NASA/ESA
Hex-Chrome Project
Phase 1 Results & Overview

Technology Evaluation for Environmental Risk Mitigation
Principal Center
Matt Rothgeb

International Workshop on Environment and Alternative Energy
October 24, 2013
ESRIN – Frascati, Italy
Current NASA TEERM CrVI Projects:

- HCFCFE (Aerospace Electronics)
  - Pretreated & Anodized
- NASA/ESA (Satellites and Launchers)
  - Pretreated & Anodized
  - Pretreated & Primed
  - Pretreated, Primed and Topcoated
- GSDOP (Ground Service Equipment Electronics)
  - Pretreated & Anodized
- ESTCP Primers
  - Primers (Lab, Field and Flight Testing)
Current NASA TEERM CrVI Projects:

- **Active CrVI Alternative Projects**
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### Phase 1

**ESA/NASA**

**Screening**
- p Alodine 1200s (added) - Control
- x Alodine 1600 - Control
- 1 p Alodine 160/161
- 2 p Alodine 5993Plus
- 3 p Interlox 5705
- 4 p MAP Silico
- 5 x Alodine EC2
- 6 x Corrlink 30A
- 7 p Deft RECC
- 8 x UMR CeCC
- 9 x EON Coat
- 10 x XBond 4000
- 11 x NANOMYTE TC-4001
- 12 x NANOMYTE PT-10
- 13 r Alodine 5900
- 14 r Iridite NCP
- 15 r Metalast HF
- 16 x Metalast HF-EPA
- 17 x Surtec 650
- 18 r Surtec 650C
- 19 n Surtec 650V

### Partial List

**HCFCFE**

**Screening**
- x Alodine EC2
- x Corrlink 30A
- x Deft RECC
- x UMR CeCC
- x EON Coat
- x XBond 4000
- x NANOMYTE TC-4001
- x NANOMYTE PT-10

**HCFCFE**

**Pretreatments**
- x Alodine 1600
- x Alodine 5900
- x Iridite NCP
- x Metalast HF
- x Metalast HF-EPA
- x Surtec 650
- x Surtec 650C
Initial Screening Testing:

- ASTM B117 – Salt Fog to Failure
- ASTM G85 - Cyclic Corrosion (A5)
- Beachfront Exposure Testing
- Wet Tape Adhesion

Substrates:

- 2024 - T3
- 7075 - T73
- 6061 - T6

Results:

- All Passed Adhesion
- Cyclic Corrosion was inconclusive
- Beachfront Analysis was inconclusive
- ASTM B117 Results showed mixed and unexpected results
Hexavalent Chrome Free Coatings
Process Optimization
Test Panel Preparation Process Optimization

- Initial Screening testing results were mixed on known commodities (Controls and Approved Non-Chromes)
- Initial re-testing did not provide clear answers
- Decision made to spend effort on optimization of pretreatment application and panel preparation processes
- ≈ 5 Rounds of process optimization were conducted (Round considered major material or process change)
Round 1A

Substrates: 2024 / 2219 / 7075 / 6061
Cleaning: Scotch Bright + Ethanol
Test Panel Preparation
Process Optimization

PROCESS 1

Cleaner
• Chemetall-Oakite NST – (5% by volume)

Deoxidizer
• 70% Nitric Acid/DI water = mixed 1:1 - agreed upon by stakeholder consensus
Solvent Hand Cleaning
Ethanol (200 proof)
Scotch-Brite Pad

Chemetall-Oakite NST – (5% by volume)
- Bath temperature - 120°F (49°C)
- Immersion time - 4 minutes
- Stirred during test panel immersion

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

70% Nitric Acid/DI water = mixed 1:1
- Bath temperature – ambient
- Immersion time – 30 seconds

DI water rinse
- 77°F (25°C)
- Lightly spray

DI water rinse
- 77°F (25°C)
- Lightly spray

Alodine 1200S
Metalast HF
SurTec 650C
Iridite NCP

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray
Test Panel Preparation  
Process Optimization

**PROCESS 2**

Cleaner
- Specialty 740 (9 oz/gal)

Deoxidizer
- Specialty 982 (15% by volume) – currently being used by local plating shop
Solvent Hand Cleaning
Ethanol (200 proof)
Scotch-Brite Pad

Specialty 740 (9 oz/gal)
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray

Specialty 982 (15% by volume)
- Bath temperature – 73°F (23°C)
- Immersion time - 2 minutes

DI water rinse
- 77°F (25°C)
- Lightly spray

Specialty 740 (9 oz/gal)
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

Alodine 1200S
Metalast HF
SurTec 650C
Iridite NCP

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray
National Aeronautics and Space Administration (NASA)

Process Optimization

RESULTS:

• **Alodine 1200S**
  - Failures on 2219 – Expected
  - Failures on 2024 – Not Expected (<168 Hours)
  - Passing on 6061 & 7075 – 336 Hours +

• **Metalast TCP**
  - Failures on 2219 – Expected
  - Passing on 2024 – Expected 168 Hours (barely)
  - Passing on 6061 & 7075 – 672 Hours +

