Evaluation of Dipsol IZ-C17 LHE Zinc-Nickel Plating

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Boeing – St. Louis
for
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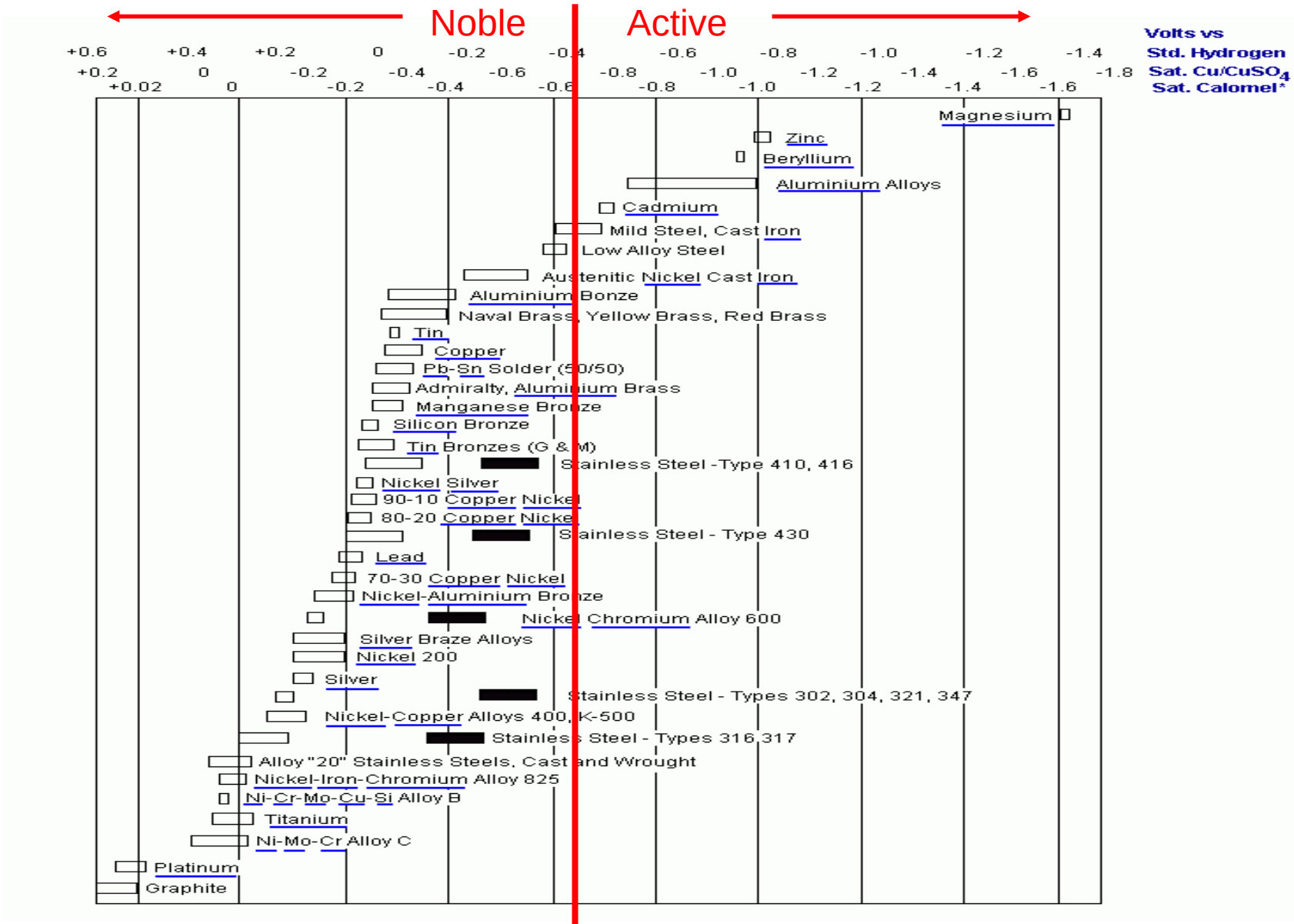
Intro

- Key Attributes for Cadmium Plating Alternatives:
  - Drop-In Replacement
  - Sacrificial to Steel When It Corrodes
  - Corrodes Slowly (Long Life in Salt Water)
  - Non-Embrittling to High Strength Steel
    - Plating Process
    - Maintenance Fluids
- So Why Zinc-Nickel Plating?

