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Efficacy of MIL-DTL-5541 Compliant, Non-Chromate Conversion Coating Repair Materials

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Conversion Coatings for Aluminum Alloys

- Chromate conversion coatings have long been the standard for protection of aluminum alloys, but will soon be eliminated due to regulatory issues
- Non-chromate chemistries are widely available and offer comparable corrosion performance and electrical properties, with some exceptions
  - No “self-healing” aspect
  - Many are effectively colorless
  - Superior thermal performance
  - Superior mechanical robustness
- Chemistries evaluated in this work are those compliant with MIL-DTL-81706 and listed in QPL-81706
  - Applied in compliance with MIL-DTL-5541
- All coatings evaluated in this work are Class 3 coatings per MIL-DTL-5541
  - Ability to maintain low-resistance electrical contact
- All materials evaluated here based on NAVAIR chemistry
  - US patents 6375726, 6511532, 6521029, and 6527841

Repair Materials and Procedures

- Conversion coatings are not particularly robust mechanically – processing damage is likely
  - Rack marks
  - Scrapes, scratches, etc.
- MIL-DTL-5541 stipulates that repaired area should be 5% or less of total surface area
  - In this work, entire surface of 3” x 10” coupon coated with the repair material
- All materials evaluated on AA2024-T3, AA5083-H32, AA6061-T6, and AA7075-T6
- All chemistries evaluated commercially available as a ready to use solution in an applicator pen
  - MIL-DTL-81706/MIL-DTL-5541 Form VI, Method D
- Specific chemistries evaluated
  - Bonderite (Alodine) 1132 – chromate baseline material (Henkel)
  - Aluminescence TX – non-chromate material (Luster-On)
  - Bonderite (Alodine) 871 – non-chromate material (Henkel)
  - TCP-HF – non-chromate material (Chemeon)

Repair Materials and Procedures

- Significant variation from vendor to vendor on acceptable procedures for coating repair
  - Alkaline etching and desmutting typical for bath-based deposition not appropriate
- Strong desire to have single application methodology appropriate for all materials
  - Coating application maintained per vendor instructions
  - Surface preparation method that bounds the various manufacturer requirements used
- Surface preparation procedure:
  - Mechanical abrasion of surface with non-woven abrasive pads wet with deionized water
    - 5 minutes in one direction, followed by 5 minutes perpendicular to initial direction
  - Panels wiped with reagent grade isopropyl alcohol until abrasive pad debris removed
  - Panels rinsed in flowing DI water, then blown dry with filtered, dry nitrogen

Repair Materials and Procedures

- Each vendor had different application methods they recommended
- Method 1
  - Soak applicator tip with solution (rewet as needed)
  - Apply by performing multiple passes in 1 direction, overlapping each previous pass by 50%
  - Allow solution to dry, then repeat application process with passes perpendicular to first set
  - Allow solution to dry
- Method 2
  - Soak applicator tip with solution (rewet as needed)
  - Apply coating solution by making multiple passes in 1 direction until entire surface is visibly wet
  - Allow solution to dry, then rinse the surface and blow dry
- Method 3
  - Clean surface to be coated with mildly acidic liquid cleaner, then rinse and blow dry
  - Soak applicator tip with solution (rewet as needed)
  - Apply coating solution by making multiple passes in 1 direction until entire surface is visibly wet
  - Reapply every 30-60 seconds to ensure surface stays wet with solution (maintain for 6 minutes)
  - Rinse solution off of surface, then blow dry

Evaluation methodology

- Coatings evaluated per MIL-DTL-5541 for Class 3 coatings
- Electrical contact resistance measured using 1 sq. in. copper platens and 200psi applied force (applied current of 100 mA)
- 1 week to an ASTM B117 salt fog exposure using 5 wt% NaCl solution.
  - Visual inspection for the number of pits on each sample (ignoring any sites 0.25 in (6 mm) from the coupon edges).
  - Repeat electrical contact resistance measurment, using the same parameters as used to assess the initial contact resistance.
- 3 Replicate coupons of each coating/alloy combination were used for the initial contact resistance measurement and 8 replicates were used for the subsequent salt fog testing (and associated pit measurement and contact resistance)

