Establishment of Tagnite™ Anodizing Line for Overhauling Magnesium Components at CCAD

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Technical Objectives

- **Demonstrate/Validate** the Use of Tagnite/Mixed Metal Technology at the **CCAD Plating Shop** on DoD Aviation Magnesium Components.

- Provide **Cost and Performance Data** on proposed system.

- **Eliminate chromate** conversion coatings during the overhaul phase through the use of Immersion Tagnite™ and Brush Tagnite™ Anodize Coatings.

**Advantages of Tagnite™:**
- Electrolyte contains only silicate, fluoride and hydroxide
- Superior corrosion protection

**Disadvantages of Chromates:**
- No corrosion protection
- Toxic/hazardous nature

Anodized Coatings (Type I) on magnesium alloy ZE41 after 168 hours in salt spray
- TAGNITE
- HAE
- DOW 17

Chromate Cr6+ Coatings on magnesium alloy ZE41 after 9 hours in salt spray
- Bare
- DOW 7
- DOW 19
Why Not Overhaul Magnesium with Anodizing?

1. Prior paints and magnesium pretreatments removal for quality anodizing
   - Presence of old coatings will contaminate the coating bath and can result in magnesium metal loss during anodization.
   - TAG has collaborated with several 3rd party companies to develop effective ways to remove legacy coatings

2. Dissimilar metals may not contact the anodization electrolyte
   - The magnesium anodization process is an oxidation process which leads to the formation of MgO on the surface of the part.
   - When dissimilar metals such as steel undergo oxidation, the process converts steel into rust! Leads to pitting of the steel and contamination of the coating bath.

**Major Innovation:** methodology to “mask off” the mixed metals allowing Tagnite™ deposition on the magnesium while maintaining the integrity of the mixed metals even with very complex geometry components!
Legacy Coating Removal

Masking Installed

After Tagnite

H84 housings
AED Approvals in Immersion Tagnite™ Dem/Val

1. Joint Test Protocol Review and Approval
   • AEF Materials/Process at Aviation Engineering Directorate (AED)
   • AEP Propulsion (Structure) at AED (N/A for non-structure Dem/Val)

2. Production Airworthiness Approval
   • Maintenance Engineering Division (MED) of AED for MEOs and DMWRs
     o DMWR – Depot Maintenance Work Requirement: A document that provides step by step instructions for depot level maintenance efforts
     o MEO – Maintenance Engineering Order: Written by AEM, once approved it revises the DMWR

3. Immersion Tagnite Line 854 PM Process at CCAD
   • Very detailed project management process approvals from the following organizations:
     o Engineering (Industrial/Equipment/Process)
     o Facilities
     o Safety
     o Industrial Hygiene
     o Environmental
     o Teams (Equipment Maintenance)
### Immersion Tagnite™ 854 PM Process at CCAD

The information below will complete approximately 90% of the 854 requirements

<table>
<thead>
<tr>
<th>Engineering (Ind/Equip/Process)</th>
<th>Facilities Engineering</th>
<th>Safety</th>
<th>Industrial Hygiene</th>
<th>Environmental</th>
<th>TEAMS (Equip Maintenance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposal / quote</td>
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<tr>
<td>Project layout drawings</td>
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<tr>
<td>Equipment drawings &amp; specifications</td>
<td>Equipment drawings &amp; specifications</td>
<td>Complete material SDS</td>
<td>Complete material SDS</td>
<td>Equipment drawings &amp; specifications</td>
<td></td>
</tr>
<tr>
<td>Process design, instructions &amp; requirements, flowchart/map (scrubber capacity and air permit impact)</td>
<td>Site specific safety plan or Accident Prevention Plan with designated Site Safety &amp; Health Officer (SSHO)</td>
<td>Process design, instructions &amp; requirements, flowchart/map (scrubber capacity and air permit impact)</td>
<td>Waste streams (to verify water treatment assessment &amp; capacity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste streams (to verify water treatment assessment &amp; capacity)</td>
<td>Complete electrical requirements; electrical diagrams (verify elec load for bldg. 340)</td>
<td>SSO completion of OSHA Safety course &amp; certificates of completion for relevant training: confined space; high voltage, etc.</td>
<td>Waste streams (to verify water treatment assessment &amp; capacity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IT Equipment requirements (PLC, sensors, IT compliant, network worthy, etc.)</td>
<td>Utility heating/cooling and floor loads (plumbing diagram)</td>
<td>Activity Hazard Analysis (AHA)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The information below will complete the remaining 10% of the 854 requirements