Cadmium Alternatives are Limited!



Proposed Cadmium Alternatives

- Cadmium Alternative Coatings for Steel
  - Aluminum (IVD-Sputter Aluminum, Alumiplate)
  - Beryllium (Too Toxic)
  - Zinc (Too Active – Corrodes Too Fast)
  - Magnesium (Extremely Active – Corrodes Rapidly)
- Zinc Alloys Can Reduce Activity of Zinc
  - Zinc-Nickel Preferred (Zn-Fe, Zn-Mn, Zn-Co, Zn-Sn, Sn-Zn Not Acceptable)
    - Zinc-Nickel is Sacrificial to Steel if Ni < ~18%
    - Nickel Alloyed to Zinc Has Low Corrosion Rate in Salt Water
      - No Excessive White Corrosion Products

Zinc-Nickel Alloys

- What is Best Ni Composition in Zinc-Nickel Plating?
  - 4 to 18% Appears to Give Good Corrosion Resistance and Sacrificial Protection to Steel
  - High % Ni Appears to Create a Non-Embrittling Plating Process
- What is Best pH for Zinc-Nickel Plating?
  - Alkaline Plating Appears to Be Easier to Use
    - Bath Easier to Maintain
    - Throwing Power Good and No Variance in % Ni

Zn-Ni Versions for Aerospace and Automotive Industry

- Aerospace Needs a Different Version of Automotive Zn-Ni Plating
  - High Strength Steel Used In Aerospace
    - Hydrogen Embrittlement
    - Fatigue Life
  - Corrosion Performance
    - Aerospace Parts Required to Have a Longer Service Life and Higher Reliability Than Automotive

Pre 2003 Zinc-Nickel Plating

- Pre 2003 There Were Two Zinc-Nickel Processes Being Considered at Boeing
  - Boeing Acid Zn-Ni Plating (with BoeNiz)
    - Passes ASTM F 519 Embrittlement Tests - BUT
      - Plating Process is Not Operator Friendly
      - ASTM F 346 Electronic Hydrogen Measurement (or Similar Method) Cannot Be Used
  - Dipsol IZ-260 Alkaline Zinc-Nickel Plating
    - Occasionally Fails ASTM F 519 Embrittlement Test
    - Plating Process is Operator Friendly - BUT
      - Needed a Nickel Strike to Pass ASTM F 519 on a Consistent Basis

LHE Alkaline Zn-Ni Plating

- C-17 Pollution Prevention Project - 2003 to 2005
  - Develop an LHE (Low Hydrogen Embrittlement) Version of Alkaline Zn-Ni Plating
    - Look at Different Zn-Ni Formulas with Nickel Composition of 5 to 17%
    - Remove Brighteners and Other Additives to Make Plating Dull (Porous)
    - Vary the Current Density

LHE Alkaline Zn-Ni Plating

- Boeing Teamed with Dipsol of America to Develop an LHE Alkaline Zn-Ni Plating
  - Dipsol Produces IZ-260 Alkaline Zn-Ni Plating
    - Used by Several DoD and Aerospace Subcontractors
      - IZ-260 Has 5 to 8% Nickel – Balance Zinc
    - Dedicated R&D Laboratory in Tokyo, Japan
    - Excellent Technical Support at Laboratory in Livonia, MI
    - Dipsol Understands Zn-Ni Plating Chemistry

2003-05 Test Results

- Based on Successful Test Results an LHE Alkaline Zn-Ni Formula was Selected for Further Development
  - Identified as Dipsol IZ-C17 (13 to 17% Ni)
- IZ-C17 Had Good Corrosion Performance
- IZ-C17 Passed Hydrogen Embrittlement and Re-Embrittlement Testing with 1a.1 and 2a
  - Re-Embrittlement Test Specimens Exposed to Distilled Water and 3.5% Salt Water

