Engineering, Test & Technology
Boeing Research & Technology

Trivalent Alternatives under Evaluation at Boeing

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Cr^{6+} Elimination Activities in BR&T

Optimizing Tri-Chrome Plating Process

- Pilot Scale Process Tanks *(BR&T-Huntsville)*

TCP Evaluation at Multiple Facilities

- Low-volume TCP implementation *(BR&T-Huntsville)*
- Paired-deox TCP for detail parts
- TCP w/ Chrome Primer for Propulsion Systems
- TCP Seal for BSAA, ASAA *(BR&T-Seattle)*
- Manual TCP for legacy OML *(Boeing Oklahoma City)*
- LIFT Non-Cr Coating System *(Industry/Gov. cost share)*

Screening of Alternative Conversion Coatings

- Multi-step trivalent chromium processes
- Inhibited sol-gels
- UV-cure, thermal-cure sol-gels

120-gallon tanks

600-gallon tanks

Commercial Usage of Cr^{6+} Conversion Coatings

Aluminum Conversion Coatings

Situation

Broad Application	*Current Design*	*Future Drivers*
Detail Parts	Chem Film (Alodine)	Airplane Programs
Sub Assembly and Assembly	Anodize (BSAA/CAA)	Supply Base
Repair/ Maintenance	Boegel (BMS10-128)	Regulations

- **Commercial Aerospace Requirements**
  - **FAA CFR, Title 14 §25.609 - Protection of structure**
    - Parts protected from weathering, corrosion, abrasion…
  - Changes to "fit, form, function"
  - Performance "As good as or better"

Commercial Drivers for Cr^{6+} Elimination

Airline Request 12345 (due Friday, March 9th)

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Product X is a trivalent chromate conversion coating for aluminum and can also be used as an anodize seal. It has been qualified to MIL-DTL-81706B. Tests have shown this material to outperform existing trivalent and hexavalent chromate conversion coatings in wear and corrosion resistance without requiring additional topcoats. See attachment.

Airline Y requests approval to use Product X as a chromate conversion coating on aluminum parts and as a seal on Boric Acid -Sulfuric Acid anodized aluminum parts on all Boeing designed Airline Y commercial airplanes.

