 Boeing Technology



Nonchromate Conversion Coatings in use at Boeing

Joseph H. Osborne
Boeing Phantom Works – Seattle

822922-1 is a trademark of Boeing Management Company. Copyright © 2008 Boeing. All rights reserved.

Overview
Boeing Technology

- **Objective:** Summary of two processes used at Boeing that reduce or eliminate the use of chromates
- **Boric Sulfuric Acid Anodizing (BSAA)**
 - replaces chromic acid anodizing
- **Boegel conversion coatings**
 - Conversion coating based on sol-gel chemistry

Copyright © 2008 Boeing. All rights reserved.

MIL-A-8625F (10 Sept 1993)
Boeing Technology

- **Types of Anodize Coatings**
 - Type I – Chromic Acid Anodizing (40V)
 - Type IB – Chromic Acid Anodizing (22V)
 - Type IC – Non-chromic acid anodizing, for use as a non-chromate alternative for Type I and IB coatings (BSAA=15V)
 - Type IIB – Thin sulfuric acid anodizing, for use as a non-chromate alternative for Type I and IB coatings
- **Specifics**
 - (3.4.1) Type IC coating shall be the result of treating aluminum ... in a bath containing mineral or mixed mineral/organic acids (non-chromic acid) ...
 - (3.4.1.1) Type IC coatings provide a non-chromate alternative to Type I and IB coatings. Unless approved by the procuring activity, substitution of a Type IC coating where Type I or IB is specified shall be prohibited
 - Similar wording for Type IIB coatings in 3.4.2 and 3.4.2.1

Copyright © 2008 Boeing. All rights reserved.

Type IC and IIB Caveats
Boeing Technology

- **Suggested substitutions (6.1.2)**
 - Type IC and IIB coatings provide non-chromate alternatives to Type I and IB coatings where corrosion resistance, paint adhesion, and fatigue resistance is required. Please note that Type IC or IIB may not serve as suitable replacements when the effects of electrolyte entrapment is the primary concern. Maximum Type IC and Type IIB coating weights of 700 mg/ft² and 1000 mg/ft², respectively, are specified in Table I for fatigue purposes. ...
- **Effect on fatigue (6.10.7)**
 - The fatigue properties of aluminum alloys can be severely reduced by anodic coatings. The amount of reduction varies with the process. As a general rule, the thicker the coating the greater the reduction in fatigue will be.

Copyright © 2008 Boeing. All rights reserved.

Boric Sulfuric Acid Anodizing
Boeing Technology

- **Direct replacement of chromic acid anodizing**
 - MIL-A-8625 Type I, Type IB, Type IC
 - Used on parts that are fatigue sensitive
 - Parts are almost invariably fully painted
 - Coating weights depend on alloy
 - 2XXX are typically 200 to 500 mg/sq.ft.
 - 7XXX are typically 400 to 700 mg/sq.ft.
 - Coating weight has tendency to self-limit
 - Fatigue debit is less than for CAA at similar coating weight
 - Seal required in BAC5632 is dilute chromate (<75ppm Cr(VI))
 - DI seal does work but not robust
 - "Class 5" unsealed is allowed for fully painted parts
 - Superior adhesion

Copyright © 2008 Boeing. All rights reserved.

Test Data
Boeing Technology

- **Boeing (Commercial Airplanes)**
 - Extensive testing of BSAA for corrosion protection, paint adhesion, fatigue
 - Multiple sources
 - Approved for use on all models as a direct replacement for chromic acid anodizing
- **Recent C-17 Results**
 - Extensive testing of corrosion, adhesion, fatigue
 - Includes alloys, materials, requirements specific to C-17
 - Results consistent with Boeing and NAVAIR data
- **NAVAIR**
 - Test data to support MIL-A-8625 revisions, NAS-NI, others
- **Air Force**
 - Sacramento ALC, others?

Copyright © 2008 Boeing. All rights reserved.

BSAA Usage

Boeing Technology

- **BSAA approved for use in place of CAA for all models of Commercial Airplanes**
 - Class 5 unsealed allowed for fully painted parts
 - Class 5 is used for all wing components
 - Chromate primers (fuel tank, interior and exterior epoxy primers)
- **Boeing Fabrication uses BSAA exclusively**
 - Boeing Canada still has CAA
- **48 approved suppliers world wide (31 in USA)**
 - Navy, Air Force installations
- **No known performance issues with 15+ years experience in the commercial fleet**

Copyright © 2008 Boeing. All rights reserved.