Zinc-Nickel Corrosion Test

IZ-C17 LHE Zn-Ni

Cadmium

ASTM B 117 – 816 Hours Exposure

IZ-C17 – HE Test Results

Test Description	Specimen Type	ID No.	200 Hour Result (Pass/Fail)	ISL After 200 Hour Test (% NFS)
Set #1 - Plate Entire Specimen	1a.1	AQ3789	Pass	80
Set #1 - Plate Entire Specimen	1a.1	AQ5767	Pass	85
Set #1 - Plate Entire Specimen	1a.1	AQ3623	Pass	90
Set #1 - Plate Entire Specimen	1a.1	AQ3675	Pass	80
Set #2 - Plate at 3 Times Current Density	1a.1	AS1279	Pass	80
Set #2 - Plate at 3 Times Current Density	1a.1	AS1487	Pass	90
Set #2 - Plate at 3 Times Current Density	1a.1	AS1026	Pass	85
Set #2 - Plate at 3 Times Current Density	1a.1	AS1248	Pass	85
Set #3 - Plate with No Preplate Acid Activation	1a.1	AS1385	Pass	95
Set #3 - Plate with No Preplate Acid Activation	1a.1	AS1085	Pass	90
Set #3 - Plate with No Preplate Acid Activation	1a.1	AS1040	Pass	90
Set #3 - Plate with No Preplate Acid Activation	1a.1	AS1281	Pass	95
Set #4 - Plate with Preplate Acid Activation	1a.1	AS1264	Pass	90
Set #4 - Plate with Preplate Acid Activation	1a.1	AS1198	Pass	90
Set #4 - Plate with Preplate Acid Activation	1a.1	AS1421	Pass	90
Set #4 - Plate with Preplate Acid Activation	1a.1	AS1148	Pass	85
Set #5 - Plate with Preplate Acid Activation	2a	44911-12	Pass	-
Set #5 - Plate with Preplate Acid Activation	2a	44911-47	Pass	-
Set #5 - Plate with Preplate Acid Activation	2a	44911-54	Pass	-
Set #5 - Plate with Preplate Acid Activation	2a	44911-1	Pass	-

Hydrogen Embrittlement Results for IZ-C17

IZ-C17 – Re-Embrittlement Tests

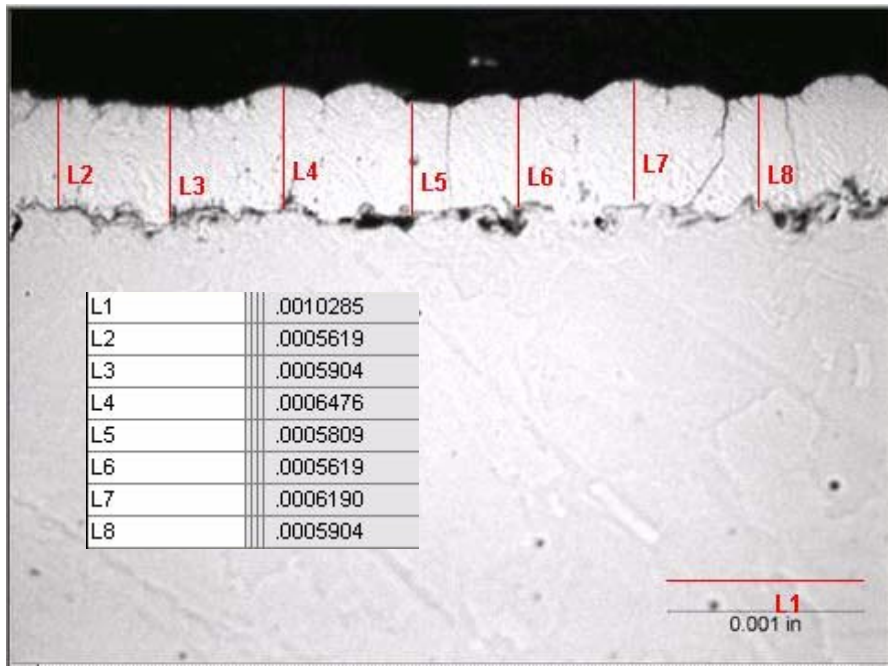
Re-Embrittlement Test Fluid	Specimen Type	ID No.	150 Hour Result (Pass/Fail)
Distilled Water	1a.1	AS1224	Pass
Distilled Water	1a.1	AS1166	Pass
Distilled Water	1a.1	AS1368	Pass
Distilled Water	1a.1	AS1169	Pass
3.5% Salt (NaCl) Water	1a.1	AS1001	Pass
3.5% Salt (NaCl) Water	1a.1	AS1415	Pass
3.5% Salt (NaCl) Water	1a.1	AS1328	Pass
3.5% Salt (NaCl) Water	1a.1	AS1286	Pass
Distilled Water	2a	44911-42	Pass
Distilled Water	2a	44911-134	Pass
Distilled Water	2a	44911-41	Pass
Distilled Water	2a	44911-76	Pass
3.5% Salt (NaCl) Water	2a	44911-42	Pass*
3.5% Salt (NaCl) Water	2a	44911-134	Pass*
3.5% Salt (NaCl) Water	2a	44911-41	Pass*
3.5% Salt (NaCl) Water	2a	44911-76	Pass*

