Use of Brush Plating and Anodizing for Aerospace and Defense

Danijela Milosevic-Popovich
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Who We Are

❖ SIFCO Applied Surface Concepts
  o Founded in 1959
  o Headquartered in Cleveland, Ohio, USA
  o Acquired as part of the Surface Coatings Division of Norman Hay in 2012.

❖ Norman Hay Group
  o Headquartered in Coventry, UK
  o Other divisions specialize in impregnation sealants, surface coatings, design, manufacture, and installation of process plant equipment.
    • Ultraseal International, Surface Technology, and NHE
  o Company founded in 1940s doing chromium plating and hard anodizing.
Agenda

• Overview of Selective Plating (Brush Plating)?
• Common surface finishing applications for Aerospace
  • Prebrazé
    - Automation Projects
  • Corrosion
  • Other Surface Enhancements
  • Anodize
  • Cadmium Replacements
    - Tin Zinc
    - Zinc Nickel
What is Selective Plating?

- The SIFCO Process is a portable method of electroplating localized areas without the use of an immersion tank.

- Power Pack
- Plating Tools
- Solution Flow System
- Solution
- Masking Materials
- Auxiliary Equipment
Selective Plating/Brush Plating

Surface Preparation

- Pre-Clean
- Electroclean
- Desmutting
- Activation
- Preplate
- Plate
Selective Plating Features

- Higher metal concentrations, allows for higher current density plating e.g. 5ASI (720 ASF)
- High solution velocity also replenishes metal ions at the surface more quickly.
- Brushing action disturbs the hydrodynamic boundary layer at the surface resulting in faster solution movement.
- Hydrogen gas bubbles are removed by the brushing action and high solution velocity.
- Brush action levels the deposit as it builds.
- Selective plating allows for easily controllable application of the coating just where it is needed on the part / component.
Selective Plating Benefits

- Selective plating → less masking, less machining
- Increased plating speed → better cycle and lead times
- Plate to size → minimize machining time and cost
- Portable process → decreased downtime and cost
- Lower chemical volumes → less environmental issues
- Automation capability → decreased labor costs, increased levels of SAFETY
Common Surface Finishing Applications in Aerospace

- Restore/Improve Corrosion Resistance
- Pre-braze Coating
- Refurbishment
  - Dimensional Restoration for MRO and OEM
- Improving Other Surface Properties
  - Hardness
  - Wear
  - Conductivity
  - Anti-galling, lubricity
- Anodizing
- Cadmium Replacements
# Common Uses Of SIFCO Deposits

<table>
<thead>
<tr>
<th>USE</th>
<th>DEPOSIT</th>
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<tbody>
<tr>
<td>Build-up Worn Parts</td>
<td>Ni, Co, Anodize</td>
</tr>
<tr>
<td>Corrosion Protection</td>
<td>Cd, Zn, Ni, Zn-Ni, Sn-Zn, Anodize</td>
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<tr>
<td>Wear</td>
<td>Ni, Ni-Co, Ni-W, Ni-P, Co-Cr$_3$C$_2$</td>
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<tr>
<td>Electrical Contacts</td>
<td>Ag, Au, Rh</td>
</tr>
<tr>
<td>Tarnish Resistance</td>
<td>Sn, Au, Pt</td>
</tr>
<tr>
<td>Bearings</td>
<td>Ag, Sn, Babbitt</td>
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<tr>
<td>Prebraze</td>
<td>Ni</td>
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</table>
Aerospace Applications: Pre-Braze

- AeroNikl 250 (7280) plating on turbine blades and vanes
  - Base Material: Rene 80
  - Thickness: 80-200 μin.

Plating Process Steps
- Electroclean
- Etch
- Desmut
- Activation
- Nickel Sulfate Preplate
- Nickel Sulfamate Plate
Aerospace Applications: Pre-Braze

Programmable Power Pack

Process Improvements:
- Frees operator from adjusting rectifier
- Repeatable and reproducible
- Optimizes deposit properties with standardized amps, volts & amp-hrs
- Increased throughput
- Fewer errors
- Data logging captures actual amperage, voltage and time
- Overall improved quality control and assurance
Aerospace Applications: Pre-Braze

- Integrated UR5 Robot, PLC, HMI, and Rectifier to control plating process and part movement

