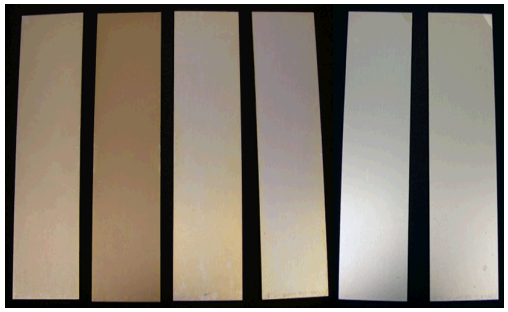
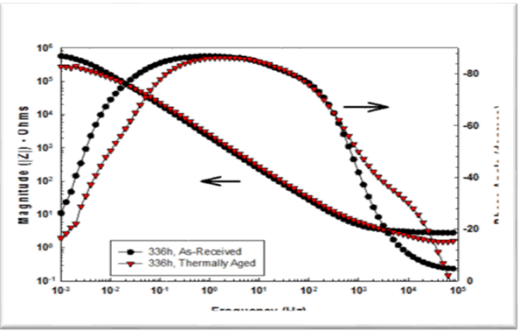
SAND2017-3096C





Assessment of Commercially Available Non-Chromate Conversion Coatings

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Introduction

- Chromate conversion coatings (CCCs)
  - Standard for decades
  - Sunset material
  - Identification of commercially viable options needed
- Coating performance needs
  - Corrosion resistance
  - Low-resistance electrical contact
  - Ability to withstand fabrication environments (thermal)
- **Objective**: Identification of coating materials that will adequately protect a range of alloys under certain processing conditions

Considerations

- Military standards
  - Covers chemical conversion coatings on aluminum and aluminum alloys
    - MIL-DTL-5541 – Coated Articles
      - » Class 1A : Maximum corrosion protection
      - » Class 3 : Low electrical resistance with corrosion protection
    - MIL-DTL-81706B – Coating Materials
      - » Class 1A : Conformance using AA2024-T3
      - » Class 3 : Conformance using AA6061-T6

Research Focus

- Evaluation of commercially available non-chromate conversion coatings deposited by vendors
  - Will the coating protect aluminum sufficiently for our applications?
  - How does the coating behave after thermal processing?
    - Low temperature powder coating applied at approximately 135C for 1 hour
    - A polyurethane foam cured at 71C for 8 hours
  - Does the coating allow and preserve low-resistance electrical contacts?
    - Many of our applications require coatings that will maintain low-resistance electrical contact

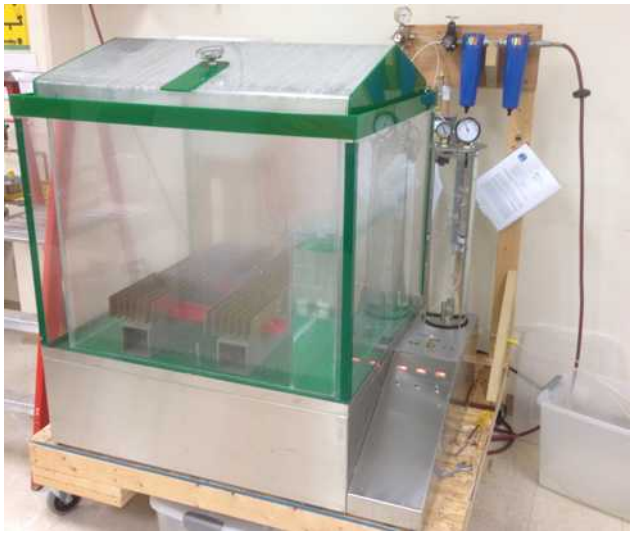
Scope of Research

- Coatings
  - Benchmark Chromate Based Conversion Coatings (CCC)
  - Non-chromate Based Conversion Coatings (NCCC)
    - Coatings A – C
      - » Trivalent Chromium chemistries based on Navy patents
    - Coating D
      - » Non Chromium based coating

- Materials tested
  - Solid solution strengthened
    - AA6061
  - Precipitation hardened
    - AA2024, AA5083, AA7075

Experimental Design

- Evaluation of coatings as received and thermally stressed
  - "Low Temperature" – 71C for 1 hour
  - "High Temperature" – 135C for 8 hours
- Conformance to MIL-DTL-5541
  - ASTM B117 Salt Fog Test
    - 3"x10" panels
  - Visual inspection for corrosion sites
  - Electrical contact resistance measurements
- Evaluation of protective capabilities
  - Electrochemical Impedance Spectroscopy (EIS)

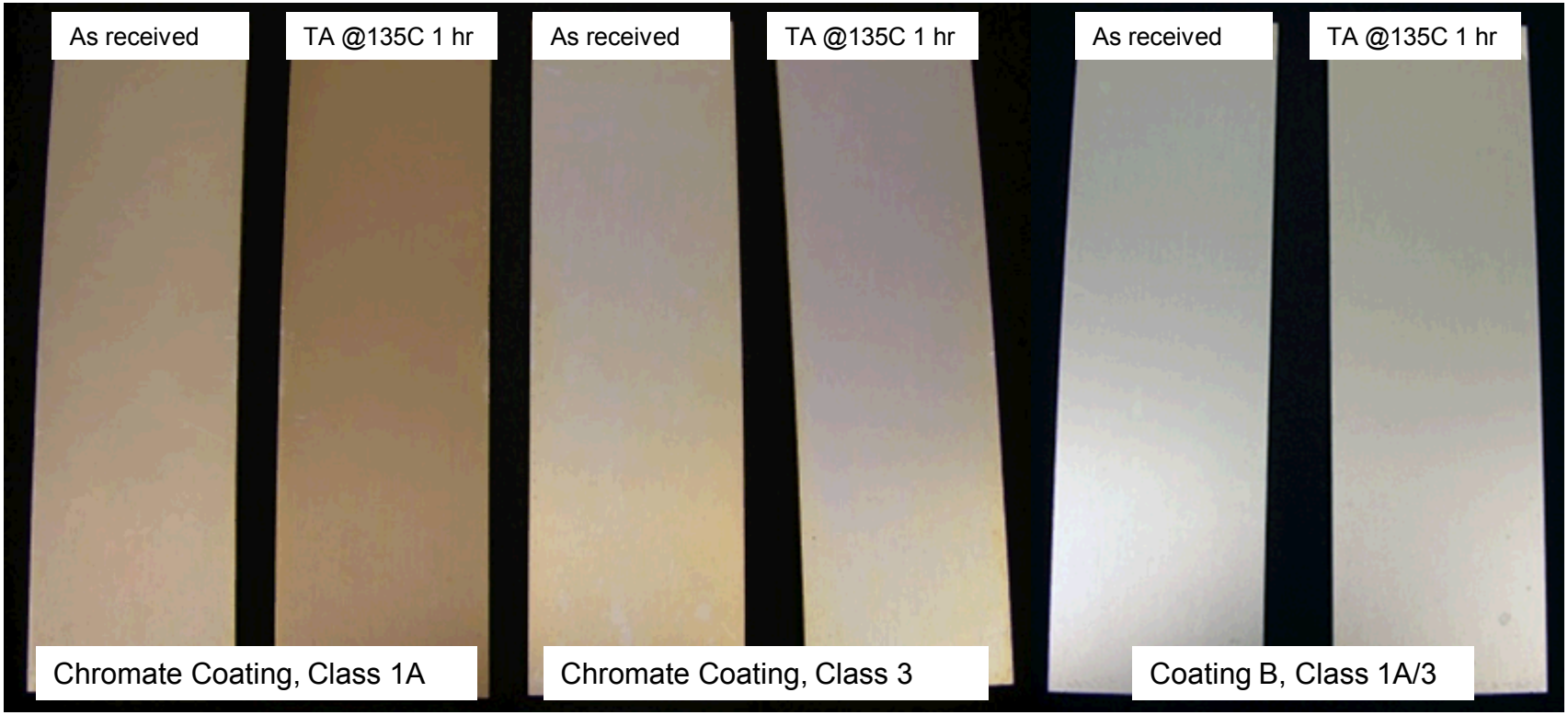


Associated Environmental Systems Model MX-9216 Salt Spray/Fog chamber.

