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INTERNATIONAL AEROSPACE
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WG2 Technical Exchange Project Summary Report, Chemical Conversion Coating

28 April 2025

Version 1.0

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Version History

Date	v#	Modified By	Section, Page(s) and Text Revised
28 April 2025	1.0	K. Bordage K. Bubel	All

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List of Acronyms

Acronym	Description
ADCR	Aerospace and Defense Chromates Reauthorisation
CCC	Chemical Conversion Coatings
Cr(III)	Trivalent Chromium
Cr(VI)	Hexavalent Chromium
CRT	Corrosion Resistance Testing
ECR	Electrical Contact Resistance
IAEG	International Aerospace Environmental Group, Inc.
NLOS	Non-Line of Sight
NSF	Neutral Salt Fog
OEM	Original Equipment Manufacturer
PPRD	Process Performance Requirement Document
SOW	Statement of Work
TCP	Trivalent Chromium Pretreatment
WPA	Wet Paint Adhesion

1 Purpose

International regulations, including REACH¹, are restricting the use of hexavalent chromium (Cr(VI)) due to its classification as a carcinogen by international occupational safety & health organizations. The International Aerospace Environmental Group, Inc. (IAEG) has identified a need to advance alternate solutions to substances and processes at risk for obsolescence due to environmental regulation. A working group was formed whose focus was to investigate substitutes to existing chromate (Cr(VI)) containing Chemical Conversion Coatings (CCC) as a critical process within the aerospace and defense industry. Several products have been proposed on the market mostly based on the use of trivalent chromium (Cr(III)) instead of hexavalent chromium (Cr(VI)).

The CCC project has progressed through multiple stages. Stage 1 involved surveying suppliers of conversion coatings, which do not use hexavalent chromium. This stage allowed for collection of data available from these suppliers and provided a list of companies and contacts to the working group. Stage 2 focused on members discussing pertinent performance criteria for alternate solutions and corresponding test methods. The working group also used this project stage to exchange data and experience available either in the public domain or obtained from members' replacement activities. Lastly, Stage 3 of the project focused on the development and execution of a test matrix aimed at investigating the replacement technologies of most interest to the participants.

¹ The Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) is a law enacted by the European Union

2 Scope

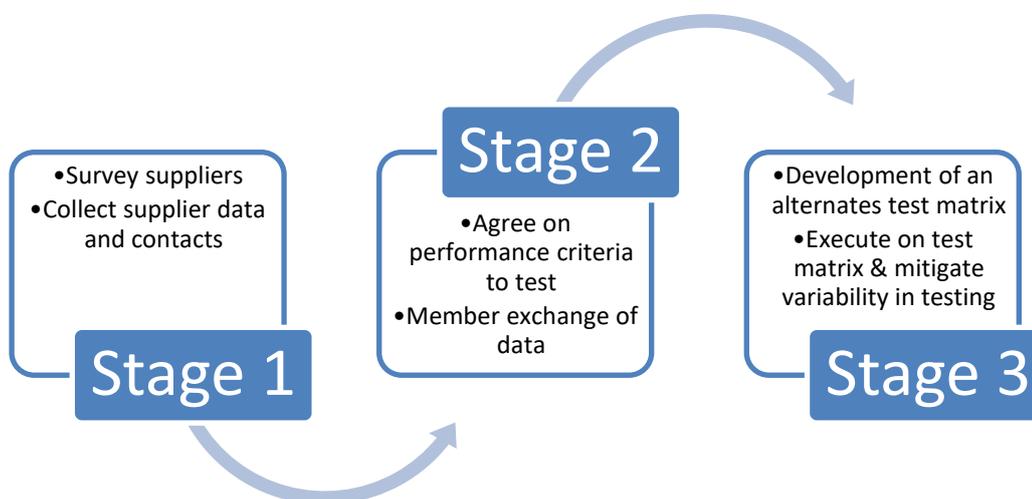
2.1 Project Scope

Conversion coatings using compounds containing hexavalent chromium are common in the aerospace and defense industry for treatment of aluminium and aluminium alloys. This project report focuses on the results from Stage 2 and Stage 3 of the working group and provides details of results obtained by either working group participants or as part of the test matrix that was developed and executed as part of Stage 3.