Adding value through automation
SPC Data Collection Summary

<table>
<thead>
<tr>
<th></th>
<th>Sample Size</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>C.O.V.</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Range</th>
<th>Cpk</th>
<th>Cp</th>
<th>Ppk</th>
<th>Pp</th>
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<tbody>
<tr>
<td>Operator Controlled</td>
<td>32</td>
<td>166.84</td>
<td>28.97</td>
<td>17.36</td>
<td>114.9</td>
<td>226</td>
<td>111.1</td>
<td>0.5</td>
<td>0.91</td>
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<tr>
<td>Programmed Rectifier Controlled</td>
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<td>141.41</td>
<td>17.02</td>
<td>12.03</td>
<td>118</td>
<td>184.1</td>
<td>66.1</td>
<td>1.39</td>
<td>1.42</td>
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<td>Automated Selective Plating</td>
<td>24</td>
<td>133.04</td>
<td>14.85</td>
<td>11.17</td>
<td>111.1</td>
<td>164.2</td>
<td>53.1</td>
<td>1.4</td>
<td>1.59</td>
<td>1.19</td>
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</table>

Cpk, Ppk versus Plating Control

Cp, Pp versus Plating Control

Process Capability of Pos 2

Process Capability of Pos 2_1_1

sifcoasc.com
Benefits of Automation

• Optimization and standardization of cycle times
• Increased throughput and productivity
• Process Control and Consistency
• Reduced human errors
• Reduced labor
• Ergonomic Risk Reduction
• Chemical Exposure Reduction
• Data Logging
Aerospace Applications: **Refurbishment**

- Ni (2085, 2086, & 5644) and Ni Sulfamate (AN 250, 500, and 575) for dimensional restoration and/or parts out of tolerance due to mis-machine or wear. Thickness range 0.0002 to 0.0300 inch.
Aerospace Applications: **Refurbishment**

- AeroNikl 7282 on Actuator Housing for wear and hardness
- Base Material: Inconel 718
- Thickness: 0.0003 – 0.0005 in
Aerospace Applications: **Refurbishment**

- Ni Sulfamate AN 250 (7280) for barrel component of landing gear
  - Base material: Nickel Aluminum Bronze
  - Thickness 0.020 – 0.030 inches
Aerospace Application: **Surface Enhancements**

- AN 575 (7282) for hardness and wear
- Cr Replacement
Aerospace Application: **Surface Enhancements**

- Ni 5646 XHB for wear on a Pitch Change Tube (shaft assembly)
- Base Material: Stainless Steel
Aerospace Application: **Surface Enhancements**

- Silver (3083) plating on bearing race for lubricity
Aerospace Application: **Surface Enhancements**

**Aeroshield 4025 Co-Cr$_3$C$_2$ Key Characteristics**

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Brush Plated Co-Cr$_3$C$_2$</th>
<th>Brush Plated Co</th>
<th>Ti-6Al-4V</th>
<th>Carbon Steel</th>
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<tbody>
<tr>
<td>Cr$_3$C$_2$</td>
<td>wt. %</td>
<td>10 – 50</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>Uniformity of Cr$_3$C$_2$</td>
<td>wt.%</td>
<td>± 3</td>
<td>-</td>
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<tr>
<td>Microhardness</td>
<td>VHN</td>
<td>360 – 500</td>
<td>360</td>
<td>330</td>
<td>150</td>
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<tr>
<td>Hardness change after 400° C exposure</td>
<td>%</td>
<td>&gt; + 10 %</td>
<td>&gt; - 10%</td>
<td>&gt; - 5%</td>
<td>&gt; - 15%</td>
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<tr>
<td>Taber wear index</td>
<td>µg/cycle</td>
<td>8.0</td>
<td>17</td>
<td>21</td>
<td>16</td>
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<tr>
<td>Taber wear index after 400° C exposure</td>
<td>µg/cycle</td>
<td>4.0</td>
<td>15</td>
<td>21</td>
<td>17</td>
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<tr>
<td>Surface finish as deposited, Ra</td>
<td>µm</td>
<td>0.5 - 1.5</td>
<td>0.5 - 1.5</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- Co-Cr$_3$C$_2$ MMC on Ni alloy Turbine Vane
- 20 wt.% Cr$_3$C$_2$
Aerospace Application: **Surface Enhancements**

- **Aeroshield 4025, Co-Cr$_3$C$_2$**
  - Stainless Steel Air Duct
  - ~5 wt.% Cr$_3$C$_2$
  - Thickness 0.008 inches
Aerospace Application: **Corrosion Protection**

- Cadmium 2023 (LHE & No-Bake) & 5070 (LHE)

Support Lugs of the Tail Section Pylon
Aerospace Application: **Corrosion Protection**