Military Standard Requires Performance Through Salt Fog Test

Thermal Aging Impacts All Alloys Differently

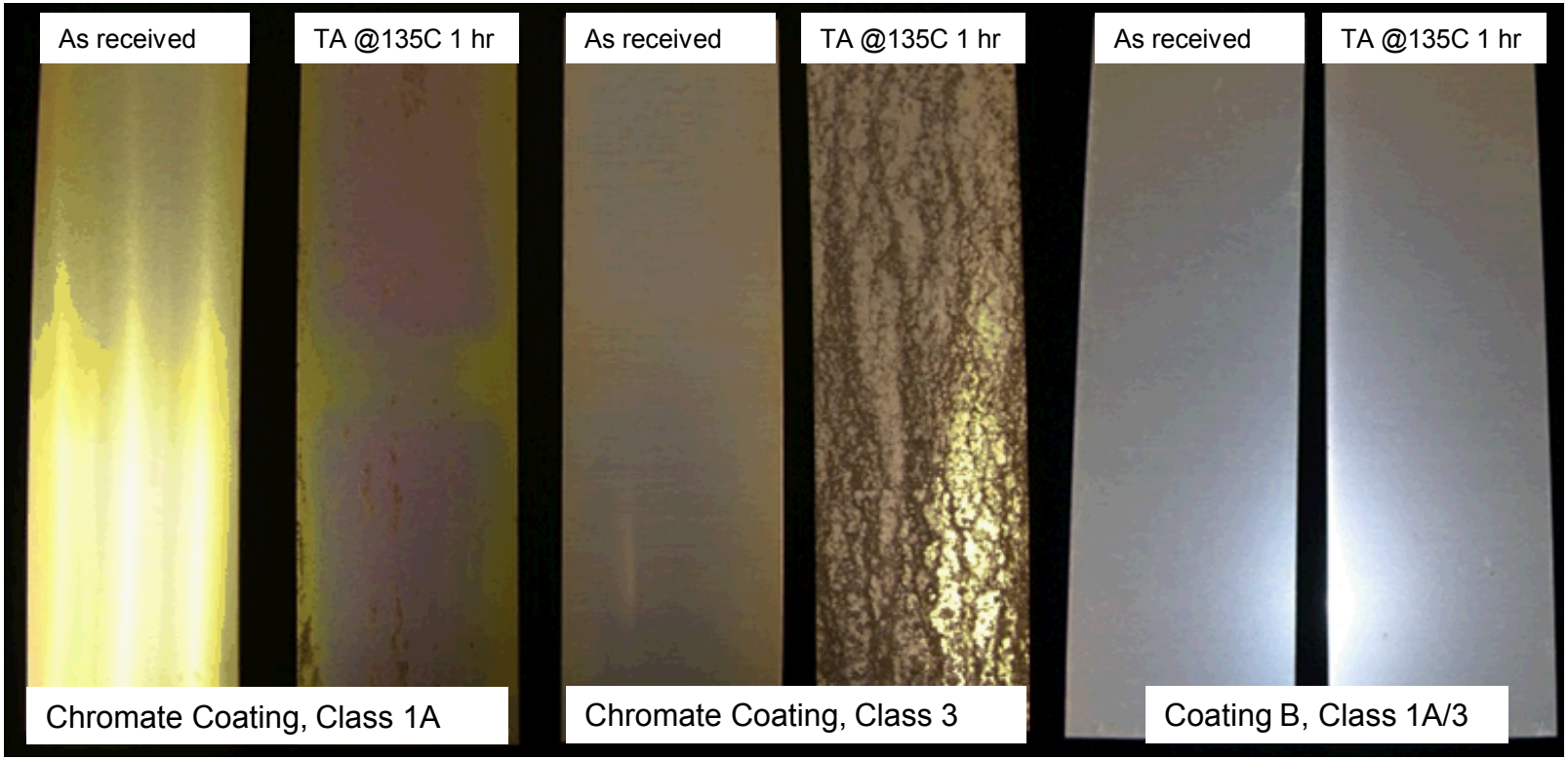
- AA5083 coated coupons following 1 week salt fog exposure



Thermal Aging Has Little Effect on Coating Performance for AA5083

Thermal Aging Impacts All Alloys Differently

- AA7075 coated coupons following 1 week salt fog exposure

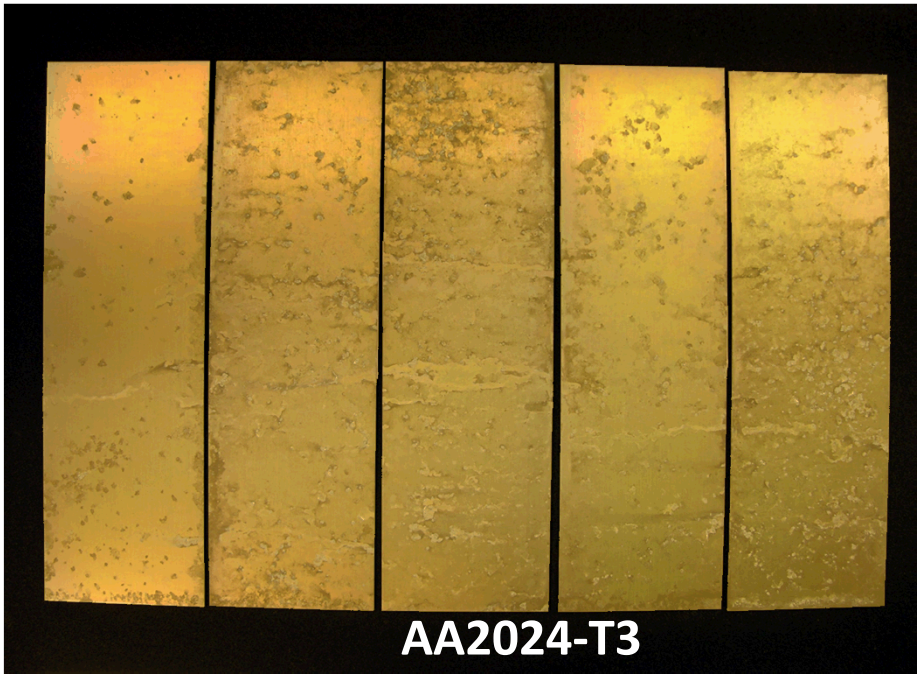


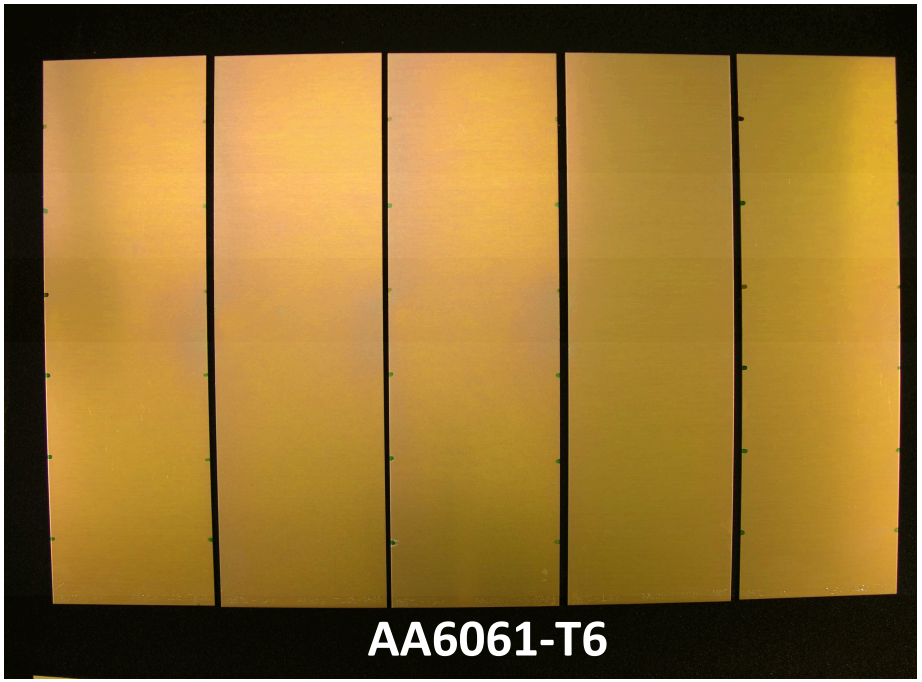
Thermal Aging Has Extreme Effects on Coating Performance for AA7075

SFT Performance of Chromate Coating

Class 3 Coatings Thermally Aged for 1 hr @ 135 C

Each Panel 3” x 10”