2.2 Project Structure

The project was comprised of three stages each with a specific set of deliverables. Figure 1 outlines project structure.

Figure 1 - Project Structure Schematic



2.2.1 Stage 1

Initial efforts of the working group included surveying the surface finishing industry for CCC, which did not utilize Cr(VI). A list of suppliers and industry contacts was established for the working group participants. Discussion was initiated on a process performance requirement document (PPRD). Lastly, within this stage the working group created a comparison document of data supplied by suppliers of the conversion coating alternates.

Deliverables:

- Industry survey of suppliers
- Process performance requirements
- Survey and data package of supplier available data

2.2.2 Stage 2

Team members focused on discussion on the process performance requirements for testing of the working group participants. Members also agreed upon pertinent test methods based on their respective experiences in testing CCC alternatives. Within this stage participating members also exchanged data and experiences that are either available in the public domain or obtained from members' replacement activities. To conclude this stage the team compared the assembled test

results and drew conclusions from the testing on the available alternates to chromated (Cr(VI)) conversion coatings.

Deliverables:

- Performance criteria and performance testing methodologies and standards
- Complete table of performance results (suppliers and participants)
- Documented conclusions

Technical performance requirements for testing were compiled by the team and summarized in the PPRD. Requirements were subdivided into three applications:

- Applications for protection against corrosion where low electrical resistance is required
- Applications for maximum corrosion protection where no prior etching is permitted
- Applications for maximum corrosion protection that require an aluminium etch prior to the application of a conversion coating

Within each of these applications there was expanded definition to performance requirements and corresponding success criteria. The performance requirements identified by the CCC team varied within these applications but generally focused on:

- Visual Aspect
- Temperature Resistance
- Film Weight
- Electrical Conductivity
- Corrosion Resistance – Unpainted
- Corrosion Resistance – Painted
- Wet and Dry Paint Adhesion
- Touch-up Procedure

2.2.3 Stage 3

The working group reviewed the performance results and determined a desire to test alternate solutions collectively. A strategic approach was taken to ensure that variability in processing parameters, test methodologies/locations, test panel quality, and other relevant variables were controlled to the satisfaction of the participating companies.

Deliverables:

- Draft of revised Statement of Work (SOW) (if required)
- A presentation summarizing performance results and data gaps from results presented to project members to decide on the next course of action and potential future projects
- Performance evaluations of four alternates to chromated (Cr(VI)) conversion coatings
- A Final or Interim Project Summary Report (as determined by the meeting with the project members)

3 Objectives

The objectives of this project were:

- Identification of environmentally preferred alternatives to common hexavalent chromium conversion coatings.
- Exchanging test data on conversion coating alternatives and using that data as a basis for implementation/substitution of hexavalent chromium conversion coatings, in the voluntary and unilateral discretion of each company.
- Identification of any additional advantages to hexavalent chromium free conversion coatings.

4 Background

The aerospace and defense industry has a need to replace hexavalent chromium compounds in surface finishing operations. One of the most used surface finishing processes is chemical conversion coatings. CCCs have many benefits including non-line-of-sight (NLOS) application in blind holes and complex geometries and therefore fit a design space need that other aluminium and aluminium alloy protection packages are unable to satisfy. Depending on the CCC selected and process duration, the technology has the benefit of providing the substrate corrosion protection, a path for electrical bonding, a pre-treatment for paint adhesion, and a pre-treatment for other aerospace coatings/polymers.

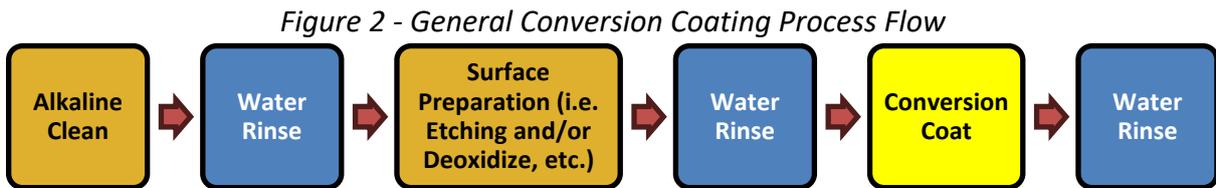


Figure 2 outlines a general conversion coating process flow. It should be noted that optionally an alkaline/acid etch step is sometimes used between the alkaline cleaning and deoxidizing step.