• **Surtec 650 C**
  - Failures on 2219 – Expected
  - Failures on 2024 – Not Expected (<168 Hours)
  - Passing on 6061 & 7075 – 504 Hours +
### Process Optimization

| Pretreatment | Process | Alloy   | 168 hrs | 336 hrs | 504 hrs | 672 hrs | 840 hrs | Process | Alloy   | 168 hrs | 336 hrs | 504 hrs | 672 hrs | 840 hrs |
|--------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Alodine 1200S| 1       | 2024-T3 | Fail    |         |         |         | Fail    |         | 2       | 2024-T3 | Fail    |         | Fail    | Fail    | Fail    |
| Alodine 1200S| 1       | 2219    | Fail    | Fail    | Fail    | Fail    | Fail    | Fail    | 2       | 2219    | Fail    | Fail    | Fail    | Fail    | Fail    |
| Alodine 1200S| 1       | 7075-T6 | Pass    | Pass    | Fail    | Fail    | Fail    | Fail    | 2       | 7075-T6 | Pass    | Pass    | Pass    | Pass    | Fail    |
| Alodine 1200S| 1       | 7075-T6*| Pass    | Pass    | Fail    | Fail    | Fail    | Fail    | 2       | 7075-T6 | Pass    | Pass    | Pass    | Pass    | Fail    |

* Test panels purchased through AnaCon Laboratories; 3x10x.040", PVC cover both sides
## Process Optimization

<table>
<thead>
<tr>
<th>Pretreatment</th>
<th>Process</th>
<th>Alloy</th>
<th>168 hrs</th>
<th>336 hrs</th>
<th>504 hrs</th>
<th>672 hrs</th>
<th>840 hrs</th>
<th>Process</th>
<th>Alloy</th>
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## Process Optimization

| Pretreatment | Process | Alloy   | 168 hrs | 336 hrs | 504 hrs | 672 hrs | 840 hrs | Process | Alloy   | 168 hrs | 336 hrs | 504 hrs | 672 hrs | 840 hrs |
|--------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| SurTec 650C  | 1       | 2024-T3 | Fail    | Fail    | Fail    | Fail    | Fail    | 2       | 2024-T3 | Fail    | Fail    | Fail    | Fail    | Fail    |
| SurTec 650C  | 1       | 2024-T3* | Pass & RTT | Fail | Fail | Fail | Fail | 2       | 2219    | Fail    | Fail    | Fail    | Fail    | Fail    |
| SurTec 650C  | 1       | 2219    | Fail    | Fail    | Fail    | Fail    | Fail    | 2       | 2219    | Fail    | Fail    | Fail    | Fail    | Fail    |

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<tr>
<td>Process</td>
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<td>Fail</td>
<td>Fail</td>
<td>Fail</td>
<td>Fail</td>
</tr>
</tbody>
</table>

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Round 1B

Substrates: 2024 / 2219 / 7075
Cleaning: Scotch Bright + Ethanol
Test Panel Preparation Process Optimization

• Focusing on hardest alloys to protect
  • 2024-T3
  • 2219-T8
  • 7075-T6

• Alodine 1200S – alter contact times for deoxidizer
  {Specialty 982 (20% by volume) only} and Alodine bath

• Hexavalent chrome-free alternatives – alter contact
time for deoxidizer only
  • 70% Nitric Acid/DI water = mixed 1:1 - agreed upon by
    stakeholder consensus
  • Specialty 982 (20% by volume) – currently being used by local
    plating shop
RESULTS:
• Alodine 1200S
  • Failures on 2219 – Expected
  • Passing on 2024 – 3 Min Deox / 5 Min Alodine - 336 Hours
  • Passing on 7075 – 840 Hours + (quit at 840)
• Metalast TCP
  • Not tested on 2219 or 7075
  • Passing on 2024 - Specialty 982 Deox / 3 Min Optimal – 168 Hours
  • Failed on 2024 - Nitric Acid Deox
• Surtec 650 C
  • Not tested on 2219 or 7075
  • Failed on 2024 – Not Expected - Specialty 982 Deox
  • Failed on 2024 – Nitric Acid Deox
Process Optimization – Alodine 1200S
2024-T3 & 7075-T6

Solvent Hand Cleaning
Ethanol {200 proof}
Scotch-Brite Pad

Specialty 740 (9 oz/gal)
• Bath temperature - 140°F (60°C)
• Immersion time - 5 minutes

DI water rinse tank
• 77°F (25°C)
• Agitate test panels

DI water rinse tank
• 77°F (25°C)
• Agitate test panels

DI water rinse
• 77°F (25°C)
• Lightly spray

DI water rinse
• 77°F (25°C)
• Lightly spray

Specialty 982 (20% by volume)
• Bath temperature – 73°F (23°C)
• Immersion time:
  1. 3 minutes
  2. 3 minutes
  3. 5 minutes

DI water rinse
• 77°F (25°C)
• Lightly spray

Alodine 1200S
Bath temperature - 73°F (23°C)
pH – 1.8
• Immersion time:
  1. 2 minutes
  2. 3 minutes
  3. 3 minutes

DI water rinse tank
• 77°F (25°C)
• Agitate test panels

DI water rinse
• 77°F (25°C)
• Lightly spray
### Process Optimization – Alodine 1200S

#### 2024-T3

<table>
<thead>
<tr>
<th>Specialty 982 Deoxidizer</th>
<th>ASTM B117</th>
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<tbody>
<tr>
<td>3 min de-ox / 2 min Alodine 1200S</td>
<td>Pit Count 168 Hours</td>
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<tr>
<td>A20 100</td>
<td>5+</td>
</tr>
<tr>
<td>A20 101</td>
<td>0</td>
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<tr>
<td>A20 102</td>
<td>5+</td>
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<table>
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<tr>
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<td>Pit Count 168 Hours</td>
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<tr>
<th>5 min de-ox / 3 min Alodine 1200S</th>
<th>ASTM B117</th>
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<tbody>
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<td>Pit Count 336 Hours</td>
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<td>A20 002</td>
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#### 7075-T6

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<td>A7 006</td>
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- Pits observed are attributed to test panel damage, scratches and dings
- Testing stopped after 840 hours

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<td>A7 003</td>
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- Pits observed are attributed to test panel damage, scratches and dings
- Testing stopped after 840 hours