Implementation -- Drawing Finishing Call Out

Boeing Technology

- FAA requires that all information required to build a part be on or referenced from the part drawing

```

    graph TD
      PD[Part Drawing  
- finish code on parts list] --> FC[Finish Code  
- "Apply chemical conversion coating to all surfaces in accordance with MIL-A-8625 Type I or BAC5019, Class 1 or Class 3"]
      FC --> PS[Process specification  
- Company specific processing instructions to meet mil spec requirements and variations thereof]
      PS --> SD[Substitution Drawing  
- Documents options to drawing parts list  
- Applies to multiple drawings]
      SD --> PD
  
```

Copyright © 2008 Boeing. All rights reserved.

Substitution Drawing for Implementation

Boeing Technology

SECTION	SPECIFIED MATERIAL	SUBSTITUTED MATERIAL	REMARKS
*4.1.3.4	ANODIZE IN ACCORDANCE WITH BAC 5019	ANODIZE IN ACCORDANCE WITH BAC 5019 CLASS 5	SUBSTITUTION ALLOWED ONLY FOR PARTS WITH ALL ANODIZED SURFACES COMPLETELY PAINTED.
	ANODIZE IN ACCORDANCE WITH BAC 5019 CLASS 3	ANODIZE IN ACCORDANCE WITH BAC 5019 CLASS 5	DEFINITION OF COMPLETELY PAINTED: ALL ANODIZED SURFACES RECEIVE A PERMANENT ORGANIC COATING AND NO ANODIZED AREAS ARE EXPOSED.
	ANODIZE IN ACCORDANCE WITH BAC 5019 CLASS 3	ANODIZE IN ACCORDANCE WITH BAC 5019 CLASS 5	
	ANODIZE IN ACCORDANCE WITH MIL-8625 TYPE 2	ANODIZE IN ACCORDANCE WITH BAC 5019 CLASS 5	
*4.1.3.4	ANODIZE IN ACCORDANCE WITH BAC 5019 CLASS 3	ANODIZE IN ACCORDANCE WITH BAC 5019 CLASS 5	SUBSTITUTION ALLOWED ONLY FOR PARTS WITH ALL ANODIZED SURFACES COMPLETELY PAINTED. DEFINITION OF COMPLETELY PAINTED: ALL ANODIZED SURFACES RECEIVE A PERMANENT ORGANIC COATING AND NO ANODIZED AREAS ARE EXPOSED.

Copyright © 2008 Boeing. All rights reserved.

CAA to BSAA Transition Issues

Boeing Technology

- **Tanks and equipment**
 - BSAA can corrode tanks/pumps/etc
 - Mild steel is not acceptable
- **Assemblies**
 - BSAA electrolyte is corrosive
 - Not appropriate for assemblies where solution may be trapped
 - Masking of dissimilar metals needs careful consideration

Copyright © 2008 Boeing. All rights reserved.

Boegel IIEP conversion coating

Boeing Technology

- **Boegel is Boeing developmental name**
 - "Sol-Gel" describes a wide variety of processes
 - Not all "sol-gel" coatings are the same!
 - "Boegel" is a specific formulation based on sol-gel processing techniques
 - Licensed to AC Tech, Henkel, Sococom
- **Mixed Zr/Si oxide system**
 - Aqueous solution -- ~3-30% solids
- **Silane component matched to primer, sealant, or adhesive**
 - Boegel-EPII is epoxy functionalized – epoxy primers/adhesives
 - Boegel-AM is amino functionalized – polyimide adhesives
 - Boegel-HS is concentrated, high temp version
- **Designed for spray/flood applications**
 - Facilitate "just in time" fabrication
 - Easily scaleable to part size
 - Little/no overhead in facilities/tanks/process solution
- **Little or no waste**
 - Neutralize and sewer
- **Superior adhesion**
 - Aluminum, titanium, CRES, nickel, ...

Copyright © 2008 Boeing. All rights reserved.

Sol-Gel Chemistry Basics

Boeing Technology

Hydrolysis:

$$\text{RO-Si(NH}_2\text{)-OR} + \text{H}_2\text{O} \rightarrow \text{RO-Si(NH}_2\text{)-OH} + \text{ROH}$$

Condensation:

$$\text{RO-Si(NH}_2\text{)-OH} + \text{HO-Si(NH}_2\text{)-OR} \rightarrow \text{RO-Si(NH}_2\text{)-O-Si(NH}_2\text{)-OR} + \text{H}_2\text{O}$$

Copyright © 2008 Boeing. All rights reserved.

