Chromate-free Exterior Painting for Boeing Commercial Aircraft

Joseph Osborne
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**Authors:**

**Performing Organization:** Boeing, P. O. Box 3707, Seattle, WA, 98124

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**DISTRIBUTION/AVAILABILITY STATEMENT**

Approved for public release; distribution unlimited

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**ABSTRACT**

ASETSDefense 2009: Sustainable Surface Engineering for Aerospace and Defense Workshop, August 31 - September 3, 2009, Westminster, CO. Sponsored by SERDP/ESTCP.
Exterior Coatings for Commercial Aircraft

Critically important to image and branding of airlines
Provides a protective function
Condition influences perception of safety & quality

- Decorative Coating Cornerstones
  - Attractive
  - Durable
  - Economical to Apply
  - Removable
Major Applications of Boegel EPII as Pretreatment

Engineering, Operations & Technology | Boeing Research & Technology

April 2008

- Trials on F-15 and KC-135
- Use on All 777 Titanium Tail Cones
- Trial on a 777-200LR Test Aircraft
- Repaint 777-200LR for Delivery
- Process Optimization
- Scale-up Test on Fuselage Test Tube

2005

- Implement on All 747, 767, & 777 Aircrafts
- Use on 787 Line No.1
- 737 Trials 3 Aircrafts
- Implement on All 737’s
- Fleet Survey on Sol-gel Aircraft
- Use on Navy’s P-8A Poseidon (737 Derivative)

2007

2008
Overview

Describe implementation of Boegel technology for BCA exterior painting

• Brief history of Rivet Rash
• The rivet solution
• The need for additional improvements
• Solgel as a conversion coating
• Paint Stripping Considerations
• Summary
Each process and material in the exterior coating system is critical to ensure overall durability.

Changes require careful consideration...and lots of testing and verification.
Aerospace’s Oldest Exterior Coating Issue

Paint Loss from Rivet Head *(Rivet Rash)*
Boeing developed sol-gel based coating system
  - Licensed to AC Tech, PPG, Socomor
  - Non-chromated adhesion promoter for painting and bonding
  - Superior adhesion on aluminum, titanium, CRES, nickel etc.

**AC-131CC PROPERTIES**
- 50:1 Mix Ratio
- 5 minute mix time
- 30 min Induction
- 24 hour pot life
- 3% solids in H₂O
- 1.0 specific gravity
- Vinegar odor
- pH 4 after mixed
- Apply with no rinse
Rain erosion testing showed improved adhesion to rivets when AC-131/Boegel is used as metal pretreatment coating.
AC-131/Boegel Rivet In-service Performance

Pre AC-131 at 18 Months

100’s of rivets missing coating in high erosion area

Post AC-131 at 14 Months

~20 rivets missing coating in high erosion area (many partials)
Testing proved the improved sol-gel adhesion was capturing dissolved Temporary Protective Coating (TPC). Cleaning methods were improved. Additional improvements were investigated.
AC-131 was flood applied liberally, just like chromated conversion coating.

Some streaks were observed after application of sol-gel.

Streaks telegraphed through primer and first layer of topcoat.

Liquid Accumulated on the Fuselage Belly

Trial Result: Successful overall; continue to optimize application process.
In-Service Data on 777-200LR World Tour Aircraft

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Rivet Rash on First 777-200LR (chromated conversion coat)

No Rivet Rash on Second 777-200LR (AC-131)
Lap joints and bottom of doors holds up sol-gel liquid, which drips down to slowly form streaks until all evaporated.

**Major Causes Of Streaks**
1. Lap Joins
2. Application Volume
3. Distance of Cascading

**Solutions**
1. Minimize application volume
2. Remove excess liquid
1. Recommended usage volumes: 737 (5 GAL) & 777 (15 GAL)
2. Combine two-part kits and mix mechanically for 5 minutes
3. Use after 30 minute induction time and within 24 hour pot life
4. **Spray to wet once by mist apply, with minimum overlaps**
5. Prime allowed 15 minutes after sol-gel applied at ambient
6. Taping and tacking allowed one hour after the sol-gel is applied
CHROMATED CONVERSION COAT

1. Remove TPC
2. Solvent Clean
3. Activate Surface
4. Rinse
5. Cr+6 Pretreatment
6. Rinse
7. Mask for Prime
8. Prime
9. Topcoat