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<td>A7 014</td>
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- Testing stopped after 840 hours
Solvent Hand Cleaning
Ethanol {200 proof}
Scotch-Brite Pad

Specialty 740 (9 oz/gal)
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

Specialty 982 (20% by volume)
- Bath temperature – 73°F (23°C)
- Immersion time:
  1. 3 minutes
  2. 5 minutes

DI water rinse
- 77°F (25°C)
- Lightly spray

DI water rinse
- 77°F (25°C)
- Lightly spray

Alodine 1200S
Bath temperature - 73°F (23°C)
pH – 1.8
- Immersion time:
  1. 3 minutes
  2. 3 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray
# Process Optimization – Alodine 1200S

## Specialty 982 Deoxidizer

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<tr>
<th>Sample</th>
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<th>Pit Count 168 Hours</th>
<th>Pit Count 336 Hours</th>
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<td>22 03</td>
<td>5 +</td>
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National Aeronautics and Space Administration (NASA)

Process Optimization – hexavalent chrome-free alternatives – 2024-T3

Solvent Hand Cleaning
Ethanol (200 proof)
Scotch-Brite Pad

Chemetall-Oakite NST – (5% by volume)
- Bath temperature - 120°F (49°C)
- Immersion time - 4 minutes
- Stirred during test panel immersion

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

70% Nitric Acid/DI water = mixed 1:1
- Bath temperature – ambient
- Immersion time:
  1. 1 minute
  2. 2 minutes
  3. 3 minutes

DI water rinse
- 77°F (25°C)
- Lightly spray

Metalast HF
SurTec 650C

DI water rinse
- 77°F (25°C)
- Lightly spray

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray
Process Optimization – hexavalent chrome-free alternatives – 2024-T3

<table>
<thead>
<tr>
<th>Metalast TCP-HF</th>
<th>ASTM B117</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 minute in deoxidizer</td>
<td>168 Hours</td>
</tr>
<tr>
<td>M20 001</td>
<td>5+</td>
</tr>
<tr>
<td>M20 002</td>
<td>5+</td>
</tr>
<tr>
<td>M20 003</td>
<td>5+</td>
</tr>
<tr>
<td>2 minutes in deoxidizer</td>
<td>168 Hours</td>
</tr>
<tr>
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</tr>
<tr>
<td>M20 005</td>
<td>5+</td>
</tr>
<tr>
<td>M20 006</td>
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<td>3 minutes in deoxidizer</td>
<td>168 Hours</td>
</tr>
<tr>
<td>M20 007</td>
<td>5+</td>
</tr>
<tr>
<td>M20 008</td>
<td>5+</td>
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<tr>
<td>M20 009</td>
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<th>SurTec 650C</th>
<th>ASTM B117</th>
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<td>168 Hours</td>
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<td>S20 007</td>
<td>5+</td>
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<td>5+</td>
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National Aeronautics and Space Administration (NASA)

Process Optimization – hexavalent chrome-free alternatives – 2024-T3

Solvent Hand Cleaning
Ethanol {200 proof}
Scotch-Brite Pad

Specialty 740 (9 oz/gal)
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray

DI water rinse
- 77°F (25°C)
- Lightly spray

DI water rinse
- 77°F (25°C)
- Lightly spray

Specialty 982 (20% by volume)
- Bath temperature – 73°F (23°C)
- Immersion time:
  1. 1 minute
  2. 2 minutes
  3. 3 minutes

Metalast HF
SurTec 650C

Specialty 982 (20% by volume)
- Bath temperature – 73°F (23°C)
- Immersion time:
  1. 1 minute
  2. 2 minutes
  3. 3 minutes

Metalast HF
SurTec 650C

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray
Process Optimization – hexavalent chrome-free alternatives – 2024-T3

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<tr>
<th>Metalast TCP-HF</th>
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<td>M20 010</td>
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<td>M20 011</td>
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<tr>
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<td>2 minutes in deoxidizer</td>
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<tr>
<td>M20 013</td>
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<td>M20 014</td>
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<td>M20 015</td>
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<td>M20 017</td>
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<tr>
<td>M20 018</td>
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<tr>
<td>S20 010</td>
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<td>5+</td>
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<tr>
<td>2 minutes in deoxidizer</td>
<td>168 Hours</td>
</tr>
<tr>
<td>S20 013</td>
<td>5+</td>
</tr>
<tr>
<td>S20 014</td>
<td>5+</td>
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<tr>
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<td>5+</td>
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<td>S20 018</td>
<td>5+</td>
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</table>
Test Panel Preparation
Process Optimization

Round 2

Substrates: 2024 / 5052 / 6061
Cleaning: MEK
Test Panel Preparation
Process Optimization

• Changing initial solvent cleaning process
  • Replace ethanol (200 proof) to methyl ethyl ketone (MEK)

• Eliminating the use of Scotch-Brite pads

• Eliminated Nitric Acid Deoxidizer

• Alloys:
  • 2024-T3
  • 5052-H32 (ADDED AS PART OF GSDOP)
  • 6061-T6 (ADDED AS PART OF GSDOP)
RESULTS:

- **Alodine 1200S**
  - Failed on 2024 - Not Expected – (<168 Hours)
  - Passed on 5052 – Expected - 336 Hours
  - Failed on 6061 – Not Expected – (<168 Hours)

- **Metalast TCP**
  - Some Passed on 2024 – Dried Before TCP Added – 168 Hours
  - Passed on 5052 – Expected 504 Hours + (quit test)
  - Passed on 6061 – Expected 504 Hours + (quit test)

- **Surtec 650 C**
  - Skipped Testing for this Round – Tested in Round 4
**Process Optimization – Alodine 1200S**

