Temperature Effects on Corrosion of Cr\textsuperscript{6+}, Cr\textsuperscript{3+}, and Non-Cr\textsuperscript{6+} Conversion Coatings on AlumiPlate, and AlumiPlate Implementations

Kelly Donaldson, AlumiPlate
ASETSDefense, Feb 2011, New Orleans, LA
# Temperature Effects on Corrosion of Cr6+, Cr3+, and Non-Cr6+ Conversion Coatings on AlumiPlate, and AlumiPlate Implementations

**ASETSDefense 2011: Sustainable Surface Engineering for Aerospace and Defense Workshop, February 7 - 10, 2011, New Orleans, LA. Sponsored by SERDP/ESTCP.**
AlumiPlate® Electrodeposited Aluminum

- Minneapolis, MN, USA
  - Established 1995
  - Technology developed, tested, qualified & implemented
  - 100% RoHS / REACH Compliant

- Electrodeposited Aluminum Corrosion Protection Coating
  - “Green” environmentally friendly replacement for toxic cadmium (Cd) plating (point of app, fly away, MRO)
  - Higher performance than present HAZMAT (Cd, Zn, Ni) corrosion protection technologies and any alternatives

- Well Established Specifications
  - MIL-DTL-83488 & Program / Application Specific
Temperature Effects on Corrosion of Cr\(^{6+}\), Cr\(^{3+}\), and Non-Cr\(^{6+}\) Conversion Coatings on AlumiPlate, and AlumiPlate Implementations

- **Test Conditions**
  - Aluminum electroplate per MIL-DTL-83488, Class 2 (0.0005”/12.5\(\mu\) min. thk.) on 4130 steel 3” x 6” coupons

- **Conversion coat with Cr\(^{6+}\), Cr\(^{3+}\), non Cr\(^{6+}\)**
  - Baseline = NO conv. coat,
  - 1 type – Cr\(^{6+}\) (commercially available)
  - 3 types -- Cr\(^{3+}\) (commercially available)
  - 3 formulations – CFP non Cr\(^{6+}\) -> (provided by NAVAIR under CRADA)

- **Temperature exposure: 30C, 250C, 350C**

- **Corrosion test per ASTM B117**

- **Protocol**
  - 24 hour bake cycle for temperature exposure
  - Results are averaged across multiple B117 test runs
Test Setup – ASTM B117 Salt Fog Test chamber
ASTM B117 – Definition of Failure

- A4 – 30C Cr₆⁺: 4,032 hrs
- C6 – 250C Cr³⁺: 3,456 hrs
- D6 – 350C Cr³⁺: 1,344 hrs
Baseline = No Conversion Coat
ASTM B117 Hours to Red Rust

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Hours to Red Rust</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>1764</td>
</tr>
<tr>
<td>250</td>
<td>2556</td>
</tr>
<tr>
<td>350</td>
<td>636</td>
</tr>
</tbody>
</table>

AlumiPlate over 4130 Steel per MIL-DTL-83488, Class 2 (0.0005" / 12.5 μm)
**Cr\textsuperscript{6+} Conversion Coat**

**ASTM B117 Hours to Red Rust**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Hours to Red Rust</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 C</td>
<td>5040</td>
</tr>
<tr>
<td>250 C</td>
<td>2688</td>
</tr>
<tr>
<td>350 C</td>
<td>876</td>
</tr>
</tbody>
</table>

*AlumiPlate over 4130 Steel per MIL-DTL-83488, Class 2 (0.0005" / 12.5 µ min.)*
Cr\(^{3+}\) Conversion Coat
ASTM B117 Hours to Red Rust

AlumiPlate over 4130 Steel per MIL-DTL-83488, Class 2 (0.0005" / 12.5 u min.)
Non-Cr\(^{6+}\) Conversion Coat

ASTM B117 Hours to Red Rust

- CFP-2:
  - 30 C: 2928
  - 250 C: 1968
  - 350 C: 888

- CFP-6:
  - 30 C: 2508
  - 250 C: 2688
  - 350 C: 504

- CFP-21:
  - 30 C: 4248
  - 250 C: 3492
  - 350 C: 540

2/14/2011 www.alumiplate.com
All Conversion Coats at **30°C**

**ASTM B117 Hours** to Red Rust

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ASTM B117 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1764</td>
</tr>
<tr>
<td>Cr6+</td>
<td>5040</td>
</tr>
<tr>
<td>Cr3+</td>
<td>3856</td>
</tr>
<tr>
<td>CFP-2</td>
<td>2928</td>
</tr>
<tr>
<td>CFP-6</td>
<td>2508</td>
</tr>
<tr>
<td>CFP-21</td>
<td>3492</td>
</tr>
</tbody>
</table>

AlumiPlate over 4130 Steel per MIL-DTL-83488, Class 2 (0.0005" / 12.5 μ min.)
All Conversion Coats at \textbf{250 C}

ASTM B117 \textbf{Hours} to Red Rust

AlumiPlate
over 4130 Steel per MIL-DTL-83488, Class 2 (0.0005" / 12.5 u min.)
All Conversion Coats at 350°C - ASTM B117

Hours to Red Rust

<table>
<thead>
<tr>
<th>Coating Type</th>
<th>Hours to Red Rust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>636</td>
</tr>
<tr>
<td>Cr6+</td>
<td>876</td>
</tr>
<tr>
<td>Cr3+</td>
<td>1124</td>
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<tr>
<td>CFP-2</td>
<td>888</td>
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<tr>
<td>CFP-6</td>
<td>504</td>
</tr>
<tr>
<td>CFP-21</td>
<td>540</td>
</tr>
</tbody>
</table>

AlumiPlate over 4130 Steel per MIL-DTL-83488, Class 2 (0.0005" / 12.5 μ min.)