BOEGEL EPII PROCESS

1. Remove TPC
2. Solvent Clean
3. Activate Surface
4. Rinse
5. Mask for Prime
6. Boegel/AC-131
7. No Rinse
8. Prime
9. Topcoat
Mask areas required for prime. Mist spray of sol-gel does not impact masking.
Implementation: After AC-131/Boegel EPII and Primer

Good appearance on aluminum and after paint

No liquid flow; no accumulation on lap joins and fuselage belly
Materials to Reduce Rivet Rash

Improved Adhesion Primers
CA7700 (PRC-DeSoto)
10P20-44M (Akzo Nobel)

3 material changes
to address rivet rash

Sol-gel coated Rivets

AC-131-CB
conversion coating
Fleet Survey Results of Improvements

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Rivet Rash Results

- Most airplanes surveyed had only AC-131 rivets and improved primer
- No coating loss beyond high erosion areas
- Zero to a handful of rivets missing coating on most surveyed airplanes
- Three airplanes had more loss but no cause has been discovered for this
Adhesion Failures to Fasteners

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• With rivet rash eliminated, what remains is Phillips head fastener appearing dark

Bolt heads with Phillips Head slots
AC-131 and Paint Stripping Considerations

The improved adhesion provided by the sol-gel coating will increase the amount of time and selection of materials used for paint stripping.

<table>
<thead>
<tr>
<th>ORDER OF DIFFICULTY FOR PAINT STRIPPING</th>
</tr>
</thead>
<tbody>
<tr>
<td>EASIER</td>
</tr>
<tr>
<td>ALODINE CONVERSION COAT &amp; CONVENTIONAL OR 1ST GENERATION HIGH SOLIDS PRIMER</td>
</tr>
<tr>
<td>HARDER</td>
</tr>
<tr>
<td>SOL-GEL CONVERSION COAT &amp; 1ST GENERATION HIGH SOLIDS PRIMER</td>
</tr>
<tr>
<td>SOL-GEL CONVERSION COAT &amp; IMPROVED ADHESION PRIMER</td>
</tr>
</tbody>
</table>
Depainting Panels with Peroxide Based Paint Remover

- On sol-gel panels, peroxide based paint remover performed better than methylene chloride remover.
- Performance is reversed on chromated conversion coated panels.
- In general, paint removal was quicker on chromated conversion coat panels than on sol-gel panels.

All panels were 9” x 16” and had been coated for 6 months minimum.
Depainting 777-200 Freighter – Peroxide-based Remover B

3-9 mils of paint

1st Strip coat

1st Strip coat & 1.5 hours dwell

Squeegee after 2nd full application coat

Alkaline cleaned 26 hours after 3rd application

Abrade and rinse
Future work to Improve Stripping Rates

- Work with paint stripper suppliers – they need to understand the challenge of the Boegel technology.

- Temperature during the stripping process is critical – 25 C or warmer.

- Sol-gel technology will end the use of Phenol/MeCl₂ paint strippers for exterior surfaces Boeing aircraft.
Summary

• In-service data shows the improvements in adhesion are working
  • Fleet surveys will continue to monitor the full life cycle of the coatings system
  • More in-service data on the sol-gel conversion coating performance will be collected
• Some limited non-systematic rivet rash has occurred
  • Root cause has not been determined.
  • Localized touch-up can successfully address this defect
• The sol-gel conversion coating is the first practical treatment for titanium in a paint hangar environment
  • Compared to acid etching and abrading
• The team effort with airline customers has been a key to the success of these improvements
## Impact to Boeing

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Boegel EP-II/AC-131-CB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Health &amp; Safety</strong></td>
<td><strong>Contains Hexavalent chromium</strong></td>
<td><strong>No Hexavalent chromium</strong></td>
</tr>
<tr>
<td></td>
<td><strong>pH = 2.1</strong></td>
<td><strong>pH= 4</strong></td>
</tr>
<tr>
<td><strong>Environmental Impact</strong></td>
<td><strong>Volume of chromated coating:</strong></td>
<td><strong>Volume of chromated coating:</strong></td>
</tr>
<tr>
<td></td>
<td>~100 gallons/twin aisle</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>~25 gallons/single aisle</td>
<td><strong>Rinse water that requires remediation:</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Rinse water that requires remediation:</strong></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>~300 gallons/twin aisle</td>
<td><strong>None</strong></td>
</tr>
<tr>
<td></td>
<td>~75 gallons/single aisle</td>
<td></td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td><strong>Rivet Rash is Problematic</strong></td>
<td><strong>Reduces Rivet Rash</strong></td>
</tr>
</tbody>
</table>
Impact to Commercial Airplane Fleet

When Boeing qualifies or otherwise approves a new technology for commercial use, it is added to the Aircraft Maintenance Manuals and authorized for use on the existing Boeing fleet of ~8,000 active airplanes.