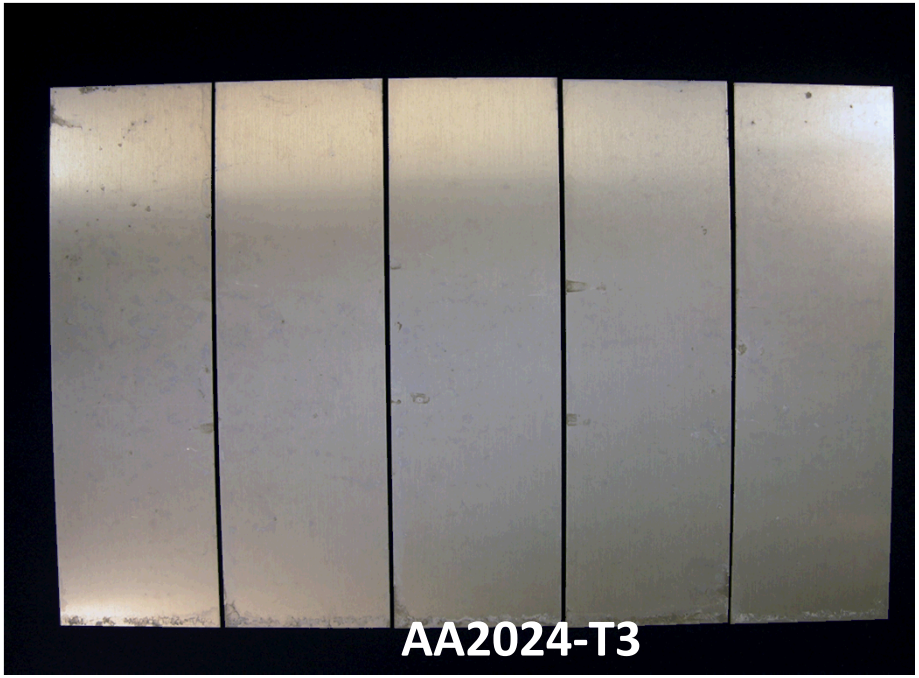


Most Alloys with Chromate Coatings Passed Visual Inspection per MIL-DTL-5541

SFT Performance of Coating A

Class 3 Coatings Thermally Aged for 1 hr @ 135 C

Each Panel 3” x 10”

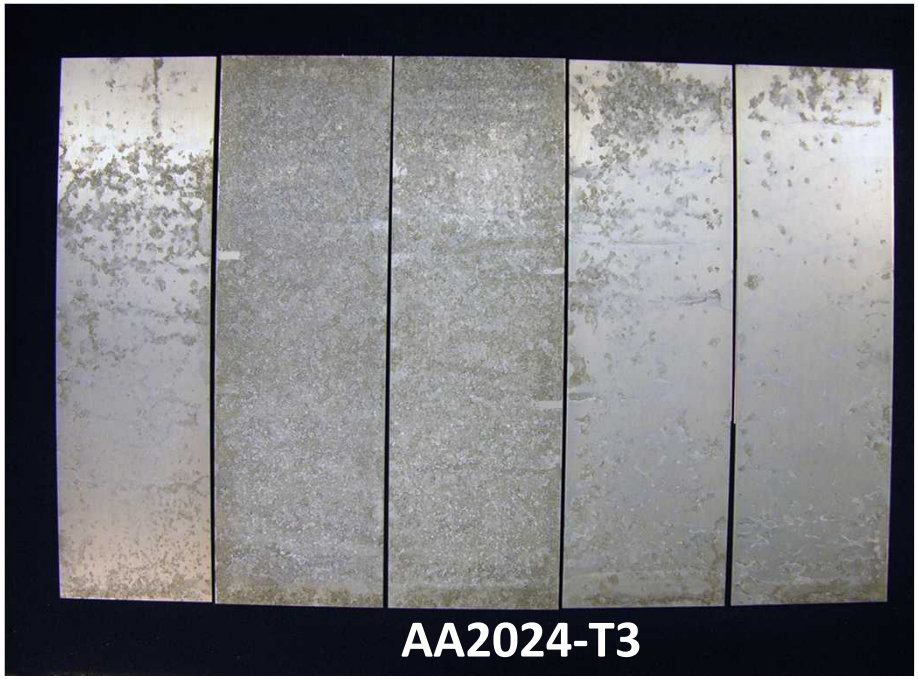


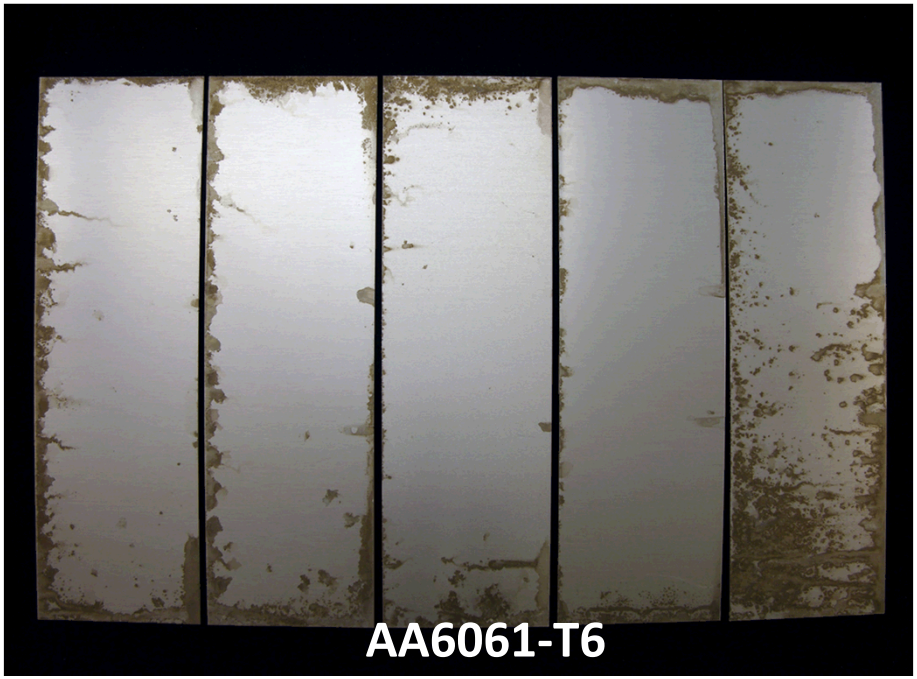
Most Alloys with Coating A Passed Visual Inspection per MIL-DTL-5541

SFT Performance of Coating B

Class 3 Coatings Thermally Aged for 1 hr @ 135 C

Each Panel 3” x 10”