<table>
<thead>
<tr>
<th>Project installation logistics plan: How will the work get done and who will do the work. Include receiving of equipment, storing of equipment, uncrating of equipment, rigging, crane work, utilities / equipment installation and removal.</th>
<th>Project installation and logistics plan</th>
<th>Project installation and logistics plan</th>
<th>Project installation logistics plan</th>
</tr>
</thead>
</table>

With 854 requirements complete and each CCAD organization signing off on the project, the CCAD Project Manager generates an eFEMS work order from the 854 for equipment installation.

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Tagnite Installation Safety Plan at CCAD stands at 506 pages and involves coordination between:

- **Prime (TAG)**
- **Project Manager (AquasGroup)**
- **Subcontractors**
  - Electrical
  - Concrete
  - Fencing/Security
  - Plumbing
  - Mechanical
Current Magnesium Overhaul Processes

**DOW 7 (Type III)**  Dichromate Immersion Conversion Coating for fully stripped housing

- **Remove Old Coatings**
  1. Chemical Strip OR
  2. Media Blast

- **Alkaline Clean** 5-15 min
- **Cold Water Rinse (CWR)**
- **Chromic Pickle** 10-30 min
- **Bifluoride Pickle** 1-5 min

**Chromate Conversion Coatings**

**Advantages**
- No Masking
- Minimal Part Preparation

**Disadvantages**
- Exposure to Cr\(^{6+}\)
- Little to no corrosion protection

**Type III DOW 7** 10-30 min 212°F

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**DOW 19 (Type VI):**  Dichromate Conversion Coating For Small Repair Areas

- **Remove Old Coatings from Localized Area**
  1. Abrasion OR
  2. Media Blast

- **Warm Part / Localized Area**
- **Type VI DOW 19** 1-10 min Room Temp
- **Dry Part / Localized Area**
Masking + Tagnite™ Magnesium Overhaul Processes

Remove Old Coatings
1. Chemical Strip OR
2. Media Blast

Inspect Housing for Complete Coating Removal

Install Masking Tools

Degreaser by approved techniques

Rinse

Alkaline Etch
70 - 80 °C
1-15 min

Double Rinse

Fluoride Activator
70 - 80 °C
30 -90 min

Rinse

TAGNITE 8200
10 -15 °C
10-45 min

Double Rinse

Dry

Final Rinse

Post Treatment
27 - 46 °C
30-60 sec

Double Rinse

New Parts

Remove Masking Tools

Inspect

Brush Tagnite

Apply Sealants /Primers/ Paints

New Parts
Tagnite™ Retrofit of D-Line at CCAD Plating Shop

Start of D-Line at Tank D-1

Middle of D-Line

End of D-Line at Tank D-13

CCAD D-Line Current Layout

Processing Flow

D-1  D-2/3  D-4  D-5/6  D-7  D-8/9  D-10  D-11/12  D-13
Tagnite™ Anodization Line Schematic Diagram

Processing Flow

Etch (D-1) → RO Water (D-2/3) → Fluoride (D-4) → RO Water (D-5/6) → Tagnite → RO Water (D-8/9) → DHP (D-10) → RO Water (D-11/12) → Tap Water (D-13)

Chilling System → Chiller Plates → Rectifier → Control Panel
# Tagnite™ Line at CCAD: Project Schedule