- **Methyl Ethyl Ketone**
  - Brushed applied

- **Specialty 740 (9 oz/gal)**
  - Bath temperature - 140°F (60°C)
  - Immersion time - 5 minutes

- **Specialty 982 (20% by volume)**
  - Bath temperature – 73°F (23°C)
  - Immersion time:
    - 5 minutes

- **Alodine 1200S**
  - Bath temperature - 73°F (23°C)
  - pH – 1.8
  - Immersion time:
    - 3 minutes

- **DI water rinse tank**
  - 77°F (25°C)
  - Agitate test panels

- **DI water rinse**
  - 77°F (25°C)
  - Lightly spray

- **DI water rinse tank**
  - 77°F (25°C)
  - Agitate test panels

- **DI water rinse**
  - 77°F (25°C)
  - Lightly spray
## Alodine 1200S

### 2024-T3

<table>
<thead>
<tr>
<th>Specialty 982 Deoxidizer</th>
<th>5 min de-ox / 3 min Alodine 1200S</th>
<th>ASTM B117 Pit Count 168 Hours</th>
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<tbody>
<tr>
<td>Al2024 01</td>
<td>5+</td>
<td>Red</td>
</tr>
<tr>
<td>Al2024 02</td>
<td>5+</td>
<td>Red</td>
</tr>
<tr>
<td>Al2024 03</td>
<td>5+</td>
<td>Red</td>
</tr>
<tr>
<td>Al2024 04</td>
<td>5+</td>
<td>Red</td>
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<tr>
<td>Al2024 05</td>
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<td>Red</td>
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<td>Average Coating Weight 72</td>
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### 5052-H32

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<th>5 min de-ox / 3 min Alodine 1200S</th>
<th>ASTM B117 Pit Count 168 Hours</th>
<th>Pit Count 336 Hours</th>
<th>Pit Count 504 Hours</th>
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<tbody>
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<td>Al5052 01</td>
<td>0</td>
<td>0</td>
<td>5</td>
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<td>Al5052 02</td>
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<td>3</td>
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<tr>
<td>Al5052 03</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Al5052 04</td>
<td>0</td>
<td>0</td>
<td>2</td>
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<td>Al5052 05</td>
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### 6061-T6

<table>
<thead>
<tr>
<th>Specialty 982 Deoxidizer</th>
<th>5 min de-ox / 3 min Alodine 1200S</th>
<th>ASTM B117 Pit Count 168 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al6061 01</td>
<td>5+</td>
<td>Red</td>
</tr>
<tr>
<td>Al6061 02</td>
<td>5+</td>
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</tr>
<tr>
<td>Al6061 03</td>
<td>5+</td>
<td>Red</td>
</tr>
<tr>
<td>Al6061 04</td>
<td>5+</td>
<td>Red</td>
</tr>
<tr>
<td>Al6061 05</td>
<td>5+</td>
<td>Red</td>
</tr>
</tbody>
</table>
**Process Optimization – Metalast TCP HF**

- **Methyl Ethyl Ketone**
  - Brushed applied

- **Specialty 740 (9 oz/gal)**
  - Bath temperature: 140°F (60°C)
  - Immersion time: 5 minutes

- **DI water rinse tank**
  - 77°F (25°C)
  - Agitate test panels

- **Specialty 982 (20% by volume)**
  - Bath temperature: 73°F (23°C)
  - Immersion time:
    - 3 minutes

- **DI water rinse**
  - 77°F (25°C)
  - Lightly spray

- **Metalast TCP HF**

- **DI water rinse tank**
  - 77°F (25°C)
  - Agitate test panels

- **DI water rinse**
  - 77°F (25°C)
  - Lightly spray
### National Aeronautics and Space Administration (NASA)

**Metalast TCP HF**

#### 2024-T3

<table>
<thead>
<tr>
<th>Specialty 982 Deoxidizer</th>
<th>3 min de-ox / 4 min Metalast</th>
<th>ASTM B117</th>
<th>Pit Count 168 Hours</th>
<th>Pit Count 336 Hours</th>
<th>Pit Count 504 Hours</th>
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<tbody>
<tr>
<td>M20 01</td>
<td>Yellow</td>
<td>5</td>
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<tr>
<td>M20 02</td>
<td>Yellow</td>
<td>5+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M20 03</td>
<td>Yellow</td>
<td>5+</td>
<td></td>
<td></td>
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<tr>
<td>M20 04</td>
<td>Yellow</td>
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<td>M20 05</td>
<td>Yellow</td>
<td>5+</td>
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*Test panels allowed to dry prior to pretreatment*

#### 5052-H32

<table>
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<tr>
<th>Specialty 982 Deoxidizer</th>
<th>3 min de-ox / 4 min Metalast</th>
<th>ASTM B117</th>
<th>Pit Count 168 Hours</th>
<th>Pit Count 336 Hours</th>
<th>Pit Count 504 Hours</th>
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<tr>
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<tr>
<td>M50 03</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
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#### 6061-T6

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<tbody>
<tr>
<td>M60 01</td>
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<td>M60 02</td>
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<td>M60 04</td>
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Test Panel Preparation
Process Optimization

Round 3

Substrates: 2024 / 5052 / 6061 / 7075
Cleaning: Acetone
Test Panel Preparation
Process Optimization

- Used on two sets of test panels processed at different times (Part of 3 Projects)
- Changing initial solvent cleaning process
  - Replace methyl ethyl ketone (MEK) with Acetone
- Adjust concentration and pH of Alodine 1200S
- Modify SurTec 650C process
RESULTS:

• **Alodine 1200S**
  - Some Passed on 2024 – 168 Hours
  - Some Passed on 6061 – 672 Hours + (quit test)
  - Passed on 7075 – 672 Hours + (quit test)
  - Passed on 5052/6061 – 672 Hours + (quit test) - GSDOP

• **Metalast TCP**
  - Failed on 2024 – (<168 Hours)
  - Passed on 6061 – 672 Hours + (quit test)
  - Passed on 7075 – 672 Hours + (quit test)
  - Passed on 5052/6061 – 672 Hours + (quit test) - GSDOP

• **Surtec 650 C (2 Deox Times)**
  - Failed on 2024 – (<168 Hours)
  - Passed on 6061 – 672 Hours + (quit test)
  - Passed on 7075 – 672 Hours + (quit test)
  - Passed on 5052 – 168 Hours – GSDOP
  - Passed on 6061 – 672 Hours - GSDOP
### Process Optimization – Alodine 1200S

**Solvent Hand Cleaning**
- Acetone

**DI water rinse tank**
- 77°F (25°C)
- Agitate test panels

**DI water rinse**
- 77°F (25°C)
- Lightly spray

**Specialty 740 (9 oz/gal)**
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

**DI water rinse tank**
- 77°F (25°C)
- Agitate test panels

**DI water rinse**
- 77°F (25°C)
- Lightly spray

**Specialty 982 (20% by volume)**
- Bath temperature – 73°F (23°C)
- Immersion time:
  - 5 minutes

**DI water rinse**
- 77°F (25°C)
- Lightly spray

**Alodine 1200S**
- Bath temperature - 73°F (23°C)
- pH – 1.8
- Immersion time:
  - 3 minutes

**DI water rinse tank**
- 77°F (25°C)
- Agitate test panels

**DI water rinse**
- 77°F (25°C)
- Lightly spray
Alodine 1200S

<table>
<thead>
<tr>
<th>2024-T3</th>
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<tbody>
<tr>
<td>1200S 20 01</td>
<td>5+</td>
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<tr>
<td>1200S 20 02</td>
<td>3</td>
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<td>1200S 20 03</td>
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<th>6061-T6</th>
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<th>@ 504</th>
<th>@ 672</th>
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National Aeronautics and Space Administration (NASA)

Process Optimization – Metalast TCP HF

Solvent Hand Cleaning Acetone

Specialty 740 (9 oz/gal)
- Bath temperature: 140°F (60°C)
- Immersion time: 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

Specialty 982 (20% by volume)
- Bath temperature: 73°F (23°C)
- Immersion time: 3 minutes

DI water rinse
- 77°F (25°C)
- Lightly spray

Metalast HF
- 28% by volume
- Temperature: 90°F (32°C)
- pH = 3.9
- Immersion Time: 4 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray

DI water rinse
- 77°F (25°C)
- Lightly spray
## Metalast TCP HF

### 2024-T3

<table>
<thead>
<tr>
<th>MTL 20 01</th>
<th>@ 168 Hr</th>
<th>@ 336 Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>5+</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>MTL 20 02</td>
<td>5+</td>
<td>N/A</td>
</tr>
<tr>
<td>MTL 20 03</td>
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<td>N/A</td>
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### 6061-T6

<table>
<thead>
<tr>
<th>MTL 60 01</th>
<th>@ 168 Hr</th>
<th>@ 336 Hr</th>
<th>@ 504</th>
<th>@ 672</th>
<th>Total</th>
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<td>0</td>
<td>0</td>
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### 7075-T6

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<th>@ 504</th>
<th>@ 672</th>
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Solvent Hand Cleaning
Acetone

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray

Specialty 740 (9 oz/gal)
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray

Specialty 982 (20% by volume)
- Bath temperature – 73°F (23°C)
- Immersion time:
  - 15 seconds – 2024-T3 only
  - 3 minutes

SurTec 650C
25% by volume
Temperature – 90°F (32°C)
pH = 3.95
Immersion Time – 4 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray
### SurTec 650C

#### 2024-T3

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Test Panel Preparation
Process Optimization

- Used on two sets of test panels processed at different times
Process Optimization – Alodine 1200S

1. **Solvent Hand Cleaning**
   - Acetone

2. **DI water rinse tank**
   - Bath temperature: 77°F (25°C)
   - Agitate test panels

3. **DI water rinse**
   - Bath temperature: 77°F (25°C)
   - Lightly spray

4. **Specialty 740 (9 oz/gal)**
   - Bath temperature: 140°F (60°C)
   - Immersion time: 5 minutes

5. **DI water rinse tank**
   - Bath temperature: 77°F (25°C)
   - Agitate test panels

6. **Specialty 982 (20% by volume)**
   - Bath temperature: 73°F (23°C)
   - Immersion time: 6 minutes

7. **DI water rinse**
   - Bath temperature: 77°F (25°C)
   - Lightly spray

8. **Alodine 1200S**
   - Bath temperature: 73°F (23°C)
   - pH: 1.8
   - Immersion time: 3 minutes

9. **DI water rinse tank**
   - Bath temperature: 77°F (25°C)
   - Agitate test panels

10. **DI water rinse**
    - Bath temperature: 77°F (25°C)
    - Lightly spray
### Alodine 1200S

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Process Optimization – hexavalent chrome-free alternatives

Solvent Hand Cleaning Acetone

Specialty 740 (9 oz/gal)
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

Specialty 982 (20% by volume)
- Bath temperature – 73°F (23°C)
- Immersion time:
  - 3 minutes

DI water rinse
- 77°F (25°C)
- Lightly spray

Metalast TCP – HF SurTec 650C

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray
# Metalast TCP HF

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Test Panel Preparation
Process Optimization

Round 4

Substrates: 2024 / 2219 / 6061 / 7075
Cleaning: Acetone
Test Panel Preparation
Process Optimization