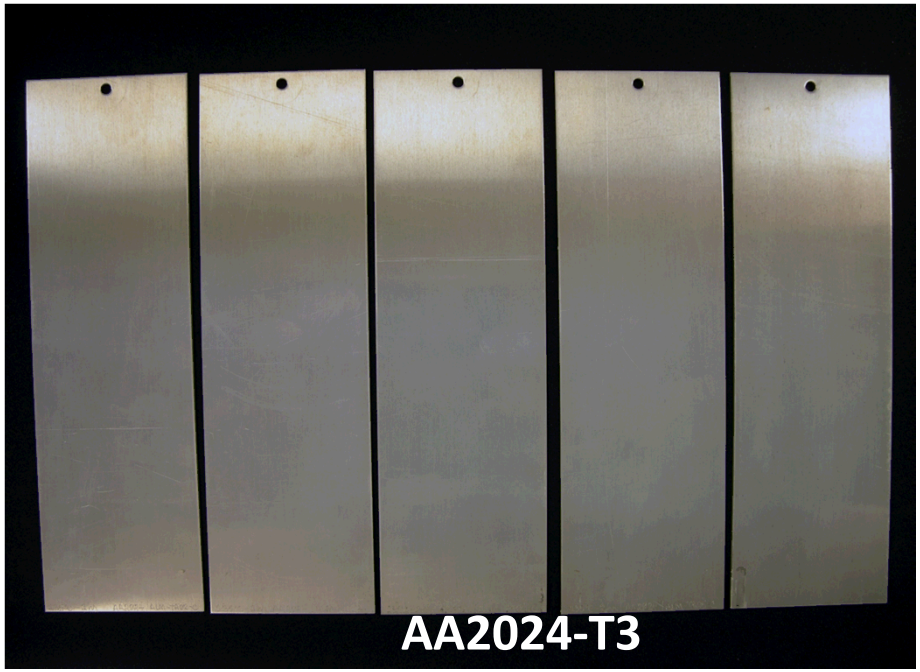


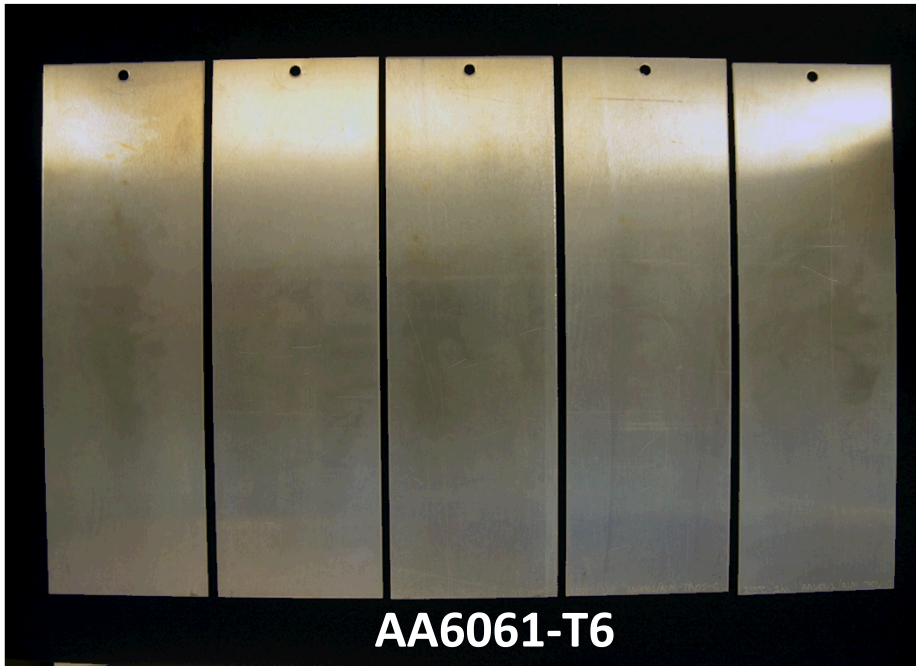
Most Alloys with Coating B Passed Visual Inspection per MIL-DTL-5541

SFT Performance of Coating C

Class 3 Coatings Thermally Aged for 1 hr @ 135 C

Each Panel 3” x 10”



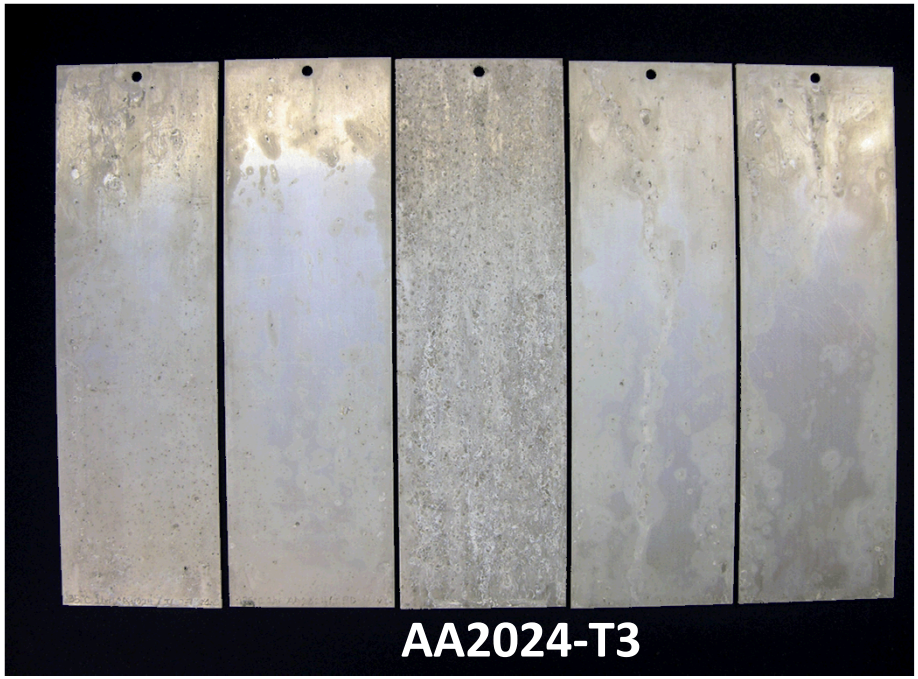


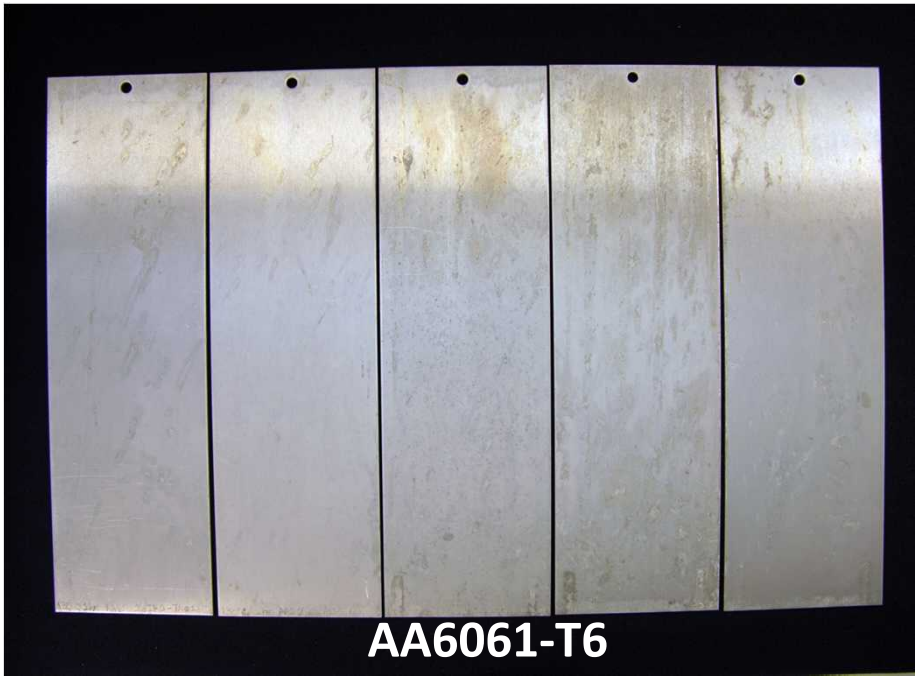
ALL Alloys with Coating C Passed Visual Inspection per MIL-DTL-5541