DESIRED ACTION:
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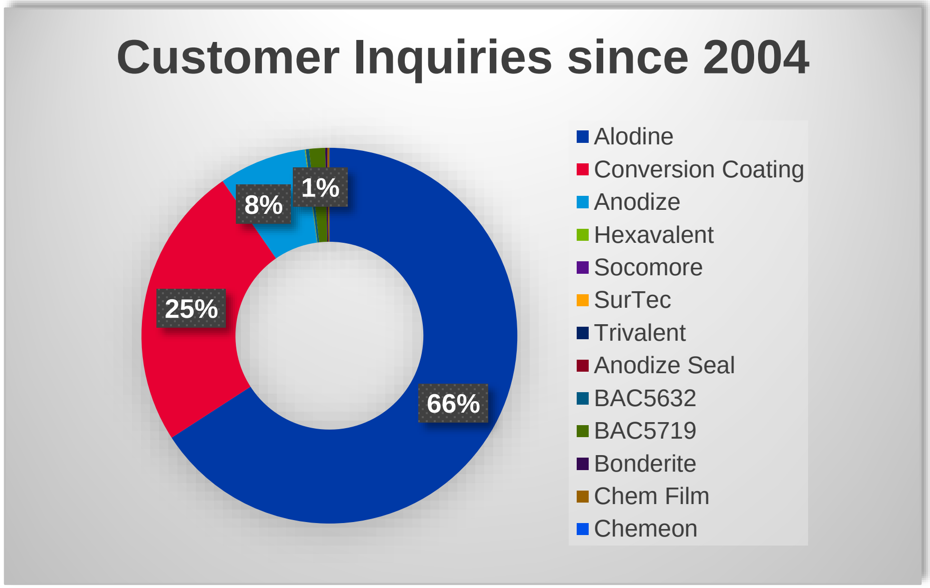
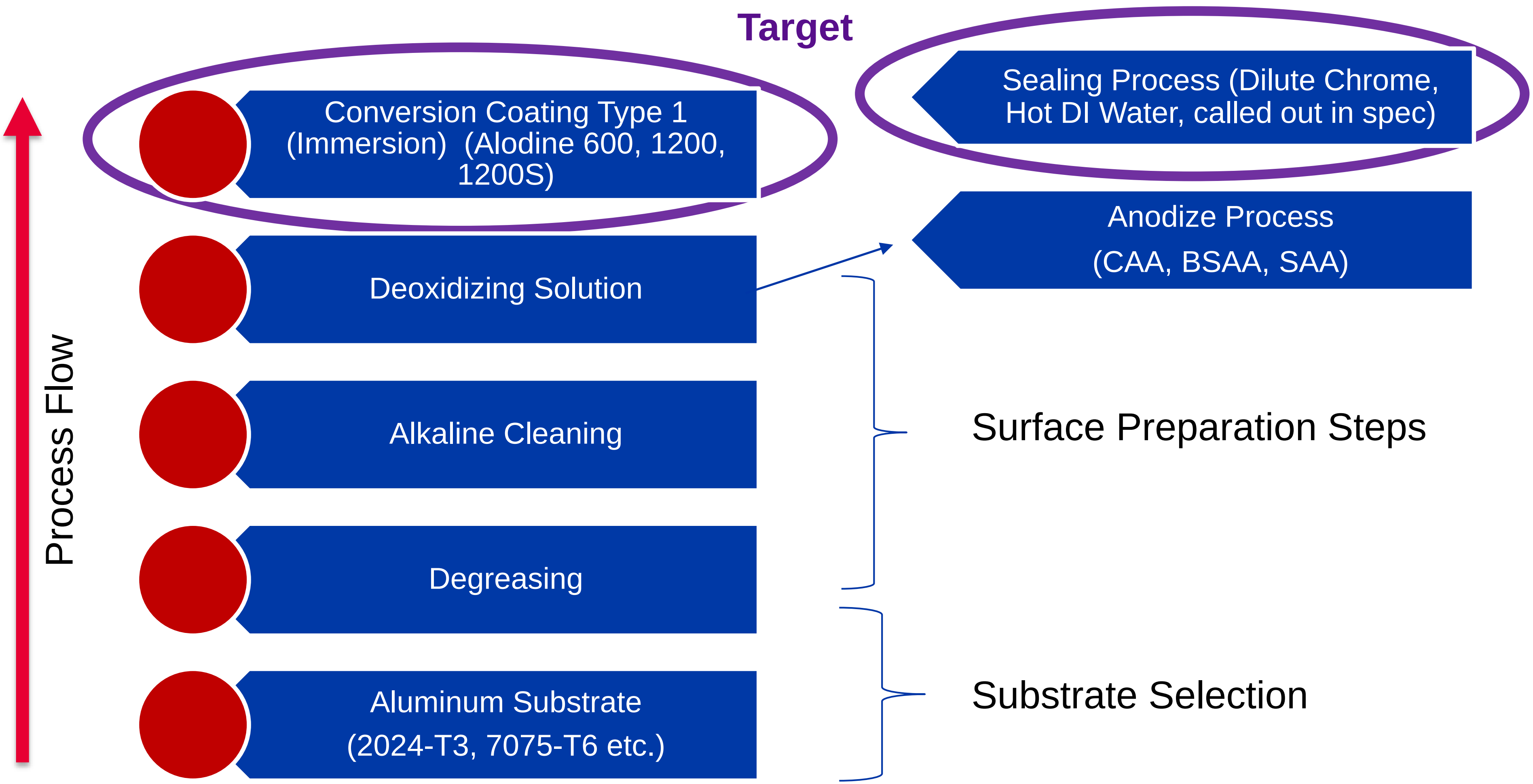
Airline Y requests Boeing approval to use Product X as a trivalent chromate conversion coating and as an anodize seal on Boric Acid - Sulfuric Acid anodized parts on all Boeing designed Airline Y commercial airplanes.