Before

Cadmium Touch-Up

After
Aerospace Application: **Cadmium Alternative Tin-Zinc**

- Sacrificial corrosion protection, lubricity, wear resistance, solderability

**Tin Zinc 4019**
- Composition: Sn 80% / Zn 20%
- Hardness: 17 Hv
- Hydrogen Embrittlement per ASTM F 519:
  - Type 2a rings and 1a.1 notch bars
  - No post bake required if
  - Plating at > 50° C
  - Plating at room temperature with nickel pre-plate
- Corrosion per ASTM B 117:
  - Without conversion coating (0.5 mil deposit) → 24 hrs. white corrosion & 96 hrs. red corrosion
  - With a trivalent chromium conversion coating (0.5 mil deposit) → 96 hrs. white corrosion & 600-800 hrs. red corrosion
Aerospace Application: **Cadmium Alternative Tin-Zinc**

- Tin Zinc 4019, touch-up on spline teeth
  - Base Material: AMS 6308
  - Thickness: 0.0003 – 0.0005 inches

- Tin Zinc 4019, adapter propeller
  - Thickness: 0.0005 – 0.001 inches
Aerospace Application: **Cadmium Alternative Zinc-Nickel**

**Zinc Nickel 4018**
- Meets AMS 2451/9 and BAC 5664
- Post plate bake not required

**Deposit Parameters**
- Composition: 8-14% Ni, balance Zn
- Structure: Microporous
- Color: Matte Grey
- Hardness: 132 Hv
- Max Thickness: 0.005 inch

**Operating Parameters**
- CD: 6 ASI (864 ASF)
- Temperature: 60 - 120° F
- Plating Rate: 0.043 inch/hr
Aerospace Application: **Cadmium Alternative Zinc-Nickel**

- **Zinc Nickel 4018**
  - Corrosion per (ASTM B117):
    - 120 hours base metal corrosion
    - With conversion coatings 3007 or 3004
      - >96 hours white corrosion
    - 1000 hours base meal corrosion
Aerospace Application: Cadmium Alternative Zinc-Nickel

Hex Chrome 3004

<table>
<thead>
<tr>
<th>0 hrs</th>
<th>96 hrs</th>
<th>500 hrs</th>
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Tri Chrome 3007

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<td><img src="image12.png" alt="Image" /></td>
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Aerospace Application: **Cadmium Alternative Zinc-Nickel**

- **Zinc Nickel 4018**

  - Post bake not required
  - Hydrogen Embrittlement (ASTM F519):
    - Bars tested within 72 hours of plating
    - Pass 1a.1 and 1a.2 notch bars

- **Processing Sequence**
  1. Degrease bar with acetone
  2. Mask bar
  3. Sandblast
  4. Mask removal
  5. Di Water Rinse
  6. Acetone clean
  7. Re-mask
  8. Plating Parameters
     - THK: 0.00065 inches
     - CD: 6 ASI at constant current
     - Temperature: Ambient
     - No prewet
     - 65 RPM
  9. Rinse with DI
  10. Apply 3007 Conversion ~ 90 sec
  11. Dry
# Aerospace Application: Anodizing

<table>
<thead>
<tr>
<th>Type of Coating</th>
<th>Specification Applicable</th>
<th>Purpose of Coating</th>
<th>Typical Thickness (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromic (Type I) 5010, 5027</td>
<td>Mil-A-8625 (Type I) AMS 2470</td>
<td>Corrosion Protection, Base for Paint and Organic Finishes</td>
<td>0.00005 - 0.0003</td>
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<tr>
<td>Boric-Sulfuric (Type IC) 5031,5032</td>
<td>Mil-A-8625 (Type IC) BAC 5632</td>
<td>Corrosion Protection</td>
<td>0.00005 - 0.0001</td>
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<tr>
<td>Sulfuric (Type II) 5011</td>
<td>Mil-A-8625 (Type II) Undyed AMS 2471</td>
<td>Corrosion and/or Wear Resistance</td>
<td>0.0001 - 0.001</td>
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<tr>
<td>Hard Coat (Type III) 5025</td>
<td>Mil-A-8625 (Type III) AMS 2468</td>
<td>Primarily Wear Resistance, also Corrosion Protection</td>
<td>0.0005 - 0.0045</td>
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<td></td>
<td>AMS 2469</td>
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<tr>
<td>Phosphoric 5023,5024</td>
<td>ASTM D 3933-80 BAC 5555 BAE 146</td>
<td>Base for Adhesive Bonding</td>
<td>0.00005 - 0.0001</td>
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</table>
Aerospace Application: **Anodizing**