- Changing deoxidizer to an iron free based deoxidizer
  - {Metalast Deox 3300(A)}

- Using new batch of Alodine 1200S

- Using new batch of Metalast HF with HPA-100 additive

- Using Alodine 5923 plus, from Henkel Europe
Process Optimization – Alodine 1200S

1. **Solvent Hand Cleaning Acetone**
2. **Specialty 740 (9 oz/gal)**
   - Bath temperature: 140°F (60°C)
   - Immersion time: 5 minutes
3. **DI water rinse tank**
   - Bath temperature: 77°F (25°C)
   - Agitate test panels
4. **DI water rinse**
   - Bath temperature: 77°F (25°C)
   - Agitate test panels

5. **Deox 3300(A) @ 45 grams/liter with 25% by volume nitric acid**
   - Ambient
   - Set 1 – 30 seconds
   - Set 2 – 3 minutes
6. **DI water rinse**
   - Bath temperature: 77°F (25°C)
   - Lightly spray

7. **Alodine 1200S**
   - Bath temperature: 73°F (23°C)
   - pH: 1.8
   - Immersion time:
     - 3 minutes

8. **DI water rinse tank**
   - Bath temperature: 77°F (25°C)
   - Agitate test panels
9. **DI water rinse**
   - Bath temperature: 77°F (25°C)
   - Lightly spray
Process Optimization – Metalast TCP HF HPA-100

Solvent Hand Cleaning Acetone

Specialty 740 (9 oz/gal)
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

Deox 3300(A) @ 45 grams/liter with 25% by volume nitric acid
- Ambient
- Set 1 – 30 seconds
- Set 2 – 3 minutes

DI water rinse
- 77°F (25°C)
- Lightly spray

DI water rinse
- 77°F (25°C)
- Lightly spray

Metalast TCP – HF : HPA-100
30% v/v + 30% v/v
- 80°F (27°C)
- pH – 3.6
- 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray
Solvent Hand Cleaning

Acetone

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray

Specialty 740 (9 oz/gal)
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray

Deox 3300(A) @ 45 grams/liter with 25% by volume nitric acid
- Ambient
- Set 1 – 30 seconds
- Set 2 – 3 minutes

SurTec 650C
- 25% by volume
- 90°F (32°C)
- pH – 3.8
- 4 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray
Process Optimization – Alodine 5923 plus

- **Solvent Hand Cleaning Acetone**
- **DI water rinse tank**
  - 77°F (25°C)
  - Agitate test panels
- **DI water rinse**
  - 77°F (25°C)
  - Lightly spray
- **Specialty 740 (9 oz/gal)**
  - Bath temperature - 140°F (60°C)
  - Immersion time - 5 minutes
- **DI water rinse tank**
  - 77°F (25°C)
  - Agitate test panels
- **Deox 3300(A) @ 45 grams/liter with 25% by volume nitric acid**
  - Ambient
  - Set 1 – 30 seconds
  - Set 2 – 3 minutes
- **DI water rinse**
  - 77°F (25°C)
  - Lightly spray
- **Alodine 5923 plus**
  - Ready To Use
  - Ambient
  - 8 minutes
- **DI water rinse tank**
  - 77°F (25°C)
  - Agitate test panels
- **DI water rinse**
  - 77°F (25°C)
  - Lightly spray
RESULTS:

- **Alodine 1200S**
  - Passed on 2024 / 6061 / 7075 – 336 Hours
  - Failed on 2219 – (<168 Hours)

- **Metalast TCP + Additive**
  - Some Pass on 2024 – 168 Hours
  - Passed on 6061 / 7075 – 504 Hours
  - Failed on 2219 – (<168 Hours)

- **Surtec 650 C**
  - Failed on 2024 – (<168 Hours)
  - Passed on 6061 – 336 Hours
  - Passed on 7075 – 504 Hours
  - Failed on 2219 – (<168 Hours)

- **Alodine 5923 Plus**
  - Some Passed on 2024 – 168 Hours
  - Passed on 6061 / 7075 – 504 Hours
  - Failed on 2219 – (<168 Hours)
### Overall Summary

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- Green: all panels had fewer than 5 pits
- Yellow/Orange: some panels failed
- Red: all panels failed
Test Panel Preparation
Process Optimization

Round 5A

Substrates: 2024 / 5052 / 6061 / 7075
Cleaning: Acetone
Test Panel Preparation Process Optimization

- Changing deoxidizer to Turco Smut-Go NC
  - Unable to acquire material at KSC prior to this

- Using SurTec 650V and 650C
  - Based on Navy Testing

- Dropped 2219

- Added 5052 (GSDOP)
Solvent Hand Cleaning Acetone

Specialty 740 (9 oz/gal)
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

Turco Smut-Go NC
- 20% by volume
- Ambient
- 1 minute

Alodine 5923 plus
- Ready To Use
- Ambient
- 8 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray
Solvent Hand Cleaning Acetone

Specialty 740 (9 oz/gal)
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray

Turco Smut-Go NC
- 20% by volume
- Ambient
- 1 minute

DI water rinse
- 77°F (25°C)
- Lightly spray

Metalast TCP – HF : HPA-100
30% v/v + 30% v/v
- 80°F (27°C)
- pH – 3.6
- 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray
Solvent Hand Cleaning Acetone

Specialty 740 (9 oz/gal)
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray

Turco Smut-Go NC
- 20% by volume
- Ambient
- 1 minute

DI water rinse
- 77°F (25°C)
- Lightly spray

SurTec 650C
- 25% by volume
- 90°F (32°C)
- pH – 3.8
- 4 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray
DI water rinse tank
• 77°F (25°C)
• Agitate test panels