Designed Nanostructured Boegel Interface

Boeing Technology

Organic Resin

Sol-Gel Layer

Metal Hardware

Metal Part Surface

- Tailorable to different resin/paint chemistries
- Robust process conditions
- Greater range of properties using inorganic and hybrid polymers than current state-of-the-art systems

Copyright © 2008 Boeing. All rights reserved.

Boegel Film Characteristics

Boeing Technology

- Oriented film - Zr toward metal, organic on top
- ESCA/Auger shows aspects of gradient coating
- IR shows Si-O and organics
- XAS indicated M-O-Zr bond
- Thickness ranges from 20 nm – 1 μm depending on formulation chemistry

Organic-Rich Region

Zirconium-Rich Region

Copyright © 2008 Boeing. All rights reserved.

Colored Boegel EPII

Boeing Technology

- Boegel/AC-131BB gives adequate coloration for process and end item evaluation
- No impact on performance properties

AC-131

AC-131 with Water Soluble Primer

AC-131BB

Copyright © 2008 Boeing. All rights reserved.

Key Results - Rain Erosion with rivets

Boeing Technology

Cr conversion coat/ Paint System 1

Boegel/ Paint System 1

Cr conversion coat/ Paint System 3

Boegel/ Paint System 3

Rain erosion testing shows improved adhesion to rivets for two different paint systems when Boegel EPII is used as pretreatment.

Copyright © 2008 Boeing. All rights reserved.

Paint Adhesion to Titanium

Boeing Technology

- Phosphate-fluoride is typical conversion coating for titanium
- Process tanks not available for large part so different approach was needed.
- Implemented as a change in process specification
 - Production Process since 1997

poor

poor

good

HF/HNO₃ etch

Phosphate fluoride

Boegel

Copyright © 2008 Boeing. All rights reserved.

Specification Summary

Boeing Technology

Ti/Al/Steel/Aluminum/Brass/Inconel/Carbon Steel	D950-10313-1, Rev C	Sol-Gel Conversion Coatings for Titanium Alloys
	BSMS-25-002	Sol-Gel Conversion Coating
	BSPS-07-002	Application of Sol-Gel Coating for Titanium Painting
	BAC 5665	Application of Sol-Gel Conversion Coatings on Corrosion Resistant Alloys for Painting
	XBMS 10-128	Sol-Gel Conversion Coating
Ti/Al/Steel/Aluminum/Brass/Inconel/Carbon Steel	BSMS-25-001	Sol-Gel Coating for Metal Bonding
	BSPS-07-001	Application of Sol-Gel Coating for Titanium Bonding
	D950-10413-1 Rev A	Sol-Gel Surface Treatment for Bonding Titanium Alloys
	XBAC5667	Sol-Gel Surface Treatment for Bonding of Corrosion Resistant Alloys
Ti/Al/Steel/Aluminum/Brass/Inconel/Carbon Steel	XBMS5-162	Sol-Gel Coating for Metal Bonding
Al	9-679N-KYB02-019	Sol-Gel Conversion Coatings for Aluminum Alloys
	BAC5663	Sol-Gel Conversion Coatings for Aluminum Alloys
	D6-181E	Paint Hangar Document
Al	9-679N-KYB02-011	Sol-Gel Prebond Treatment for Aluminum Alloys
	SRM Chapter 51	Structural Repair Manuals, BCA

Copyright © 2008 Boeing. All rights reserved.

Implementation

Boeing Technology

Everett Decorative Paint Operations implemented Boegel EPII/AC131-CB for 777s in March 2007



Elimination of ~ 400 gallons of chromated pretreatment and wastewater material per 777

Copyright © 2008 Boeing. All rights reserved.

Summarize applications

Boeing Technology

- **Painting Titanium parts**
 - Several applications on B787
 - Tail cone
 - F-22 Booms and tubes
- **Bonding**
 - Ti rotor blade debris caps
 - Structural Repair of Aluminum aircraft
 - Several Ti-to-composite parts on B787
- **Painting Aluminum**
 - Wide body paint hangers (B777)
 - Part-by-part approval for components
 - Drawing changes, working on substitution dwg callout
- **List is growing**

Copyright © 2008 Boeing. All rights reserved.

Summary

Boeing Technology

- Sol-gel technology can be used to improve performance while saving on manufacturing and environmental costs
- Inorganic polymer technology has just begun to be exploited as a means of forming polymer and composite systems
- These are enabling technologies in aerospace manufacture that will allow us to achieve new properties, enable new processes, and greater durability materials
- All sol-gels are not alike

Copyright © 2008 Boeing. All rights reserved.

Questions?



Boeing Technology



Copyright © 2008 Boeing. All rights reserved.