Appearance/nonuniformities

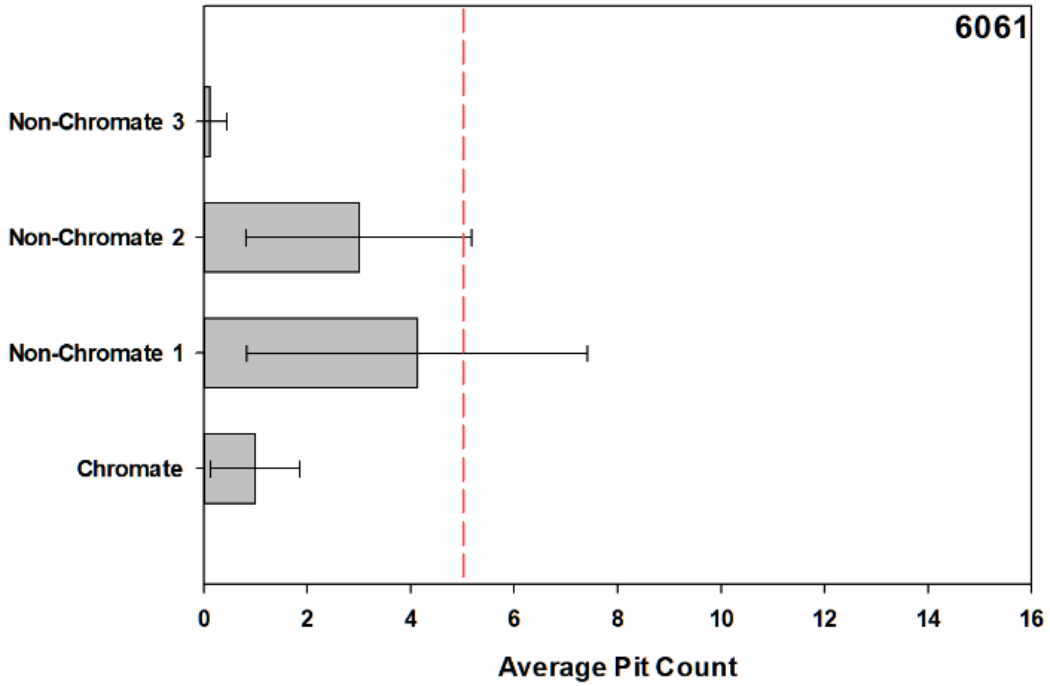
- Coatings dramatically more non-uniform than their bath applied counterparts
- Coatings where the solution is allowed to dry have more significant staining

