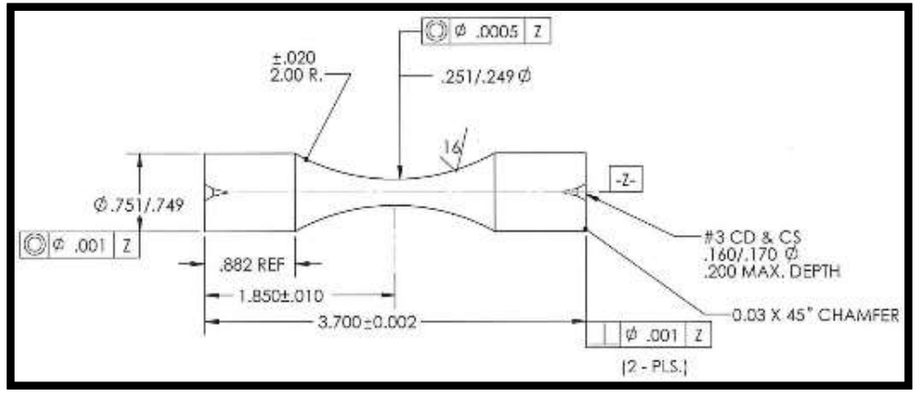
MPI Image

LHE Alkaline Zn-Ni SBIRs AF071-320
Fatigue Test Summary

Coupon Description & Coating Thickness (inches)	Stress Levels (KSI) for R = - 1.0					
Coupon Description	160	170	180	190	200	
Stress Levels (KSI) for R = - 1.0	Number of Coupons					Qty
Bare	6	6	6	6	6	30
Cd	6	6	6	6	6	30
LHE Zn-NI	6	6	6	6	6	30
					Total Quantity	90

Coupon Description & Coating Thickness (inches)	Stress Levels (KSI) for R = 0.1						
Coupon Description	160	170	180	190	200	210	
Stress Levels (KSI) for R = 0.1	Number of Coupons						Qty
Bare	2	2	6	6	6	0	24
Cd	0	2	6	6	6	6	26
LHE Zn-NI	0	2	8	9	7	6	32
						Total Quantity	82

Coupon Material	**0.75 Inch Diameter, AISI 4340 Bar IAW AMS 6414 (All coupons from the same lot)**
Grind	MIL-STD-866
Nital Etch	MIL-STD-867
Heat Treat	260-280 KSI IAW AMS-H-6875 (All coupons heat treated in the same lot)
Non-Destructive Inspection	Magnetic Particle Inspection per ASTM E1444. Inspection criteria per MIL-STD-1907, Grade C.
Plating	Cd Plate IAW MIL-STD-870
	LHE Zn-Ni Plate IAW Dipsol LHE Alkaline Zn-Ni Technical Data Sheet, and USAF DWG201027456



MIL-DTL-5002 Restrictions

3.6.1.1 Cadmium coatings shall not be used for the following applications:

a. Parts that may be in contact with hydraulic fluids, fuels, lubricating oil, and other petroleum based fluids.

b. Parts in frictional contact where gouging or binding may be a detrimental factor.

c. In confined spaces, in the presence of organic materials that give off corrosive or damaging vapors.

d. On titanium parts or fasteners. In addition, cadmium plated parts, including interference-fit fasteners and press-fit bushings, shall not be used in contact with titanium. Under certain conditions, titanium can be embrittled by contacting cadmium components. Embrittlement has been determined to occur in cadmium plated titanium parts at temperatures as low as 150° F.

e. Parts that will be subsequently soldered.

f. Components that will come into contact with graphite composites.

g. Parts that will be exposed to temperatures above 450° F (232° C).

NOT MEASUREMENT SENSITIVE

MIL-DTL-5002E
12 July 2011
SUPERSEDING
MIL-S-5002D
30 November 1989

DETAIL SPECIFICATION

SURFACE TREATMENTS AND INORGANIC COATINGS FOR METAL SURFACES OF WEAPONS SYSTEMS

Reactivated after 12 July 2011 and may be used for new and existing designs and acquisitions.

Expanded effort addresses additional cadmium use restrictions

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NAVAIR Integration Strategy

Industrial Capability	Process Specification	Military Specification (MIL-PRF-32660)	MIL-DTL-5002	Authorization
Process Line Installation ***Complete***	Detail processing requirements LPS 450 ***100 % Draft***	Performance Requirements (In Review) ***100 % Draft***	Design Authority Process Restrictions ***No Restrictions***	NAVAIR Authorization for High Strength Steel Applications ***Complete***

SELECTIVE ELECTROPLATING

As technology matures increased emphasis is necessary for selective repair using brush electroplating techniques.

NAVAIR SBIR Phase II.5 - ES3

- Evaluation of COTS Brush Zinc-Nickel Solutions (Expansion Effort)
  Topic: AF071-320

NAVAIR SBIR Phase II.5 – Corrdesa

- Improved Hardware and optimized processing (Dalistick & Modeling)
  Topic: N112-154

USAF SBIR Phase I – ES3

- Developing and evaluating new brush electroplating formulations
  Topic: AF172-002

SERDP/ESTCP

- Chemicals
- Process
- Tooling
- Hardware

Coordinated Effort Required

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Summary: Dipsol IZ-C17+

Zinc-Nickel Demonstrated Improved

- Corrosion Performance
- Durability
- High Temperature Performance
- Titanium Compatibility
- Mitigation of ESH Risk

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Summary: Dipsol IZ-C17+

NEXT STEPS

- CRES Repair Bushings
- Component Specific Approval
- Mfg Tooling/Fixtures
- FRCSW Plating Line
- Supplemental Fatigue Testing (Alloys)
- Field Repairs

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Questions

NAVAIR