* 2a Test Specimens that passed the 150 hour distilled water test were used for the salt water test.

Hydrogen Re-Embrittlement Results for IZ-C17

IZ-C17 Thickness and Adhesion

- IZ-C17 Has Good Adhesion
  - Passes Bend-To-Break Tests
- Thickness Control is Very Good



2006 – 2007 Test Objectives

- Install Plating Tank at Boeing – St. Louis with Dipsol IZ-C17
  - Perform More Hydrogen Embrittlement Tests
  - Perform Fatigue Tests
  - Perform Lubricity Tests
  - Optimize Operating Parameters
    - Verify Operating Limits of Plating Bath
  - Plate Parts with Complex Geometries
    - Determine Need for Auxiliary Anodes and Special Tooling
      - Plate ID of Tubular Parts
- Qualify IZ-C17 for C-17 Program
  - Create Draft DPS for IZ-C17
    - Identify Process Controls
    - Hydrogen Embrittlement Test Methods
    - Select Repair Procedures

2006 Status

- IZ-C17 Tech Bulletin (Draft) Prepared
  - Information Provided by Dipsol and Boeing
- Purchased and Installed Plating Tank and Support Equipment
  - IZ-C17 Chemical Received From Dipsol of America – Livonia, MI
    - Original Zn-Ni Chemicals Came From Dipsol – Japan
- Bare Test Specimens Prepared

IZ-C17 Tech Bulletin

DIPSOL OF AMERICA, INC.
34005 Schoolcraft Road, Livonia, MI 48150
TEL (734) 261-0633, TOLL FREE: 1-866-DIPSOL-1
FAX (734) 261-0655, E-mail: main@dipsolamerica.com
www.dipsolamerica.com

TECHNICAL BULLETIN

ZINC AND ZINC ALLOY PLATING PROCESSES

LHE Zinc Nickel system

DIPSOL IZ-C17

Low Hydrogen Embrittlement Alkaline Zinc Nickel Alloy Plating

IZ-C17 Zn-Ni Plating Process

1. TCE Vapor Degrease or Solvent Clean with MPK
2. Grit Blast with aluminum oxide (120 grit or finer) at ~ 60 psig
3. Rinse in water to remove loose grit
4. Apply LHE zinc-nickel plate: IZ-C17 – 3 A/dm^2 – RT – 30 to 45 minutes (produces 0.3 to 0.6 mils)
5. Rinse
6. Embrittlement Relief Bake at 375 +/- 25^oF for 24 hours. Bake within 4 hours after plating
7. Rinse
8. Chromate Conversion Coating: Apply IZ-258 @ 140^o F, 60 seconds
9. Rinse
10. Dry @ < 140^o F – 10 minutes