- **Chromic Type 1 (5010 & 5027)**
  - Base for organic finishes and corrosion protection
  - Chromic Gel suitable in applications where pumping solution is a problem
    - Damaged areas of refueling tubes and slat skins of helicopter components
    - Repair of wing droop leading edges, damage during maintenance or in service use

- **Boric-Sulfuric Type IC (5031 & 5032)**
  - Environmentally friendly alternative to chromic acid anodizing. Superior to chromate conversion coatings (i.e. Aldine)
  - Application: Damaged areas along OD of guide cylinder and accumulator pistons.
Aerospace Application: **Anodizing**

- Type I Anodizing 5010 for Lead Lag Damper
  - Base Material: Al 7075
  - Thickness 0.0002 inches
Aerospace Application: **Anodizing**

- **Hard Coat Type III (5025)**
  - Corrosion protection, wear resistance, dimensional restoration
  - Applications
    - On flange faces of tail rotor drive shaft, leading edge of corroded vanes, mounting faces and seal areas of underwater motor control and motor control base.

- **Sulfuric Type 2 (5011)**
  - Corrosion protection, wear resistance, dimensional restoration
  - Application: Repair for main gearbox support fittings, forward sponson mounts, and tail cone fuselage support fittings.
Aerospace Application: **Anodizing**

- Anodize Hardcoat 5025 on Actuator Body
  - Al 6061T
  - Thickness 0.0025 inches
Aerospace Application: **Anodizing**

- Phosphoric (5023 & 5024)
  - Al surface preparation for adhesive bonding and preparatory procedure for subsequent plating operation
  - Applications
    - Punctured aircraft skin repair used to assist adhesive bonding
# Aerospace Approvals

<table>
<thead>
<tr>
<th>FINISHES</th>
<th>DESCRIPTIONS</th>
<th>MILITARY</th>
<th>AMS</th>
<th>FEDERAL/AMS REFERENCE</th>
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<tbody>
<tr>
<td>Brush Plating</td>
<td>Plating, Brush General</td>
<td>MIL-STD-865</td>
<td>2451</td>
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<td>Brush Plating Nickel</td>
<td>Nickel Brush Plating</td>
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<td>QQ-N-290 &amp; AMS 2403</td>
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<td>Brush Plating Nickel</td>
<td>Nickel Low Stress, Hard Brush Plating</td>
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<td>Nickel Low Stress, Low Hardness Brush Plating</td>
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<td>Brush Plating Cadmium</td>
<td>LHE Cadmium Brush Plating</td>
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<td>Brush Plating Chromium</td>
<td>Chromium Brush Plating</td>
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<td>Brush Plating Copper</td>
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<td>Nickel Low Stress, Medium Hardness Brush Plating</td>
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<td>Brush Plating Silver</td>
<td>Silver Non-Cyanide Brush Plating</td>
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<td>QQ-N-290</td>
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<td>Nickel Plate, Soft</td>
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<td>Gold Plate</td>
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<td>MIL-G-45204</td>
<td>2422</td>
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<td>QQ-S-365</td>
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<td>Silver Plate</td>
<td>Silver Plating, Electrodeposited</td>
<td>2412&quot;</td>
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<td>Tin-Zinc Plate</td>
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<td>Tin Plate</td>
<td>Tin Plating, Electrodeposited</td>
<td>MIL-T-10727*</td>
<td>2408*</td>
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<tr>
<td>Anodizing</td>
<td>Anodized Coatings</td>
<td>MIL-A-6603* TYPE I, II &amp; III</td>
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### Commercial Specifications (Partial List)

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<tbody>
<tr>
<td>American Airlines</td>
<td>P12-16</td>
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<tr>
<td>Bell Helicopter</td>
<td>BPS 4312</td>
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<tr>
<td>Boeing</td>
<td>BAC 5554</td>
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<td>British Aerospace</td>
<td>Ba146</td>
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<td>Douglas</td>
<td>PS-13113</td>
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<td>Dowty Aerospace</td>
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<td>GAMPS 6103</td>
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<td>Sikorsky</td>
<td>SS 8443</td>
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<tr>
<td>TRW Aeronautical Systems</td>
<td>SPD 1000</td>
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*Tank plating standard. SIFCO ASC does not perform tank plating, but manufactures many deposits that meet the performance requirements of the standard.*