Source: Customer Inquiry Database, Accessed May 2018

Targeted Conversion Coating and Anodizing Processes



Screening Tests for Multi-step Cr^{3+} Process

- Sheet metal panels were provided by Boeing for processing at supplier.
- Screening tests performed for conversion coating and anodize seal (Thin Film Sulfuric Acid Anodize).

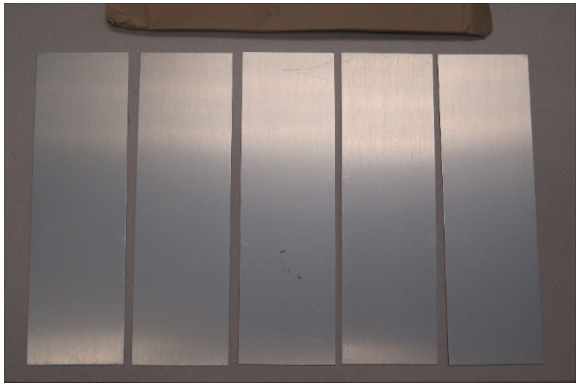
Test	Test Specification	Material Specification
Coating Weights	MIL–DTL–81706	N/A
Dry Adhesion	BSS7225, Type 1 Class 3 & 5	BMS10-11 Ty I Gr. B
Wet Adhesion	BSS7225, Type 3 Class 3 & 5	BMS10-11 Ty I Gr. B
Unpainted Corrosion	ASTM B117-03	BAC5719 (168 hours)
		BAC5022 (336 hours)
Painted Corrosion	ASTM B117-03	BMS10-11 Ty I Gr, B

- Process brought in-house May 2018 (pilot tankline).
- 2018 plan: Repeat screening tests using Boeing's common processes (e.g., BSAA).

Summary of Test Results – Multi-step Cr^{3+} Process

Test	Process	Alloy	Results
Coating Weights	Conversion Coating	2024-T3	PASS
		7075-T6	PASS
		6061-T6	PASS
Wet/Dry Adhesion Testing	Anodize (TFSAA) + BMS10-11	2024-T3	PASS
		2024-T3 Clad	PASS
		7075-T6 Bare	PASS
		7075-T6 Clad	PASS
		6061-T6	PASS
Wet/Dry Adhesion Testing	Conversion + BMS10-11	2024-T3	PASS
		2024-T3 Clad	PASS
		7075-T6 Clad	PASS
		6061-T6	PASS
Unpainted Corrosion, TFSAA (Anodized)	Anodize (TFSAA)	2024-T3	PASS
		2024-T3 Clad	PASS
		7075-T6	PASS
		7075-T6 Clad	PASS
		6061-T6	PASS
Unpainted Corrosion, (Conversion only)	Conversion Coating	2024-T3 Bare	PASS
		2024-T3 Clad	FAIL
		7075-T6 Bare	PASS
		7075-T6 Clad	PASS
		6061-T6	PASS
Painted Corrosion, Conversion + Paint	Conversion + BMS10-11	2024-T3	Darkening in scribe
		2024-T3 Clad	
		7075-Bare	Currently testing
		7075-T6 Clad	Blistering along scribe line
		6061-T6	
Painted Corrosion, Anodize + Paint	Anodize (TFSAA) + BMS10-11	2024-T3	Darkening in scribe
		2024-T3 Clad	
		7075-T6	
		7075-T6 Clad	
		6061-T6	