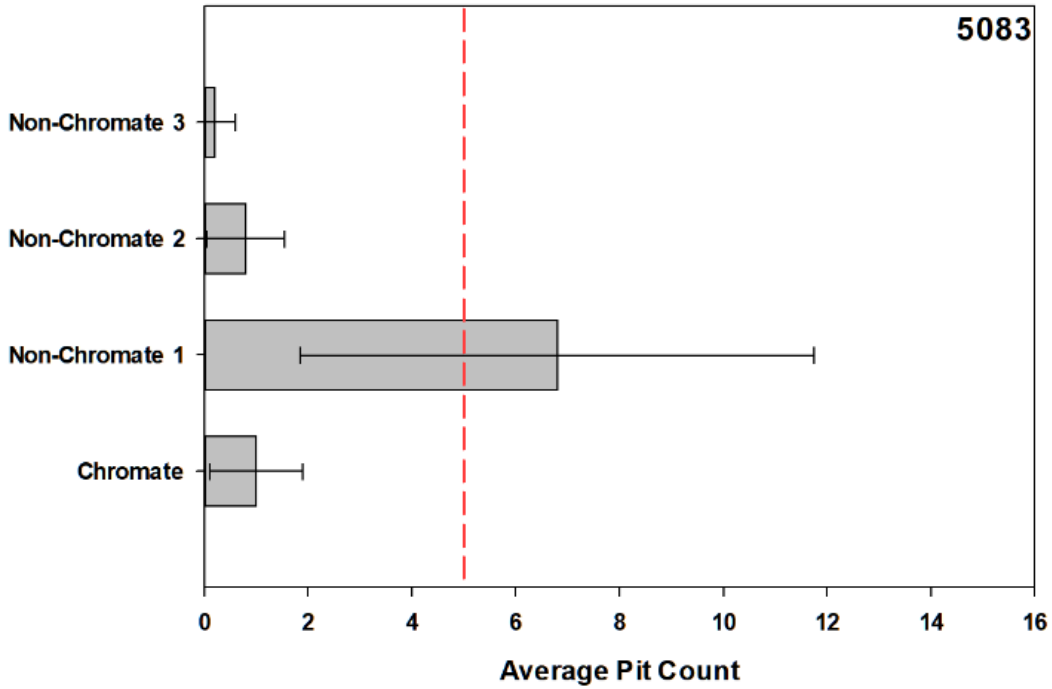
Pit density

- Multiple 3” x 10” coupons prepared and coated per previous slides
- Per MIL-DTL-5541 no more than 5 localized corrosion/pits on each coupon, with none larger than 0.031 in. (0.8mm) in diameter.
- 7075 difficult, typical for conversion coatings
- Underperform bath applied coatings

Pit Density for Workhorse Alloys

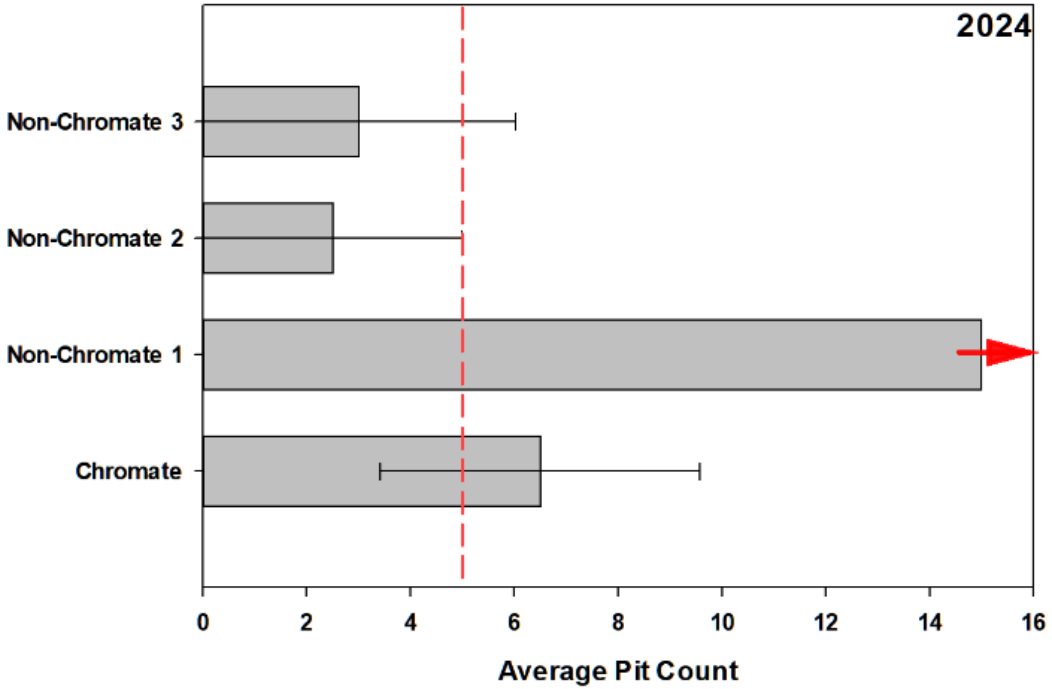
- Average number of pits per sample (30 in2 or 193 cm2)
- Performance within specification, but below bath applied materials