5 Participating Companies

COMPANY	REPRESENTATIVE(S)
Airbus SAS	Tuba Alpar-Mandas Wilfried Michaelis
BAE Systems (Operations) Ltd.	Gareth Whittle
Leonardo S.p.A.	Steve Jenkins Vitor Marques
Northrop Grumman Systems Corporation	Steven Davidson Ryan Johnson Hal Ozpaker Eric Schoch Kevin Chasse Noel McCracken
RTX	Kevin Bordage Michelina Molongoski Thiru Munisamy Blair Smith
SAAB AB	Ronja Flink Nicola Naujoks Lars Olsson Mattias Samuelsson Viktor Strand
Safran AeroSystems, Inc.	Francois Corman Jean-Arthur Drevet
Spirit AeroSystems, Inc.	Laura Dame Santry Kimberly Delzeit Thu Doan
Textron	Tyler Pollok April Sawyer Stacey Sullivan
The Boeing Company	Nestor Gonzalez-Pereyra Bruce Griffin Michelle McElvaine

6 Project Results

6.1 Stage 1: Supplier Engagement

A total of 10 suppliers were engaged who formulate trivalent chromium pretreatment (TCP) technologies. All were provided an individual forum, wherein they outlined performance attributes of their proprietary process solutions, (i.e., cleaners, etchants, deoxidizers and conversion coatings), and results from their internal test and product development programs.

6.2 Stage 2: Performance Criteria, Working Group Participant Results

Military specifications, MIL-DTL-81706 (Chemical Conversion Materials for Coating Aluminium and Aluminium Alloys) and MIL-DTL-5541 (Chemical Conversion Coatings on Aluminium and Aluminium Alloys), served as the basis for establishing performance requirements for chemical conversion coating types and classes, and as a benchmark for comparison with Original Equipment Manufacturer (OEM) performance requirements, which may be further defined by their particular customer base.

Following review of reference documents and project member's process specification performance and process control requirements, conversion coating performance attributes outlined in Table 1 were selected for measurement and evaluation in Stage 3.

Table 1 - Conversion Coating Performance Attributes

ATTRIBUTE	UNIT	INDUSTRY SPECIFICATION
Coating Weight	mg/m ² (mg/ft ²)	MIL-DTL-81706
Corrosion Resistance Performance ^(FL2)	hours	MIL-DTL-5541/81706
Electrical Conductivity, as processed	mΩ per in ²	MIL-DTL-81706
Electrical Conductivity, post-salt fog exposure	mΩ per in ²	MIL-DTL-81706
Paint Adhesion, Dry Tape	Pass/Fail	ASTM D 3359/FED-STD-141, Method 6301
Paint Adhesion, Scribed Wet Tape	Pass/Fail	
Paint Adhesion, Scribed Wet Tape	Score	
Storage Stability	Months	MIL-DTL-81706

Notes:

^{FL2} Neutral Salt Fog (NSF) Testing, controlled in accordance with ASTM B117.

6.3 Stage 3: Working Group Performance Evaluations

For Stage 3 of the project there were two separate rounds of fabrication completed. During the first round of fabrication the team evaluated a baseline hexavalent conversion coating against three different TCP solutions. In the second round of fabrication the team evaluated a second set of panels with the same baseline conversion coatings against two additional TCP solutions. For both rounds of fabrication, the same three test methods were used to assess the performance of the alternate solutions against a hexavalent chromium containing conversion coating process. Stage 3 aimed to conduct tests on industrial conversion coating lines, using consistent panel suppliers and consistent test labs to control data variation.