## CCAD Tagnite Project Schedule

| WEEKS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|-------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Receive PO & Down Payment (5/24 & 6/1/16) | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mechanical Drawer Approval Package | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Receive Second Milestone Payment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Electrical Drawer Approval Package | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Project Item | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mechanical Engineering | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Electrical Engineering | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fabrication | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tagnite Tank | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Base Frame for Rectifier | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pump Skid & Holding Tank | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Liner for D4 Tank | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Assembly | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Controls | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mech. Assy | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Elect Assy | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Test | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Purchase | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Chiller | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pumps | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Heat Exchanger | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Misc. Plumbing comp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Electrical comp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Site Work | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pour Chiller Pad | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Run Electrical Power to Line w/Disconnects | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Run Electrical Power to Chiller w/Disconnect | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Run Chiller Cooling supply & Feed Lines | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ship to CCAD | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Receive Third Milestone Payment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Installation of Equipment at CCAD | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Remove D7 Hot Water Tank | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Install Tagnite Tank | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Locate Chiller | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Locate Rectifier | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Locate Pump Skid | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Interconnect Plumbing to Components | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Control Wiring | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Start-Debug | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Training | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Receive Final Payment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

### Notes:
- Work to left of yellow line has been completed
- Right of yellow line on hold until 854 Process approval from CCAD
CCAD D-Line Retrofit

Site Work
a. Pour Chiller Pad and erect security fence (located outside of Plating Shop Building)
b. Pour foundation for Rectifier (Plating Shop Basement under D-Line)
c. Run electrical power to D-Line and rectifier
d. Run electrical power to chiller
e. Run chiller cooling supply and feed lines from outside building to chiller plates in Plating Shop Basement

Fabrication
a. New Tagnite Tank (replace old Tank D-7)
b. Metal Support Frame for Rectifier (to elevate above potential flooding level)
c. Chiller Pump Skid and Holding Tank
d. Liner for D4 Tank (Fluoride Activator)
CCAD D-Line Retrofit

D-Line Retrofit Work
1. Install new Tagnite Tank (D-7) and circulation pump
2. Install plastic liner and electric heaters in Fluoride Activator Tank (D-4)
3. Install rectifier control panel on production deck near Tagnite Tank (D-7)
4. Place rectifier and chiller plates in basement
5. Place chiller skid on pad outside
6. Charge chiller system with ethylene glycol
7. Power up rectifier and chilling system

Retrofit Time Line
• Anticipated 854 Plan approval date Dec 2016 – Jan 2017
• After 854 Plan is approved by CCAD Safety Department, site work will begin
• Estimate 16 – 24 weeks to complete D-Line Retrofit
• Anticipated startup date for Tagnite anodization is June/July 2017
• Dem/Val completion by FY17 pending the Production Airworthiness Approval
Tagnite™ Line Startup and Training

During CCAD Tagnite Line Startup, 1 – 2 Tagnite personnel will be on-site for trouble shooting and training.

Startup and Training Sequence:

1. Fill all tanks with water - test heating, chilling and circulation equipment along with individual tank integrity.
2. Charge etch, fluoride activator, Tagnite and DHP post-treatment tanks with chemical
   • Train operators on chemical handling and bath makeup procedures
   • Train lab personnel on Tagnite process analysis procedures
3. Test performance of Tagnite rectifier and chilling system using large sheets of AZ31A magnesium to provide the rectifier/chiller load
   • Train operators on Tagnite processing and rectifier operation
   • Train lab personnel on Taber Wear Abrasion equipment and procedures
4. Tagnite processing of scrap parts to
   • Training operators on masking, racking/fuxturing and Brush Tagnite processing
5. Transition to production parts
Demonstration Part: H60 Center Housing

Alloy: ZE41A

Surface Area: 4.0 ft²

Able to process 4 - 5 parts per a run

<table>
<thead>
<tr>
<th>Tagnite Processing Times</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UV Masking Time</td>
<td>10 minutes</td>
<td>0.15 man-hr</td>
</tr>
<tr>
<td>Masking Time</td>
<td>20 minutes</td>
<td>0.3 man-hr</td>
</tr>
<tr>
<td>Unmasking Time</td>
<td>10 minutes</td>
<td>0.15 man-hr</td>
</tr>
<tr>
<td>Brush Tagnite Time</td>
<td>15 minutes</td>
<td>0.25 man-hr</td>
</tr>
<tr>
<td>Immersion Tagnite Time (Minimum)</td>
<td>95 minutes</td>
<td>1.6 man-hr</td>
</tr>
<tr>
<td>Immersion Tagnite Time (Maximum)</td>
<td>230 minutes</td>
<td>3.8 man-hr</td>
</tr>
</tbody>
</table>
Demonstration Part: H60 Output Housing