IZ-C17 Plating Tank

- 60 L Plating Tank Installed in Laboratory

Conversion Coat Tank

- Installed IZ-258 Chromate Conversion Coating Tank

IZ-258

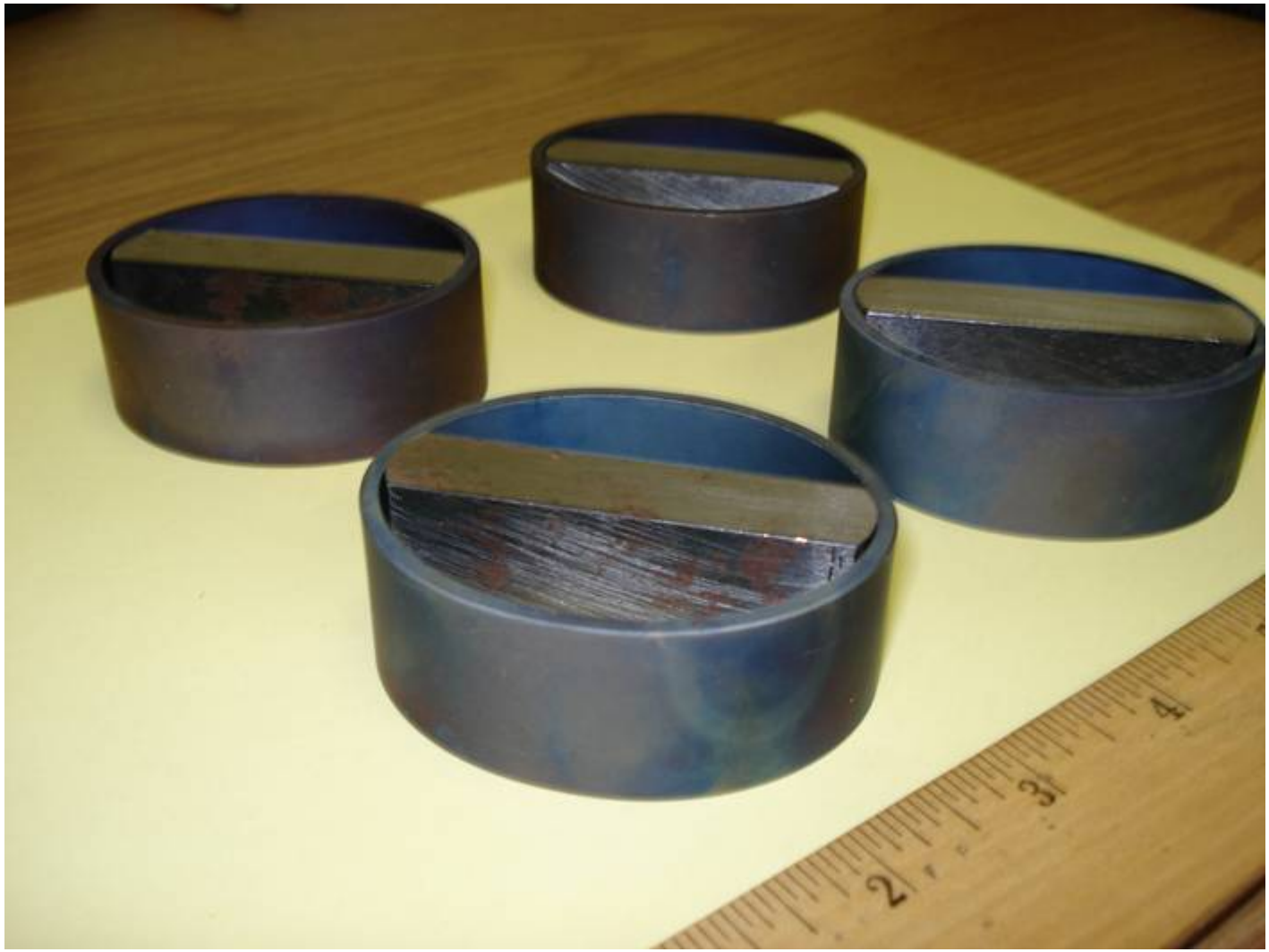
2006 Status (Cont.)