SFT Performance of Coating D

Class 3 Coatings Thermally Aged for 1 hr @ 135 C

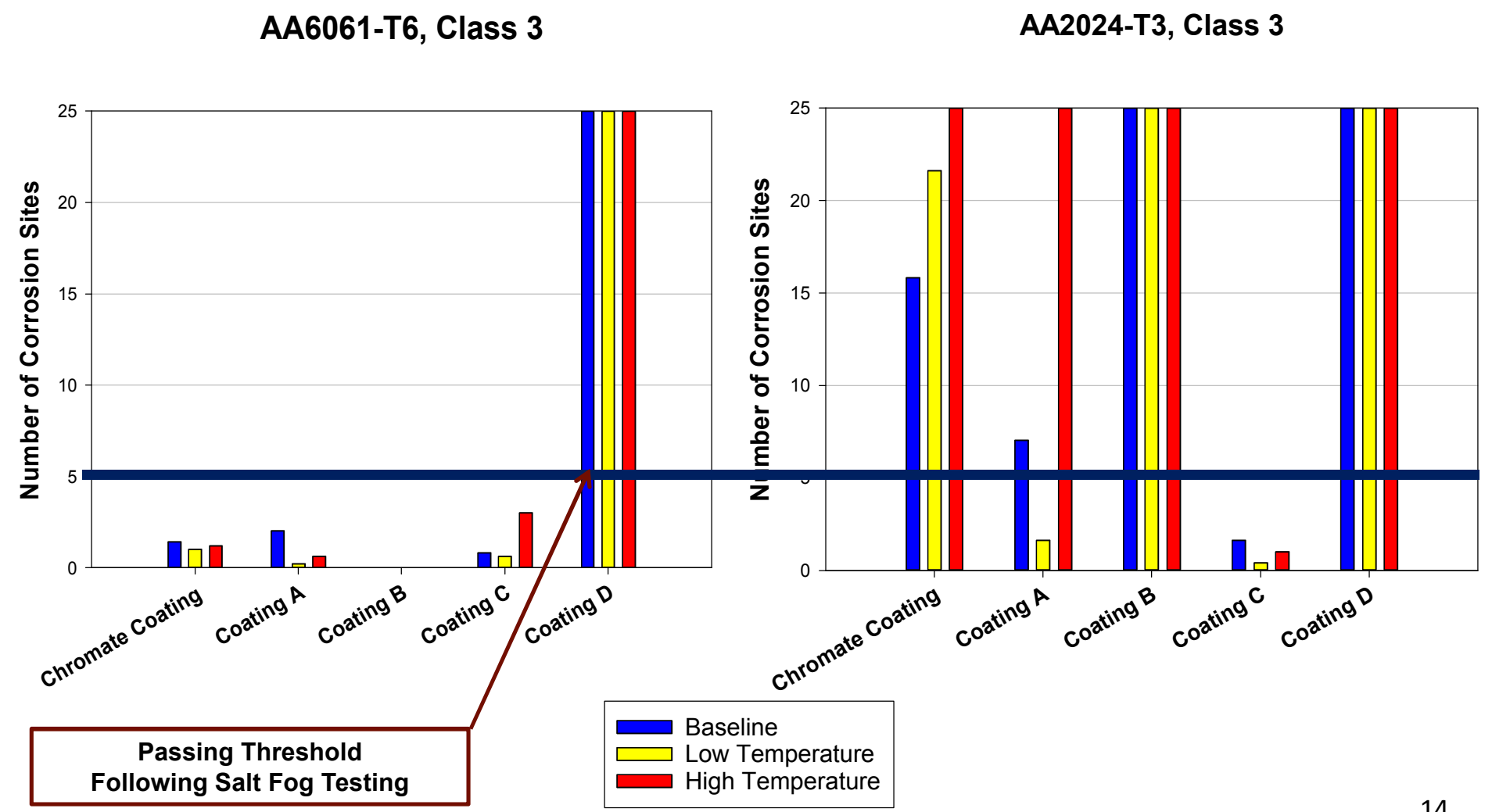
Each Panel 3” x 10”





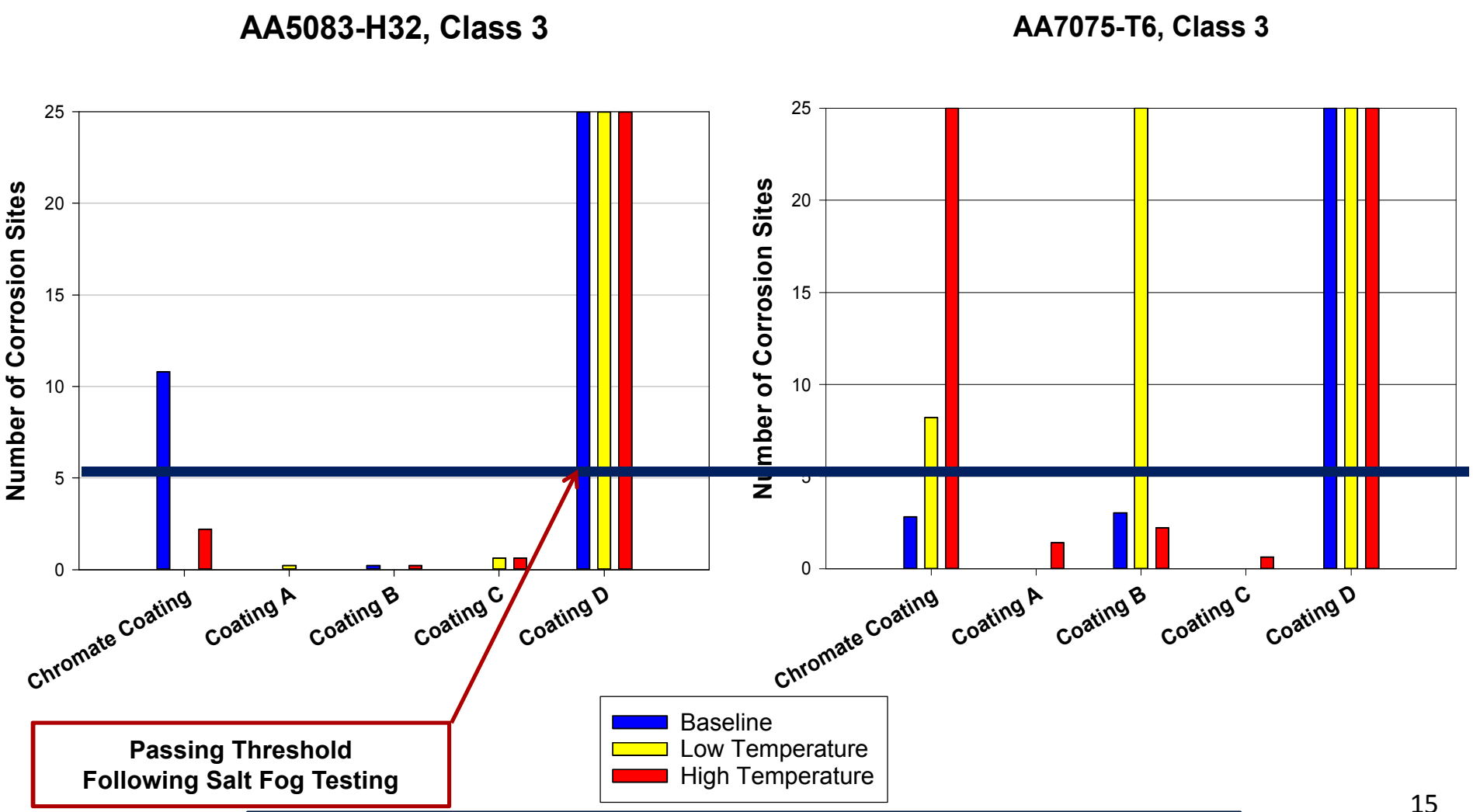
NONE of the Alloys with Coating D Passed Visual Inspection per MIL-DTL-5541