Wet Adhesion on 2024-T3 Bare


336-hr NSS of TFSAA on 2024-T3 Bare


3000-hr NSS painted 2024-T3 Bare

Project Next Steps

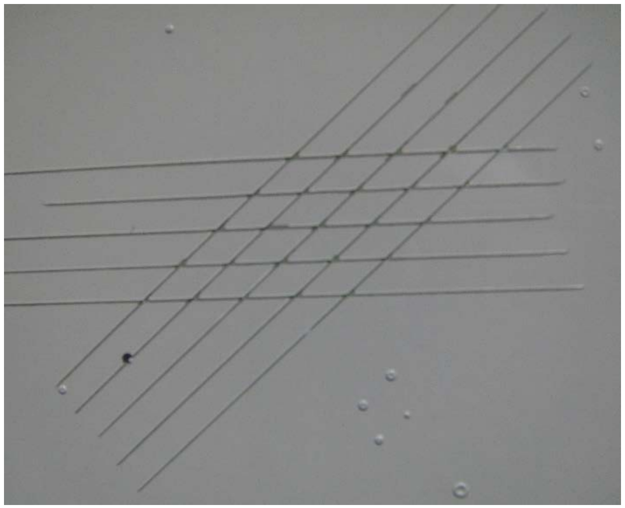
- Implemented multi-step Cr^{3+} process in BR&T-Huntsville pilot tankline.
  - Characterize process stability & repeatability.
  - Demonstrate manufacturability for multiple processes.
    - E.g., Generate test data for multi-step Cr^{3+} sealing with BSAA process.
- Evaluate non-chrome deoxidizers with BSAA standard process & Cr^{3+} seals.

Test Plan to Evaluate Systems-level Interactions

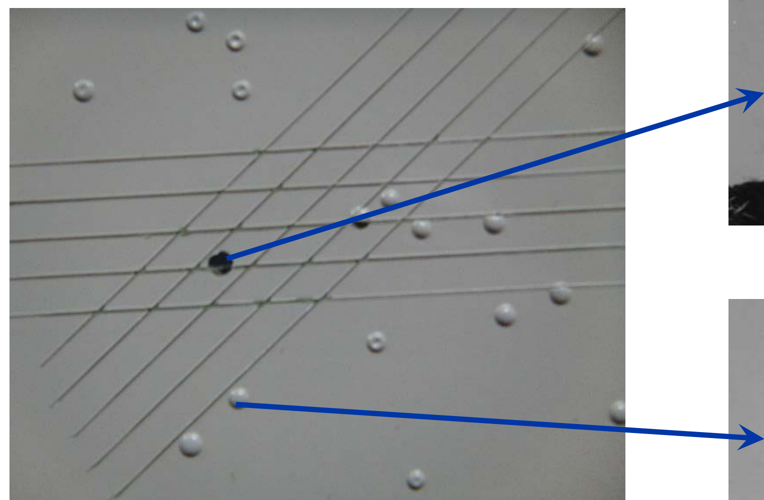
	Control	Candidate Process	Non-Chrome Deox Only
Degrease	Brulin Isoprep	Brulin Isoprep	Brulin Isoprep
Deox	Cr^{6+}	Non-chrome (BAC5765)	Non-chrome (BAC5765)
Anodize	BSAA	BSAA	BSAA
Seal	Dilute Cr^{6+} seal	Cr^{3+} seal	Dilute Cr^{6+} seal

Coating Systems-level Interactions

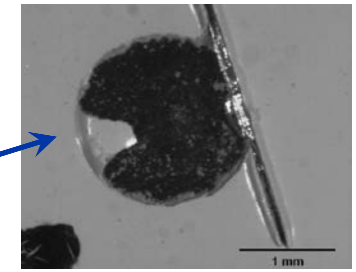
Adhesion Testing after 30-day Exposure to Condensing Humidity



2024-T3 bare
Alodine
Chromated epoxy primer
Epoxy topcoat



2024-T3 bare
TCP
Chromated epoxy primer
Epoxy topcoat



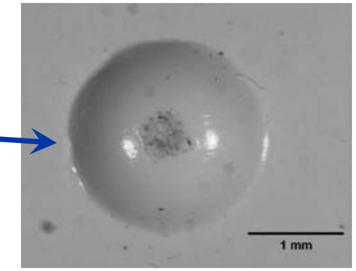
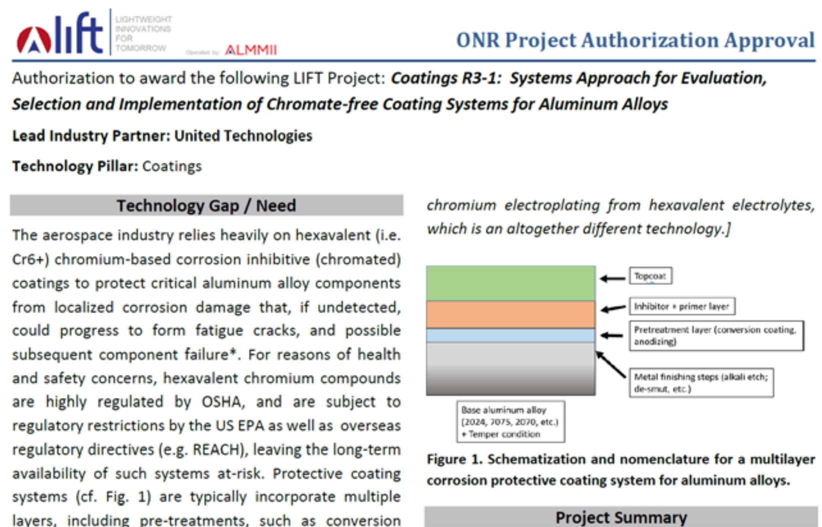