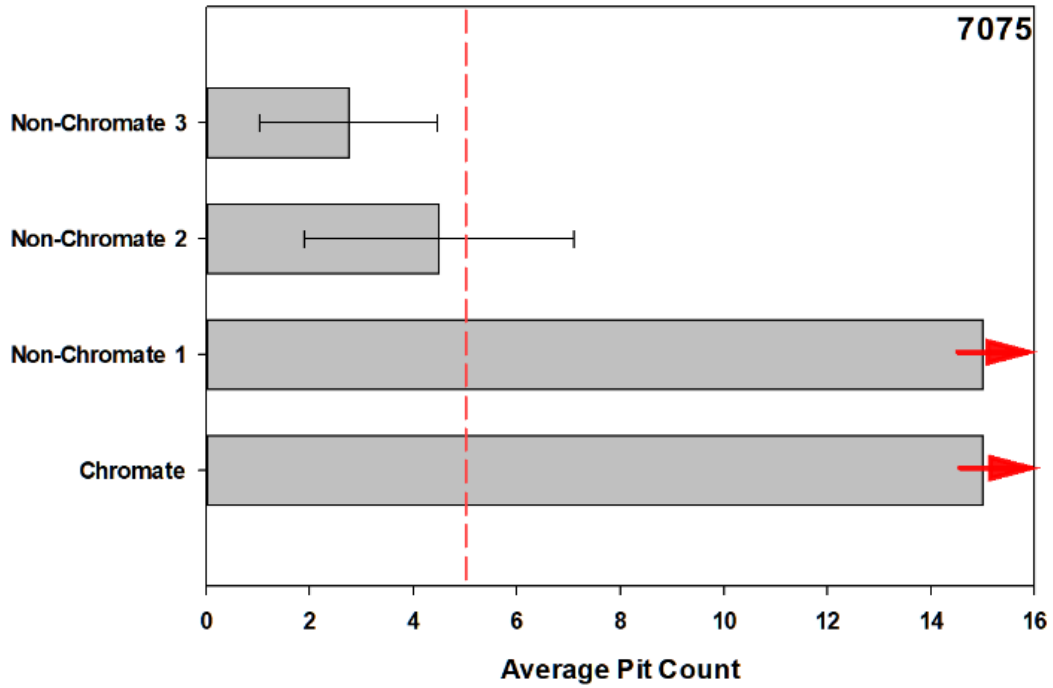




Pit Density for High Strength Alloys

- Precipitation hardened alloys exhibited poorer performance
- 7075 particularly problematic