Any operator repainting heritage Boeing aircraft is authorized to use Boegel EPII as an option to chromate conversion coatings.

This translates into a significant reduction in chromated materials and wastewater for the approximately eight hundred aircraft which are stripped and repainted each year.
Looking to the Future

Boeing continues to implement Boegel technology in place of chromated conversion coats for both interior and exterior finishes.

Boeing is actively pursing improvements in all the materials and processes associated with finishes technology:
- Nonchromate primers for selected applications
- Nonchromate exterior primer testing well with AC-131/Boegel
- KLM using nonchromate system
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Boeing delivers KLM’s 777-300ER with chrome-free paint

- This KLM 777-300ER is painted with a chrome-free exterior decorative paint. In addition to simplifying health and safety monitoring requirements, a chrome-free primer reduces the environmental impact of the paint and stripping process. Removing chrome from the paint and primer eliminates special handling of paint waste, clean up and designated offsite disposal areas.

- Aug 25, 2009
Exterior Decorative Paint Systems

- Nonchrome primer:
  CA7502 made by PPG/PRC-DeSoto

- Available Topcoats:
  BMS10-72 Type VIII (Desothane HS)
  BMS10-72 Type IX (Eclipse)
Qualification Process

- Screen test candidates

- Perform qualification tests – Engineering and Manufacturing

- Perform large scale application validation

- Production trials: validate the primer application in paint hangar environment on production airplanes

- List material as a qualified product in BMS10-72

- In-Service Evaluations: validate in-service performance of the primer in various in-service environments

- Offer the product in the Catalog
Summary of Key Test Results

• Adhesion
  No adhesion failures even on fasteners

• Fluid resistance (fuel, hydraulic fluid, oil)
  Similar to currently qualified system

• Corrosion resistance
  – Acceptable corrosion performance on 2024 clad
  – Acceptable corrosion performance on 2024 bare
  – Corrosion performance on 7075 clad is not equivalent to chromated control

• Removability
  – Acid activated benzyl alcohol strippers required.
  – Boeing will incorporate acid stripper into maintenance manuals.

• Large scale application
  Easy application, good appearance
Paint removal rate of xenon (500KJ) aged paint systems

<table>
<thead>
<tr>
<th>paint system</th>
<th>Peroxide 1</th>
<th>Peroxide 2</th>
<th>acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>10P20-44M Eclipse</td>
<td>tc - 9 hrs</td>
<td>tc - 9 hrs</td>
<td>tc&amp;p - 7 hrs</td>
</tr>
<tr>
<td></td>
<td>p - &gt;13 hrs</td>
<td>p - 11 hrs</td>
<td></td>
</tr>
<tr>
<td>CA7502 Desothane HS</td>
<td>Failed to strip</td>
<td>Failed to strip</td>
<td>tc&amp;p - 7 hrs</td>
</tr>
<tr>
<td>CA7700 Desothane HS</td>
<td>tc&amp;p - 9 hrs</td>
<td>tc - 7 hrs</td>
<td>tc&amp;p - 9 hrs</td>
</tr>
</tbody>
</table>

Acid activated benzyl alcohol strippers are required to remove the non-chromated primer. Several of these strippers have been used successfully in repaint facilities and Boeing currently lists two approved acid strippers in an internal stripping document. Boeing will incorporate these two acid strippers into the maintenance manuals.
To summarize, CA7502 non-chromated paint system showed good laboratory test results.

- For 7075 clad aluminum, used on non-pressurized fuselage areas, testing indicates that for some in-service environments, the CA7502 primer may not provide the same level of corrosion protection as today’s chromated primers.
  - Nominal use of 7075 clad aluminum on 737 exterior.

- Boeing will continue to use chromated primer on all non-clad aluminum surfaces of the airplane. (e.g., window plugs, 747/767 fin).
Questions?