Visual Inspection Results



Coating Failures May be Attributed to Application Process

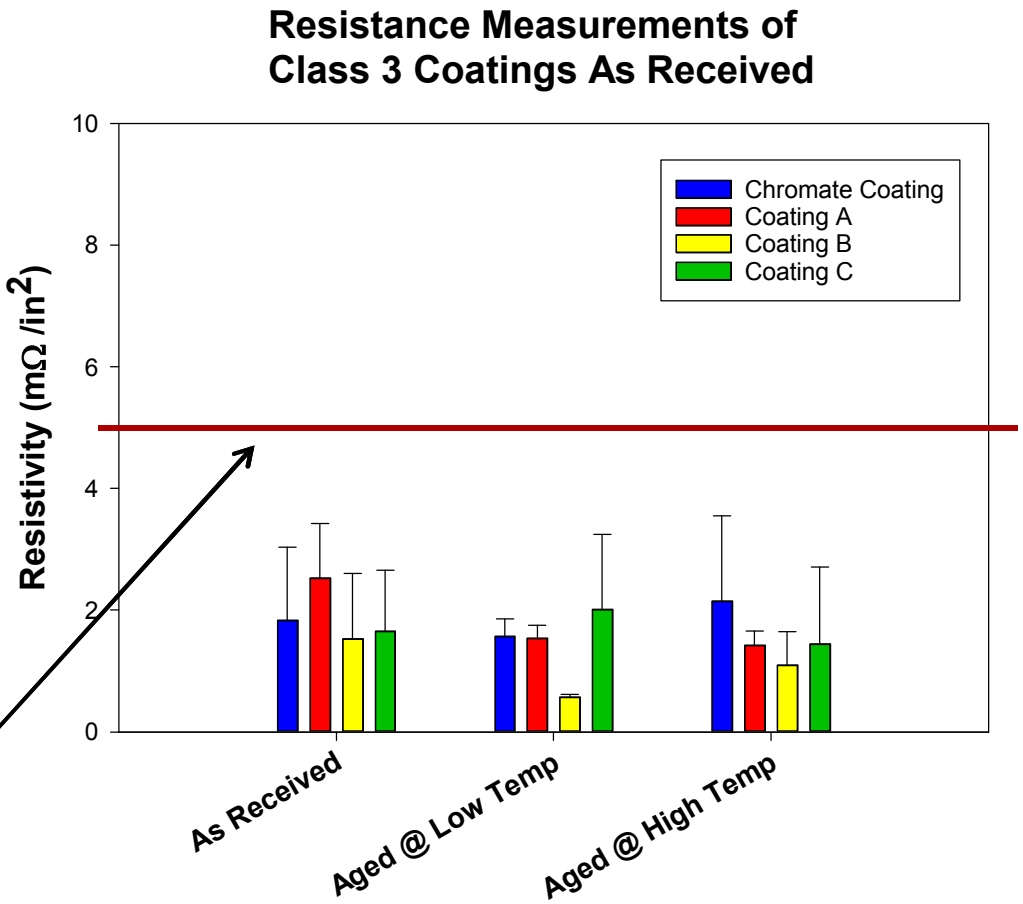
Visual Inspection Results



Coating Failures May be Attributed to Application Process

Contact Resistance Results Prior to SFT

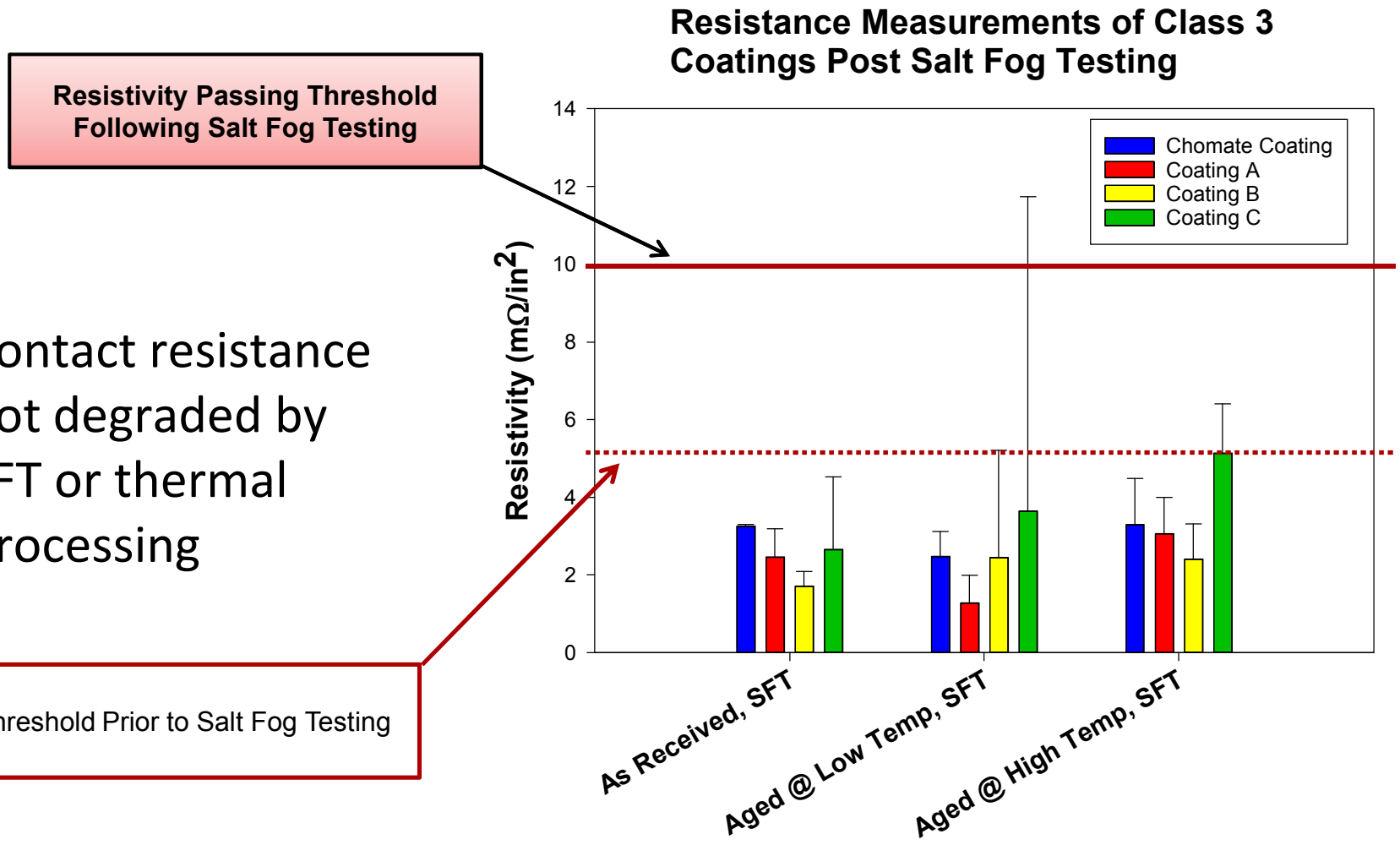
- Snapshot of resistance measurements recorded to date
  - Combined results for all alloys averaged for each coating