DI water rinse
• 77°F (25°C)
• Lightly spray

SurTec 650V
10% by volume
• 104°F (40°C)
• pH – 3.8
• 3 minutes

DI water rinse tank
• 77°F (25°C)
• Agitate test panels

DI water rinse
• 77°F (25°C)
• Lightly spray

Specialty 740 (9 oz/gal)
• Bath temperature - 140°F (60°C)
• Immersion time - 5 minutes

DI water rinse tank
• 77°F (25°C)
• Agitate test panels

DI water rinse
• 77°F (25°C)
• Lightly spray

Solvent Hand Cleaning Acetone

DI water rinse tank
• 77°F (25°C)
• Agitate test panels

Turco Smut-Go NC
• 20% by volume
• Ambient
• 1 minute

SurTec 650V
10% by volume
• 104°F (40°C)
• pH – 3.8
• 3 minutes

DI water rinse
• 77°F (25°C)
• Lightly spray

Acetone

Process Optimization – SurTec 650V
RESULTS:

• **Alodine 1200S**
  - Failed on 2024 – (<168 Hours)
  - Passed on 5052 – 504+ Hours
  - Passed on 6061 – 336+ Hours
  - Passed on 7075 – 336 Hours

• **Metalast TCP + Additive**
  - Failed on 2024 – (<168 Hours)
  - Passed on 5052 – 672 Hours (quit)
  - Passed on 6061 – 672 Hours (quit)
  - Passed on 7075 – 504 Hours

• **Surtec 650 V**
  - Passed on 2024 – 336+ Hours
  - Passed on 5052 - 672 Hours (quit)
  - Passed on 6061 - 672 Hours (quit)
  - Passed on 7075 - 672 Hours (quit)

• **Alodine 5923 Plus**
  - Failed on 2024 – (<168 Hours)
  - Passed on 5052 – 672 Hours (quit)
  - Passed on 6061 – 672 Hours (quit)
  - Passed on 7075 – 672 Hours (quit)

• **Surtec 650 C**
  - Some Passed on 2024 – 168 Hours
  - Passed on 5052 – 672 Hours (quit)
  - Passed on 6061 – 672 Hours (quit)
  - Passed on 7075 – 504 Hours
National Aeronautics and Space Administration (NASA)

### Overall Summary

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</table>

Green - all panels had fewer than 5 pits
Yellow/Orange - some panels failed
Red - all panels failed
Test Panel Preparation
Process Optimization

Round 5B

Substrates: 2024
Cleaning: Acetone
Test Panel Preparation
Process Optimization

• Changing deoxidizer times for Turco Smut-Go NC
  • Brackets around previous Round (60 seconds)
  • 0s, 10s, 30s, 120s

• Only evaluating 2024-T3

• Removed Alodine 1200S

• Removed Surtec 650 C
Solvent Hand Cleaning Acetone

Specialty 740 (9 oz/gal)
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray

Alodine 5923 plus
- Ready To Use
- Ambient
- 8 minutes

DI water rinse tank
- 77°F (25°C)
- Agitate test panels

DI water rinse
- 77°F (25°C)
- Lightly spray

Turco Smut-Go NC
- 20% by volume
- Ambient
- Immersion Time:
  - 0
  - 10 seconds
  - 30 seconds
  - 2 minutes
**Process Optimization – Metalast TCP HF HPA-100**

**Solvent Hand Cleaning Acetone**

**Specialty 740 (9 oz/gal)**
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

**DI water rinse tank**
- 77°F (25°C)
- Agitate test panels

**DI water rinse**
- 77°F (25°C)
- Lightly spray

**Metalast TCP – HF : HPA-100**
- 30% v/v + 30% v/v
- 80°F (27°C)
- pH – 3.6
- 5 minutes

**DI water rinse tank**
- 77°F (25°C)
- Agitate test panels

**DI water rinse**
- 77°F (25°C)
- Lightly spray

**Turco Smut-Go NC**
- 20% by volume
- Ambient
- Immersion Time:
  - 0
  - 10 seconds
  - 30 seconds
  - 2 minutes

**DI water rinse**
- 77°F (25°C)
- Lightly spray
**Process Optimization – SurTec 650V**

**Solvent Hand Cleaning Acetone**

**Specialty 740 (9 oz/gal)**
- Bath temperature - 140°F (60°C)
- Immersion time - 5 minutes

**DI water rinse tank**
- 77°F (25°C)
- Agitate test panels

**DI water rinse**
- 77°F (25°C)
- Lightly spray

**SurTec 650V**
- 10% by volume
  - 104°F (40°C)
  - pH – 3.8
  - 3 minutes

**DI water rinse tank**
- 77°F (25°C)
- Agitate test panels

**DI water rinse**
- 77°F (25°C)
- Lightly spray

**Turco Smut-Go NC**
- 20% by volume
- Ambient
- Immersion Time:
  - 0
  - 10 seconds
  - 30 seconds
  - 2 minutes

**DI water rinse**
- 77°F (25°C)
- Lightly spray

**DI water rinse tank**
- 77°F (25°C)
- Agitate test panels

**DI water rinse**
- 77°F (25°C)
- Lightly spray
RESULTS:

• **Alodine 5923 Plus**
  • Failed on 2024 – all deox times

• **Metalast TCP + Additive**
  • Failed on 2024 – all deox times

• **Surtec 650 V**
  • Some Passed on 2024 – 168 Hours (0s)
  • Passed on 2024 – 336 Hours (10s)
  • Some Passed on 2024 – 336 Hours (30s, 120s)
Overall Summary

<table>
<thead>
<tr>
<th>Pretreatment</th>
<th>De-ox</th>
<th>168</th>
<th>336</th>
<th>504</th>
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</tbody>
</table>