Alloy: ZE41A

Surface Area: 8.7 ft$^2$

Able to process 2 parts per run

<table>
<thead>
<tr>
<th>Tagnite Processing Times</th>
<th>Time</th>
<th>Man-Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Masking Time</td>
<td>20 minutes</td>
<td>0.3 man-hr</td>
</tr>
<tr>
<td>Unmasking Time</td>
<td>10 minutes</td>
<td>0.15 man-hr</td>
</tr>
<tr>
<td>Brush Tagnite Time</td>
<td>10 minutes</td>
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<td>230 minutes</td>
<td>3.8 man-hr</td>
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</table>
Lessons Learned

1. Demonstration helicopter parts to be coated at CCAD Tagnite Line:
   a. Too much of budget (execution focus) went to developing masking for
      wish list of candidate parts.
   b. Final decision on candidate parts needed to be made earlier in the
      process.

2. Engineering review of CCAD D-Line should have been scheduled earlier
   in the process
   a. Cost and time requirements to retrofit CCAD D-Line were little greater
      than the anticipated
   b. Plan ahead to get estimate quotes etc.

3. The approval process at CCAD was not fully explained until retrofit
   proposal was submitted
   a. Submittal requirements need to be available earlier in the demonstration
      proposal process (lack of experiences for both government other than
      CCAD and TAG))
   b. Grossly underestimated time needed for project approval at CCAD
Acknowledgements

• Funding provided by the ESTCP WP-201319
• Research was sponsored by the Army Research Laboratory and was accomplished under Cooperative Agreement Number W911NF-13-2-0019. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the Army Research Laboratory or the U.S. Government
• Collaborations by AMRDEC MED for providing the numerous SAFR parts
• Collaborations by Hill AF and providing a SAFR part
• Collaboration without the funding by Bob Olson group at the Industrial Operations Division, AMRDEC
• Collaborations without the funding by AMCOM G4, Environmental Division
• Collaborations in the Technical Working Group by PM Apache, PM Cargo, PM Utility
• Planned funding of post Tagnite™ hard paint MIL specification by DLA
• Planned full scale Tagnite™ implementation at CCAD by AMCOM G4 thru TMR
• Technology Applications Group cost share
Backups
Introduction

Technology
• Cleaning and masking technology that allows legacy magnesium aerospace parts containing dissimilar metals to be anodize coated with a chrome-free solution which results in same corrosion protection seen with new replacement parts.

Demonstration Site/Platform:
Demo at CCAD Plating Shop – Line D

Demonstration Objectives
• Replace Cr6+ with Tagnite anodize without damaging inserts, liners and fasteners. Success based on compatibility with repair techniques, improved corrosion resistance and lack of damage to dissimilar metal inserts.

Performance Results
• Prove Tagnite compatibility with current/future repair techniques
• Qualify Brush Tagnite for use on Aerospace Alloys – AZ91C, EV31, QE22, ZE41
• and install/demo/validate Tagnite coating line at CCAD.

Project Progress
• Tagnite Repair Compatibility Study Complete – under review by AED
• Brush Tagnite Qualification Study Complete – under review by AED
• Demonstration Plan has been approved by project working group
• Masking for Demonstration Parts has been completed
• Quote to retrofit CCAD D-Line finished, undergoing CCAD review

Implementations
• Target Weapons Systems: AH-64, UH-60, CH-47, T-38

Performers: ARL, AFRL, CCAD, NAVAIR, AMCOM G-4, AMRDEC AEF, AMRDEC MED, Technology Applications Group (TAG)

Observers: AMCOM G4, PM Apache, PM Utility, PM Cargo
Masking + Tagnite

Advantages:
• Superior Corrosion Protection; increased service life
• Compatible with existing repair techniques including Cold Spray
• Chromate free; health and environment begin
• Minimal disposal requirements; EPA Reg. friendly

Disadvantages:
• Increased production time >50% and labor costs due to extensive masking and Brush Tagnite
• More training to master masking and Tagnite application processes
• Potential for higher utility costs due to rectifier and chilling system (electric demand)
Joint Test Protocol (JTP)