Resistivity Passing Threshold Prior to Salt Fog Testing

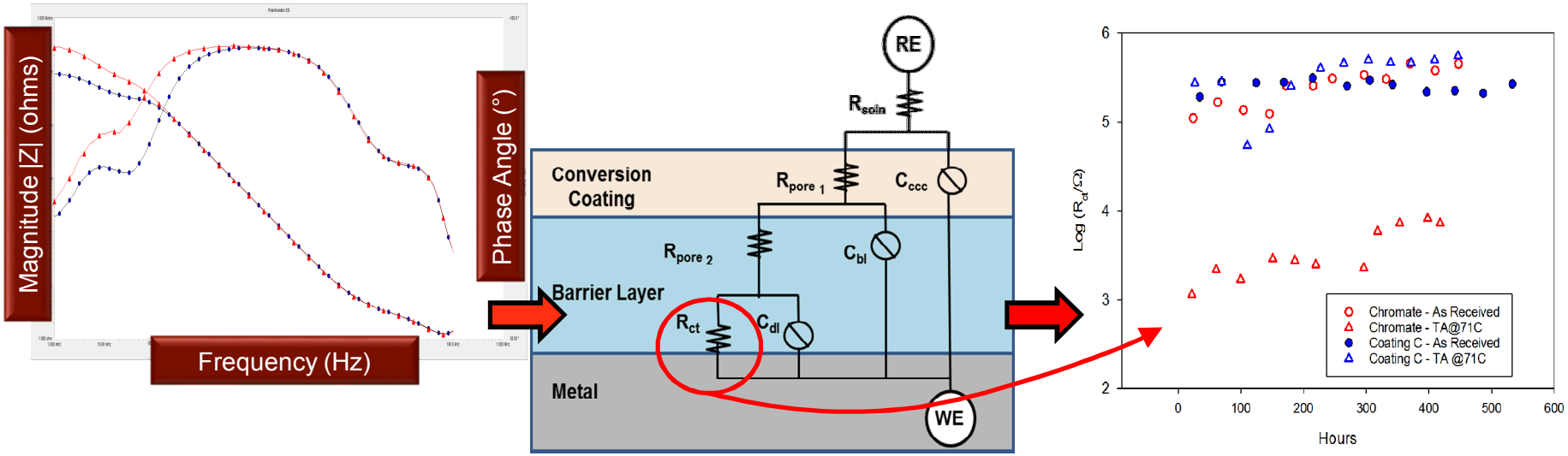
Contact Resistance Results after SFT

- Contact resistance not degraded by SFT or thermal processing



Electrochemistry gives a more detailed assessment

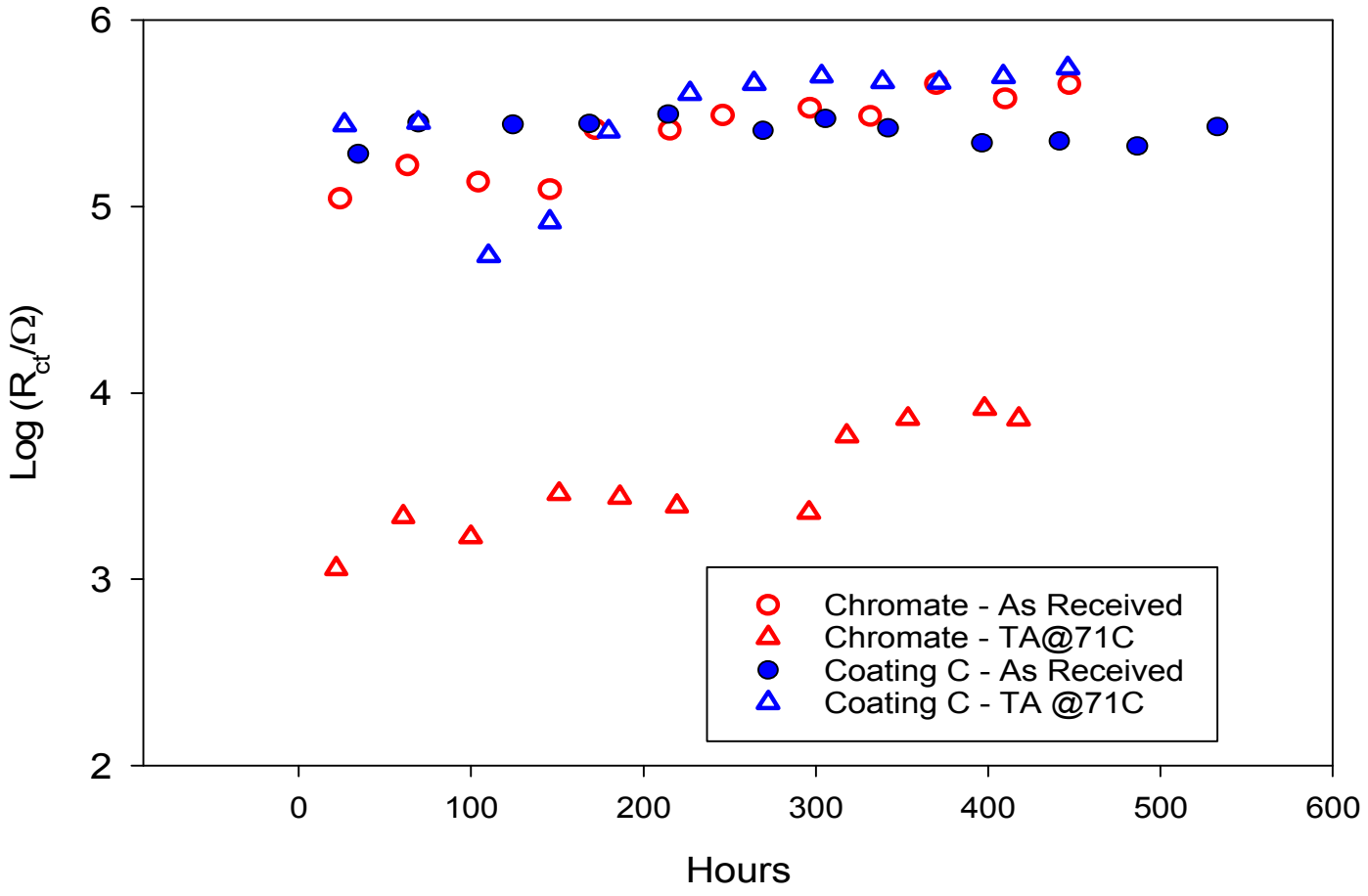
- EIS allows us to model the processes taking place on the coated surface → better picture of residual protective capability



Model adapted from P. Campestrini, et al., Chromate Conversion Coating on Aluminum Alloys: I. Formation Mechanism; Journal of The Electrochemical Society, 151 (2) B59-B70 (2004).[1]

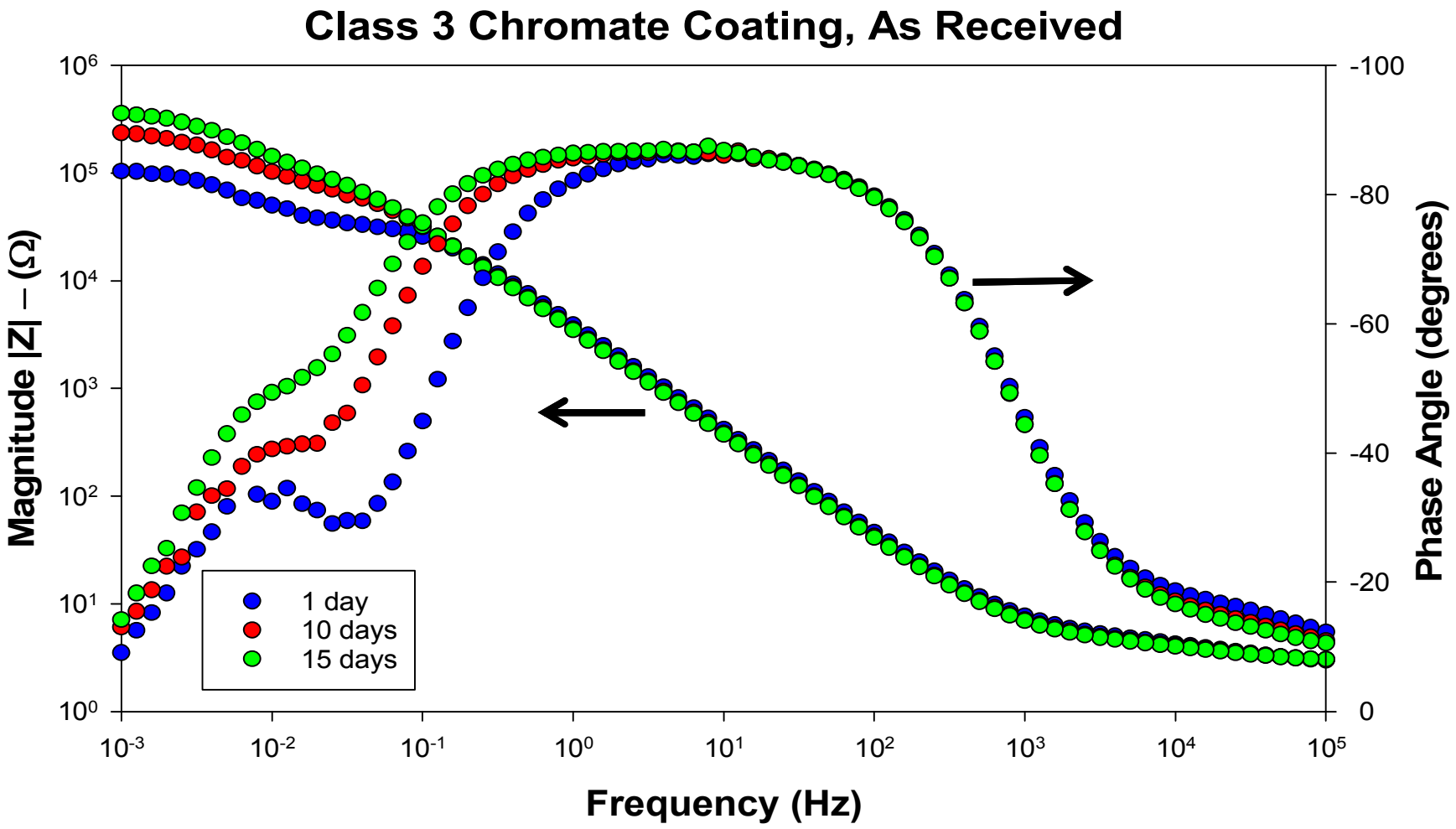
Results from Modeling As Received Samples of AA6061