Green - all panels had fewer than 5 pits
Yellow/Orange - some panels failed
Red - all panels failed
Black - data not collected
Test Panel Preparation
Process Optimization

Round 5C

Substrates: 2219
Cleaning: Scotch Bright (for Clad) + Acetone
Test Panel Preparation
Process Optimization

- Tested only Alloy 2219 (limited quantity available)
  - Clad test Panels scrubbed with Scotch-Brite pads to a dull surface
  - Bare test panels; no Scotch-Brite scrubbing

- Tested only Surtec 650V
Process Optimization – SurTec 650V

- **Solvent Hand Cleaning Acetone**
- **Specialty 740 (9 oz/gal)**
  - Bath temperature: 140°F (60°C)
  - Immersion time: 5 minutes
- **DI water rinse tank**
  - Bath temperature: 77°F (25°C)
  - Agitate test panels
- **DI water rinse**
  - Bath temperature: 77°F (25°C)
  - Lightly spray

- **SurTec 650V**
  - 10% by volume
  - pH: 3.8
  - 3 minutes
- **DI water rinse tank**
  - Bath temperature: 77°F (25°C)
  - Agitate test panels
- **DI water rinse**
  - Bath temperature: 77°F (25°C)
  - Lightly spray

- **Turco Smut-Go NC**
  - 20% by volume
  - Ambient
  - 1 minute
- **DI water rinse**
  - Bath temperature: 77°F (25°C)
  - Lightly spray

- **Surfactent 740 (9 oz/gal)**
  - Bath temperature: 140°F (60°C)
  - Immersion time: 5 minutes
- **DI water rinse tank**
  - Bath temperature: 77°F (25°C)
  - Agitate test panels
- **DI water rinse**
  - Bath temperature: 77°F (25°C)
  - Lightly spray

- **SurTec 650V**
  - 10% by volume
  - pH: 3.8
  - 3 minutes
- **DI water rinse tank**
  - Bath temperature: 77°F (25°C)
  - Agitate test panels
- **DI water rinse**
  - Bath temperature: 77°F (25°C)
  - Lightly spray
Process Optimization

RESULTS:

• Surtec 650 V
  • Passed on 2219 Clad – 336 Hours
  • Some Passed on 2219 – 168 Hours
<table>
<thead>
<tr>
<th>Alloy</th>
<th>Pretreatment</th>
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<th>ASTM B 117 Results</th>
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*Pits on test panel #8 were very small and difficult to detect
NASA/ESA Phase I
Project Results
&
Overview of Next Phases
### Screening

- Alodine EC2
- Corrlink 30A
- Deft RECC
- UMR CeCC
- EON Coat
- XBond 4000
- NANOMYTE TC-4001
- NANOMYTE PT-10

### Pretreatments

- Alodine 1600
- Alodine 5900
- Iridite NCP
- Metalast HF
- Metalast HF-EPA
- Surtec 650
- Surtec 650C

### Phase 1

#### ESA/NASA

**Screening**

- Alodine 1200s (added) - Control
- Alodine 1600 - Control
- Alodine 160/161
- Alodine 5993Plus
- Interlox 5705
- MAP Silico

1. Alodine 1600
2. Iridite NCP
3. Metalast HF
4. Metalast HF-EPA
5. Surtec 650
6. Surtec 650C

**Technical**

- Alodine 5900
- Alodine EC2
- Corrlink 30A
- Deft RECC
- UMR CeCC
- EON Coat
- XBond 4000
- NANOMYTE TC-4001
- NANOMYTE PT-10

8. Surtec 650
9. Surtec 650C
Screening (phase 2)

Substrate:
- 2024-T3

Testing:
- ASTM B117 – Salt Fog
- Adhesion – PATTI Jr.

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<td>+ MAP Silico</td>
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<td>+ Deft 084</td>
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<td>MAP Silico</td>
<td>+ Hentzen 16708</td>
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<tr>
<td>MAP Silico</td>
<td>+ PM820</td>
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<tr>
<td>Alodine 5923Plus</td>
<td>+ MAP Silico</td>
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<td>+ PM820</td>
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<td>+ NAVALCOAT</td>
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Phase 2
ESA/NASA

Pretreatments
- Alodine 1200S
- Iridite 14-2
- Metalast TCP
- MAP Silico
- Alodine 5923Plus
- SurTec 650V

Substrates:
- 2024-T3
- 2024-T8
- 6061-T6
- 7075-T6
- 7075-T73

Testing:
- B117 – Salt Fog
- Humidity Exposure
- Thermal Cycling
- Adhesion – X-Cut Tape
- Resistivity
Phase 3
ESA/NASA

Pretreat+Primer

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<td>PR4 (ESA Alternative 2)</td>
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Substrates:
- 2024-T3
- 2024-T8
- 6061-T6
- 7075-T6
- 7075-T73

Testing:
- B117 – Salt Fog
- Atmospheric Exposure
- Adhesion - X-Cut Tape
- Adhesion – PATTI Jr.
Phase 3
ESA/NASA

Pretreat+Primer+Topcoat

<table>
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<th>Product</th>
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<tr>
<td>SurTec 650V</td>
<td>+ PR4 + TC</td>
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Substrates:
- 2024-T3
- 2024-T8
- 6061-T6
- 7075-T6
- 7075-T73

Testing:
- B117 – Salt Fog
- Atmospheric Exposure
- Adhesion - X-Cut Tape
- Adhesion – PATTI Jr.
THANK YOU!

NASA TEERM
Principal Center

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Kurt Kessel
kurt.r.kessel@nasa.gov
(321) 867-8480
Any Questions?