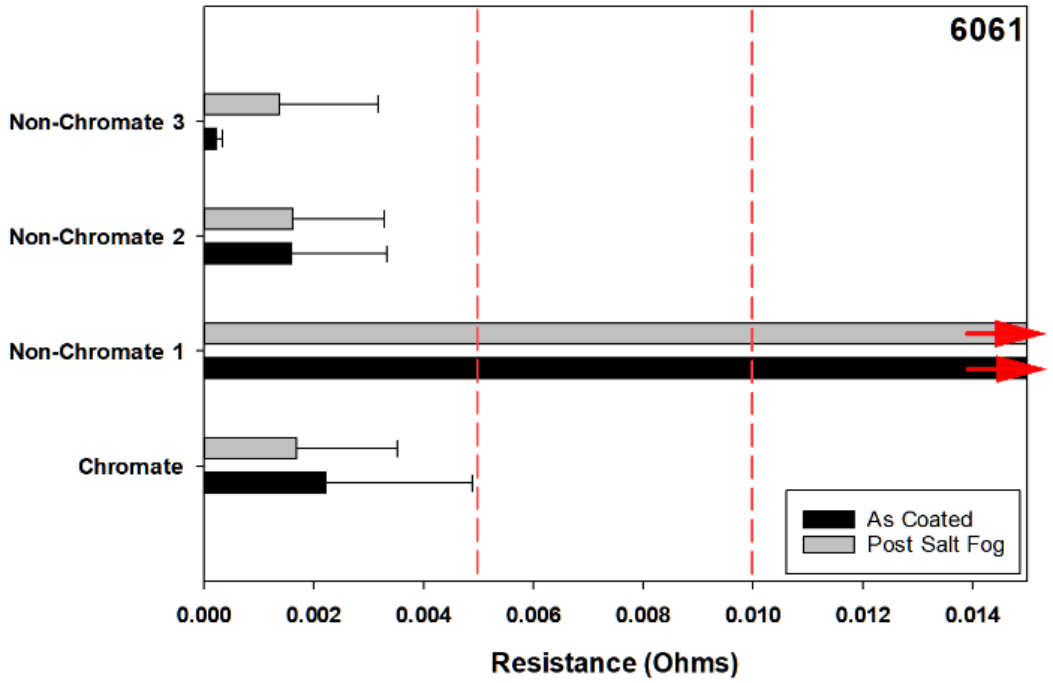


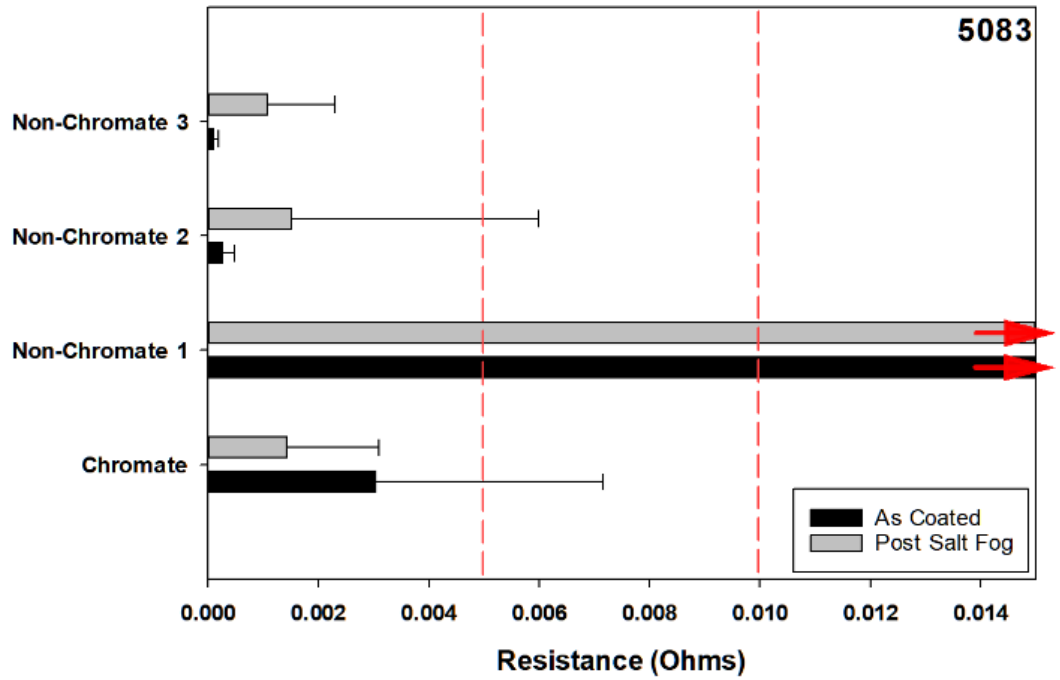
Contact Resistance Procedure

- Coatings were evaluated in the as-coated condition in accordance with MIL-DTL-5541 for a Class 3 coating.
  - Measured by pressing a 1 in^2 (6.5 cm^2) flat copper platen onto the surface of the coupon using a force of 200 psi (1.38 MPa)
  - Lower platen larger than upper platen
  - Applied current of 100 mA
  - 4-wire arrangement.
- 10 measurements per coupon.
  - Measurements were made in the same locations for each sample (two linear arrays of 5 measurements).
- Contact resistance measurement was considered destructive due to the risk of copper deposition onto the aluminum surface
  - Samples evaluated for contact resistance were not used in subsequent salt fog testing.

Electrical Properties for Workhorse Alloys

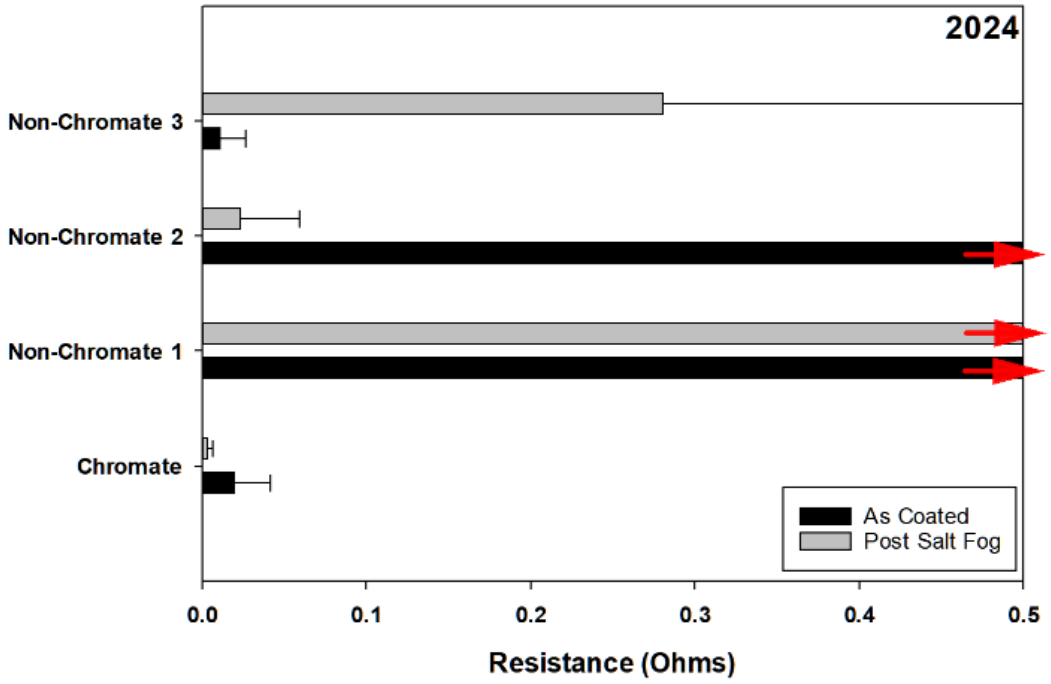
- Reduced electrical performance for one particular material, corresponding to coupons with heavier staining (residual coating solution)
- Materials performed well in salt fog, easily meeting specifications with aforementioned exception