- Comparison of Chromate Coating with Non-Chromate Coating C

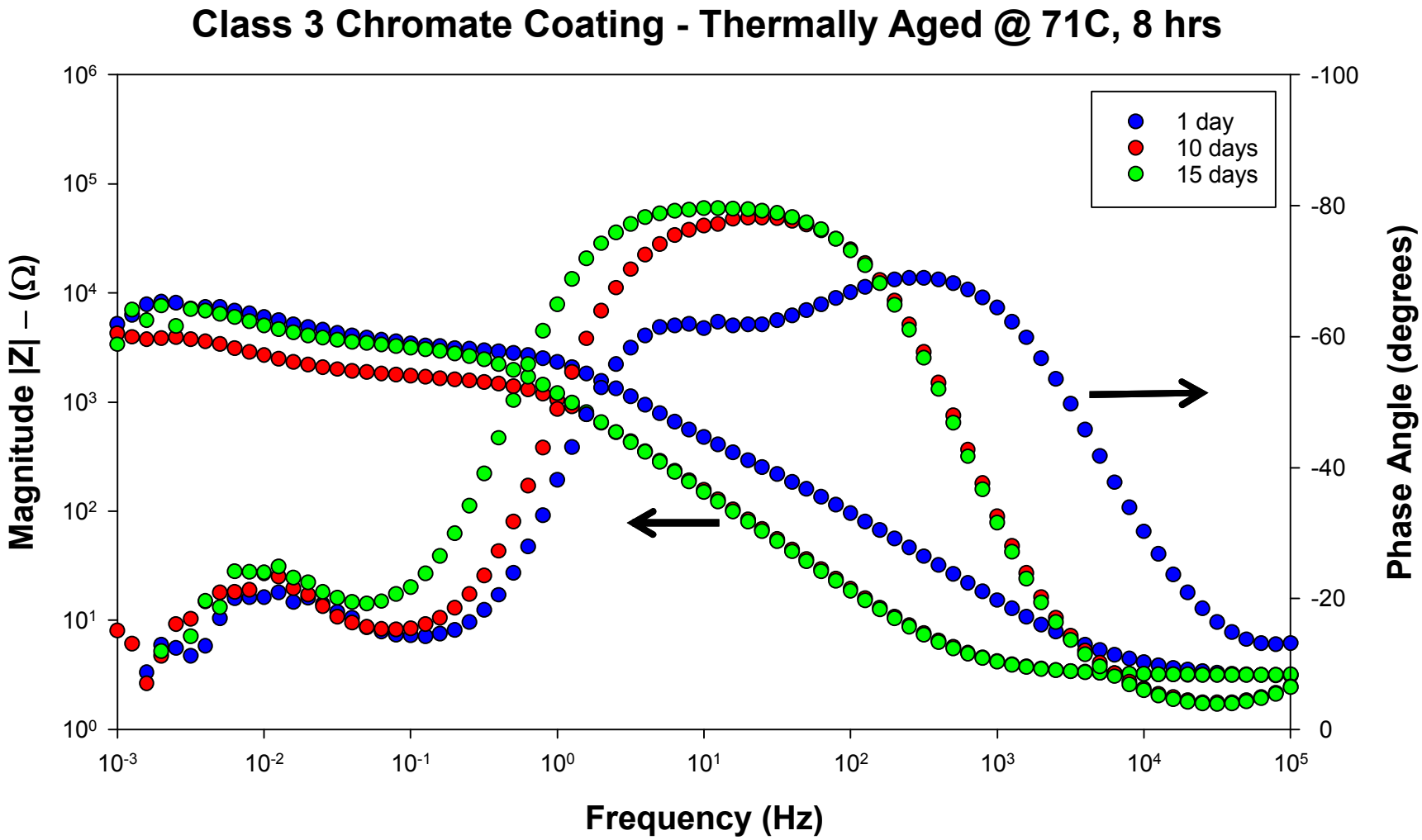


Non-Chromate Conversion Coating not Impacted by Thermal Aging

Data from EIS Measurements of As Received Samples of AA6061



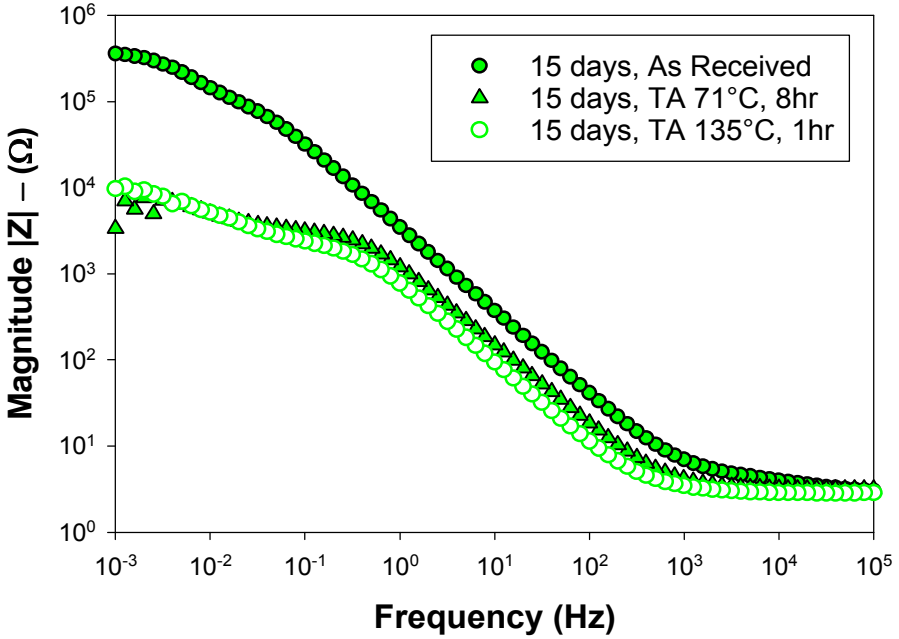
Data from EIS Measurements of Thermally Aged Samples of AA6061



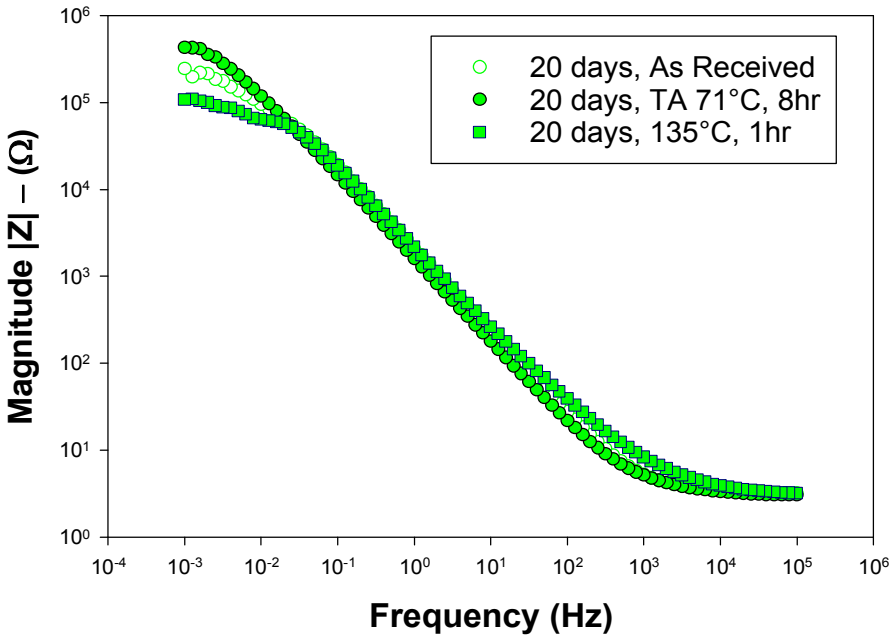
Impact of Thermal Aging to Samples

- Magnitude of impedance is inversely proportional to corrosion rate

Class 3 Chromate Coating



Coating C



Thermal stress impacts corrosion resistance of chromate

Summary & Conclusions

- Results to date indicate NCCCs will allow and preserve low-resistance electrical contacts
- Thermal aging significantly degrades chromate coatings and has a relatively minor effect on non-chromate coatings tested to date
- Performance of coating may depend on application process/vendor


Questions

References

[1] P. Campestrini, et al., Chromate Conversion Coating on Aluminum Alloys: I. Formation Mechanism; *Journal of The Electrochemical Society*, 151 (2) B59-B70 (2004).

[2] G.J. Brug, et al., *Journal of Electroanalytic Chemistry,* 176 (1984) 275-295

[3] "Aluminum Data." Bloomsburg Metal Company LLC. Web. 22 Sept. 2015. <http://www.bloomet.com/pdf/pdf-aluminum.pdf>.

[4] Jones, Denny A. Principles and Prevention of Corrosion. 2nd ed. Upper Saddle River, NJ: Prentice Hall, 1996. Print.

[5] "Potentiostatic EIS Tutorial - Getting Started." EIS-Electrochemical Impedance Techniques. Gamry Instruments. Web. 23 Sept. 2015. <http://www.gamry.com/application-notes/EIS/potentiostatic-eis-tutorial/>.

[6] "Basics of Electrochemical Impedance Spectroscopy." Gamy Instruments. Web. 23 Sept. 2015. <http://www.gamry.com/application-notes/EIS/basics-of-electrochemical-impedance-spectroscopy/>.