6.3.1 Developmental Approach and Experimental Plan

In order to obtain statistically meaningful data, and understand the influence of the test panel quality, substrate (aluminium alloys), coating parameters, and testing lab, the participants agreed on the following testing principles:

- Use 3 different sources of test panels.
- Use aluminium alloys 2024-T3 and 7075-T6 substrates for Corrosion Resistance Testing (CRT), and aluminium alloy 6061-T6 for Electrical Contact Resistance (ECR).
- Have each solution coated by 2 different applicators: participants' internal coating lines when possible, and subcontractors' coating lines otherwise, with the obligation to share process parameters at the time of application.
- Have 'witness panels' (2024-T3 only for CRT, 6061-T6 for ECR) coated with a well-known chromated solution, from a single applicator's production line.
- Run the performance tests (CRT and ECR) in 3 different participants' internal labs.
- For each combination of the above, use batches of 5 panels.
- CRT testing: count corrosion pits at 168h and 336h (and until failure if the Lab has the capacity).
- ECR measurements: as coated, and after an exposure of 168h to neutral salt spray, on different panels.

For Wet Paint Adhesion (WPA) testing:

- Use 1 source of test panels.
- Use 2024-T3, 7075-T6 and 6061-T6 substrates.
- TCP coating made by one applicator, with the obligation to share the coating parameters used.
- Have 'witness panels' of each substrate coated with a well-known chromated solution, from a single applicator's production line.
- Paint coating made by 2 applicators, with the obligation to share the coating parameters used.
- Run the WPA performance tests in 2 different participants' internal labs.
- For each combination of the above, use batches of 3 panels.
- WPA testing to be made according to FED-STD-141 Method 6301.
 - Pass criteria determined to be no loss of adhesion (5A per ASTM D3359).

7 Recommendations/Conclusions

Stage I provided project participants with an overview of commercially available trivalent chromium pre-treatment products and an overview of related surface preparation products (i.e., degreasing, cleaning, etching and deoxidizing solutions) offered by the same suppliers. Suppliers of TCPs and project participants understand the importance of surface preparation prior to application of inorganic finishes (CCC or anodized). However, materials presented during Stage I also helped to expose the gap between supplier assumptions regarding the condition of detail parts delivered for processing and the project participant's experience with oils, soils and surface oxides present on detail parts delivered to chemical process lines for application of inorganic finishes; thereby providing cursory explanation for the performance gap observed between hexavalent chromium conversion coatings and most all of the early generation TCP products.

Stage II provided structured test plans that included application of 2nd generation TCPs in production conversion coating facilities, and with encouraging results in the form of TCP products exhibiting corrosion resistance and electrical contact resistance equivalent to the control. The generation of TCP products now commercially available exhibit performance attributes that meet or exceed industry requirements, even when substrate materials are exposed to more aggressive cleaners, etchants and deoxidizers used to remove common oils, soils and surface oxides. It should be noted however that TCP products still require additional validation against supplementary requirements derived internally at aerospace and defense companies or imposed by their customer base. These requirements in instances are significantly more stringent than industry requirements. Due to this the Project Team recommends opportunities to share this Project Report, and future updates, with Authorization Consortia such as ADCR (Aerospace and Defense Chromates Reauthorisation). This report and future discussion will provide information about the need within the aerospace and defense sector to ensure all requirements are validated prior to introducing alternate technologies. It will also support the existing need for re-authorisation of impacted hexavalent chromium compounds which are included in (Cr(VI)) containing CCC formulations.

Based on lessons learned the following can be recommended:

- Select a TCP based on product performance but also consider that data secondary to the customer service provided by the TCP manufacturer.
- Disclose all cleaners, etchant and deoxidizers used to the TCP manufacturer and the reasons for using the particular products.
- Disclose the quality of water used in the process line and be flexible if process line changes or rearrangement is suggested.
- Rely on the TCP manufacturer for help to assure timely and successful process control.

8 References

- Public Specifications:
 - ASTM B 117 – Standard Test Practice for Operating Salt Spray (Fog) Apparatus
 - ASTM D 3359 – Standard Test Method for Rating Adhesion by Tape Test
 - EN4875 – Test Method for Measurement of Electrical Contact Resistance
 - FED-STD-141 – Paint, Varnish, Lacquer, and Related Materials: Methods of Inspection, Sampling and Testing
 - MIL-DTL-5541 – Chemical Conversion Coatings on Aluminium and Aluminium Alloys
 - MIL-DTL-81706 – Chemical Conversion Materials for Coating Aluminium and Aluminium Alloys