Image Credit: K. Spicer, OSU

	Alloy	Process	BMS10-11 Ty I Gr B	BMS10-11 Ty I Gr B + BMS10-11 Ty II Gr D
Mandrel Bend (Flexibility at RT)	2024-T3 Bare	TCP 1	6,8,8	10,10,10
		TCP 2	5,8,8	10,10,10
		BSAA Unsealed	10,10,10	10,10,10
		Alodine 600	7,8,7	10,10,10

LIFT Project Coatings R3-1:

Systems Approach for Evaluation, Selection and Implementation of Chromate-free Coating Systems for Aluminum Alloys


lift LIGHTWEIGHT INNOVATIONS FOR TOMORROW ALMMII

ONR Project Authorization Approval

Authorization to award the following LIFT Project: ***Coatings R3-1: Systems Approach for Evaluation, Selection and Implementation of Chromate-free Coating Systems for Aluminum Alloys***

Lead Industry Partner: United Technologies

Technology Pillar: Coatings

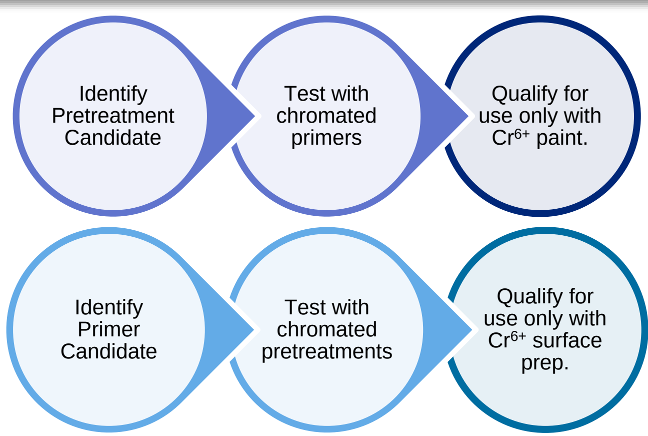
Technology Gap / Need

The aerospace industry relies heavily on hexavalent (i.e. Cr6+) chromium-based corrosion inhibitive (chromated) coatings to protect critical aluminum alloy components from localized corrosion damage that, if undetected, could progress to form fatigue cracks, and possible subsequent component failure*. For reasons of health and safety concerns, hexavalent chromium compounds are highly regulated by OSHA, and are subject to regulatory restrictions by the US EPA as well as overseas regulatory directives (e.g. REACH), leaving the long-term availability of such systems at-risk. Protective coating systems (cf. Fig. 1) are typically incorporate multiple layers, including pre-treatments, such as conversion

chromium electroplating from hexavalent electrolytes, which is an altogether different technology.]

Figure 1. Schematization and nomenclature for a multilayer corrosion protective coating system for aluminum alloys.

Project Summary



Piecemeal Approach Leads to Hybrid Coating Systems

Project Objectives

- Rapidly advance TRL/MRL of coating system: Cr^{3+}, non-chromated primers and associated topcoat layers.
- Leverage lessons-learned from qualification of "hybrid" coating system architectures.
- Produce matrix of corrosion test coupons for one legacy alloy (2024-T3) and one advanced alloy (e.g. 2070, 2060).
- Utilize analytical methods to identify root cause aspects of coating system failures.
- Understand and validate remedies that can be implemented within the scope and duration of the project.

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