- IZ-C17 Test Plan Prepared
  - Hydrogen Embrittlement (1a.1, 1a.2, 2a)
  - Adhesion and Metallurgy
  - Corrosion Testing (Salt Spray and Galvanic)
  - Fluid Immersion (ASTM F 483)
  - Lubricity (Fasteners)
  - Strippability (BCA – Ammonium Nitrate pH 10)
  - Throwing Power (JCAT Method and Tubes)
  - Fatigue

2006 Status (Cont.)

- IZ-C17 Tank Up and Running Since 8-18-06
  - Chemistry Meets Specifications
    - Need to Use only Nickel Anodes (or Ni Plated Steel)
  - Passed Thickness, Composition and Adhesion Tests
  - Passed Hydrogen Embrittlement for Type 1a.1, 1a.2 and 2a Specimens
- Prepared Corrosion Specimens (4”x6” Steel)
- Prepared Fatigue Bars
- Prepared Fluid Immersion Test Specimens (ASTM F 483 1”x2” Steel Specimens)
- Prepared Throwing Power Test Specimens

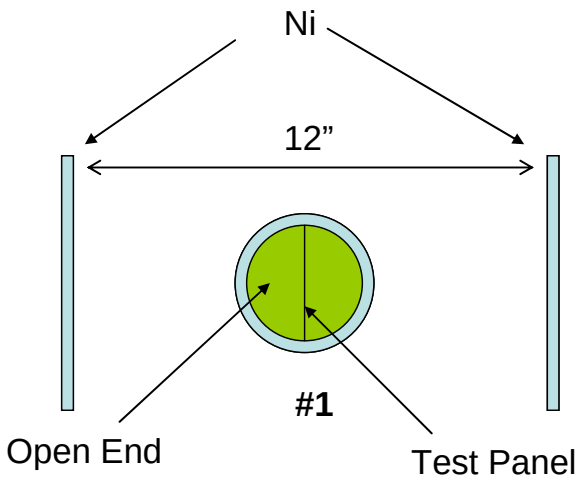
Type 2a HE Testing

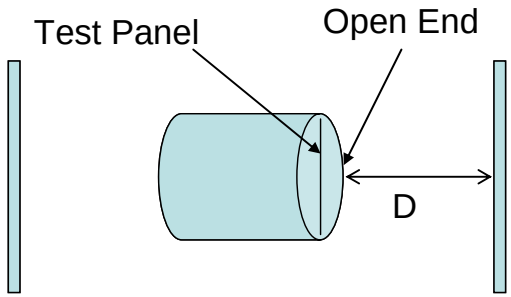


Fatigue Test Specimens

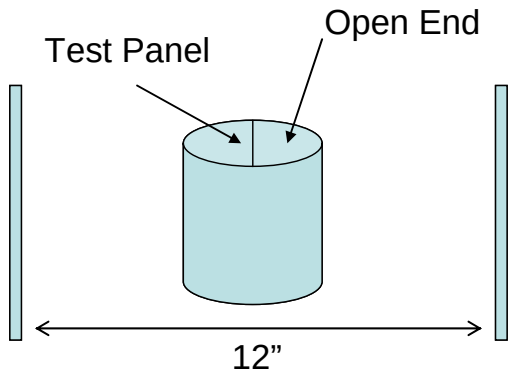
Throwing Power Test

Throwing Power Test





#2: D = 2 to 3 inches (two anodes)
#2A: D = 10 to 12 inches and only one anode at open end



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2007 Activity

- Prepare Zn-Ni Plated Fasteners (In Work)
- Perform Tests on Zn-Ni Plated Specimens
- Plate Tube IDs With Internal Anodes
- Prepare Specimens with Different Zinc – Nickel Ratios in Plating Bath
- Prepare DPS Draft Specification for LHE Zn-Ni Plating
- Support JCAT Phase II and III JTP