2/14/2011 www.alumiplate.com
All Conversion Coats at All 3 Temperatures
ASTM B117 Hours to Red Rust

Baseline | Cr6+ | Cr3+ | CFP-2 | CFP-6 | CFP-21
---|---|---|---|---|---
30 C | 1764 | 2556 | 2412 | 2928 | 4248
250 C | 636 | 876 | 1124 | 888 | 540
350 C | 636 | 876 | 1124 | 888 | 540
Conversion Coat & Temperature Performance Summary

In general, across the conversion coatings tested, corrosion performance decreases as temperature increases (new non-Cr\textsuperscript{6+} CFP generally better)

Cr\textsuperscript{3+} & non-Cr\textsuperscript{6+} CFP provide equivalent or better high temperature corrosion protection compared to Cr\textsuperscript{6+}

The non-Cr\textsuperscript{6+} CFP formulations show promising high temp corrosion protection when compared to Cr\textsuperscript{3+} (WIP)
### Status Update - Recent AlumiPlate Implementations on Present Programs

<table>
<thead>
<tr>
<th>PROGRAM</th>
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</tr>
</thead>
<tbody>
<tr>
<td>B-2 Spirit</td>
<td>F-16 Fighting Falcon</td>
</tr>
<tr>
<td>BHT 4 Series Model 429</td>
<td>F-18 Hornet</td>
</tr>
<tr>
<td>M119A Howitzer</td>
<td>F-22 Raptor</td>
</tr>
<tr>
<td>RQ-4 Global Hawk</td>
<td>C-5 Galaxy</td>
</tr>
<tr>
<td><strong>CH53K Super Stallion</strong></td>
<td><strong>F-35 Lightning II</strong></td>
</tr>
<tr>
<td>(Landing Gear)</td>
<td><strong>Joint Strike Fighter</strong></td>
</tr>
<tr>
<td></td>
<td>(Landing Gear, LEFAS, Elec. Conn.)</td>
</tr>
</tbody>
</table>

**US Army Initiative – High Purity Electrodeposited Aluminum to Replace Cd on Fasteners & Electrical Connectors**
Recent Applications – CH53K – Landing Gear

Images of AlumiPlate coated CH53K landing gear not shown for ITAR reasons. Please contact AlumiPlate for details.
F-35 LEFAS  Environmental Qual Tests (in order): Rain (2hr), Icing (168hr), Humidity (250hr), SO$_2$ Salt Fog (336hr), & Sand & Dust (9hr)

Ti-Cad

AlumiPlate

After 4+ Week Test

www.alumiplate.cc
Recent Applications – Elec Conn

AlumiPlate finish on selected F-35 JSF electronic components (Honeywell TMC)

LMA PH010
MIL-DTL-83488

2/14/2011 www.alumiplate.com
Recent Applications – Elec Conn

ELECTRICAL CONNECTOR SPECIFICATIONS

Electrical Connector Specifications that include “Class P” for Pure Dense Electrodeposited Aluminum as a Cadmium Alternative

<table>
<thead>
<tr>
<th>MIL-DTL-24308G</th>
<th>MIL-DTL-32139A</th>
<th>MIL-DTL-83513G</th>
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</thead>
<tbody>
<tr>
<td>MIL-DTL-38999</td>
<td>MIL-DTL-28840</td>
<td>MIL-DTL-26482</td>
</tr>
<tr>
<td>MIL-DTL-83723</td>
<td>MIL-DTL-22992G</td>
<td>MIL-DTL-3607C</td>
</tr>
<tr>
<td></td>
<td>AS85049</td>
<td></td>
</tr>
</tbody>
</table>
Recent Applications – Fasteners

STRYKER Wheel Bolts – Field Trial

Zn Plate with Cr\textsuperscript{6+} + CARC Topcoat

AlumiPlate with Cr\textsuperscript{3+} NO Topcoat

Torque-Tension @ 75% Proof Load

- Cadmium w/ 30 Weight Oil (K=.14)
- Aluminum w/ Everlube 9002 (K=.16)
- Cadmium - Dry (K=.24)
- Aluminum w/ Magni B18 Silver (K=.30)
- Aluminum w/ 30 Weight Oil (K=.33)

Grade 10.9
M12 x 50mm
All from same heat lot
30 samples each test condition

TnT & GM9540P & etc.
Electrodeposited Aluminum

Performance Status

- Proven performance vs. Cd Cr\(^{6+}\)
  - (CH\(_3\)CO\(_2\)K ground runway deicers)
- High temperature performance with Cr\(^{3+}\) & non-Cr\(^{6+}\)
- Potential lower lifetime costs (lower corrosion costs)
- ESOH Friendly (at point of application & coating on product)
- Commercially available (TRL 7+, MRL 8)

Implementation Status

- Slow but steady adoption program by program (part by part)
- Supply chain availability a challenge but being addressed thru DPA Title III Project Request working with a S.E. Michigan metal finishing company partner
  - New large capacity plating line targeted for late 2012
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