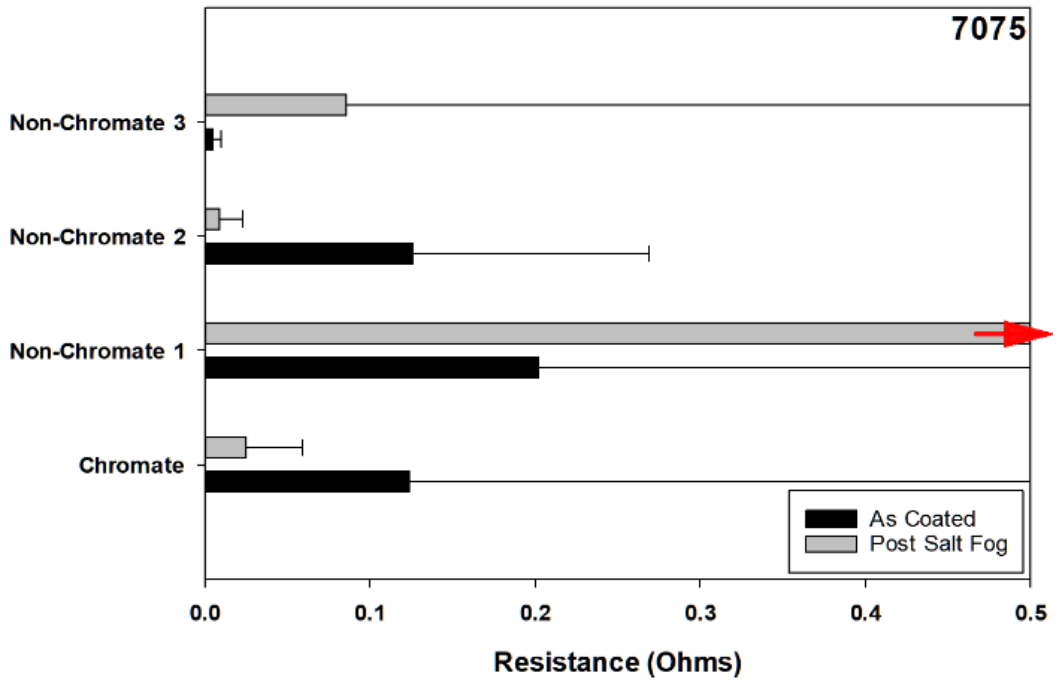




Electrical Properties for High Strength Alloys

- Very poor performance for high strength alloys
- Emphasizes reason to restrict use of repair materials for critical interfaces





Summary, Conclusions, and Recommendations

- All of the coatings where the manufacturers procedure allowed or required that the coating material dry on the aluminum surface were non-uniform in appearance.
- The visual heterogeneities observed on the sample surfaces often corresponded to regions where the corrosion performance of the coating was substantially compromised.
- All but one of the non-chromate coating chemistries were able to rigidly meet MIL-DTL-5541 Class 3 requirements.
- None of the non-chromate coating materials were able to meet the contact resistance requirements on AA2024 or AA7075
- The observed performance of the materials evaluated here indicate that caution must be used when employing these chemistries as a primary coating (i.e., not as a repair material), particularly on high strength alloys such as AA2024 or AA7075, as while all are MIL-DTL-81706 qualified, none were able to achieve the low contact resistances stipulated for a Class 3 coating