Evaluation of Dipsol IZ-C17 LHE Zinc-Nickel Plating

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Boeing – St. Louis

for
HCAT/JCAT Meeting
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### Title and Subtitle

**Evaluation of Dipsol IZ-C17 LHE Zinc-Nickel Plating**

### Performance Organization

**Boeing, P. O. Box 516, St. Louis, MO, 63166**

### Distribution/Availability Statement

Approved for public release; distribution unlimited

### Notes

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

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

**Hydrogen Embrittlement Results for IZ-C17**
## IZ-C17 – Re-Embrittlement Tests

### Hydrogen Re-Embrittlement Results for IZ-C17

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

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

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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°F for 24 hours. Bake within 4 hours after plating
7. Rinse
8. Chromate Conversion Coating: Apply IZ-258 @ 140°F, 60 seconds
9. Rinse
10. Dry @ < 140°F – 10 minutes
IZ-C17 Plating Tank

- 60 L Plating Tank Installed in Laboratory
Conversion Coat Tank

• Installed IZ-258 Chromate Conversion Coating Tank
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

#1
Open End
Test Panel

Ni

12"

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

Test Panel
Open End

D

#3

Test Panel
Open End

12"
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