Task 1: Compatibility of Immersion and Brush Tagnite with Current Repair Techniques

Magnesium Alloy to be Tested: ZE41A

Magnesium Coatings to be Tested
- Immersion Tagnite
- DOW 19
- Brush Tagnite
- TCP

Current Repair Techniques
- DEVCON Liquid Aluminum F2
- DEVCON Titanium Paste
- TIG Weld Repair using ZE41 welding rod
- HVOF using Al$_{12}$Si
- Aluminum Cold Spray using 6061 Al

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Acceptance Criteria</th>
<th>Results</th>
</tr>
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<tbody>
<tr>
<td>MIL-PRF-23377 Non-Chromate Primer Pull-off Adhesion</td>
<td>ASTM D 4541</td>
<td>Performance equal to or better than currently used process (DOW 19)</td>
<td>Met Acceptance Criteria</td>
</tr>
<tr>
<td>Galvanic Corrosion</td>
<td>ASTM G 71</td>
<td>Performance equal to or better than currently used process (DOW 19)</td>
<td>Met Acceptance Criteria</td>
</tr>
<tr>
<td>Visual Inspection</td>
<td>TAG Observation</td>
<td>No evidence of lifting, softening, adverse coating deposition</td>
<td>Limitations with DEVCON TI Paste</td>
</tr>
</tbody>
</table>
JTP Task 1 (cont)

Repair Compatibility Observations after Tagnite Application
1. DEVCON Liquid Aluminum F2 – No lifting or separation after Tagnite
2. DEVCON Titanium Paste – Prolonged exposure in Tagnite Fluoride Pretreatment led to softening and lifting of Ti repair
3. TIG Welding – No lifting or separation after Tagnite
4. HVOF - No lifting or separation after Tagnite
5. Al Cold Spray - No lifting or separation after Tagnite

Below: Closeup of ZE41 panels with Ti Devcon repair after 3 hour soak in fluoride activator followed by Immersion Tagnite

Solution: **Strict time limit** (30 – 40 mins) in Fluoride Activator bath solved lifting issue
Joint Test Protocol (JTP)

**Task 2:** Validation and Approval of the Use of Brush Tagnite Touchup on Additional Magnesium Alloys

**Magnesium Alloys to be Tested:**
- AZ91E
- EV31A
- QE22A
- ZE41A

**Magnesium Coatings to be Tested**
- Immersion Tagnite
- Brush Tagnite
- DOW 19
- TCP

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<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial Fatigue Strength</td>
<td>ASTM E 466</td>
<td>Fatigue Strength Deficit not to exceed requirements set by AMRDEC AED</td>
<td>Testing complete, Waiting for AED review</td>
</tr>
<tr>
<td>Primer Pull-off Adhesion</td>
<td>ASTM D 4541</td>
<td>Performance equal to or better than currently used process (DOW 19)</td>
<td>Brush Tagnite Met the Acceptance Criteria</td>
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<tr>
<td>Neutral Salt Fog</td>
<td>ASTM B117/D1654</td>
<td>Performance equal to or better than DOW 19</td>
<td>Brush Tagnite Met the Acceptance Criteria</td>
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<tr>
<td>Acidified (SO2) Salt Fog</td>
<td>ASTM G 85, Annex A4/D1654</td>
<td>Performance equal to or better than DOW 19</td>
<td>Brush Tagnite Met the Acceptance Criteria</td>
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<tr>
<td>Outdoor Exposure</td>
<td>SOW to NASA</td>
<td>Performance equal to or better than DOW 19</td>
<td>Brush Tagnite Met the Acceptance Criteria</td>
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<tr>
<td>Galvanic Corrosion</td>
<td>ASTM G 71</td>
<td>Performance equal to or better than DOW 19</td>
<td>Brush Tagnite Met the Acceptance Criteria</td>
</tr>
</tbody>
</table>
Brush Tagnite™ Qualification

Brush Tagnite with MIL-PRF-23377:

- Left: 1 panel removed after 46 hrs
- Middle: 1 panel removed after 69.5 hrs
- Right: 3 panels removed after 71.5 hrs

All 5 panels exposed for 123 hrs

DOW 19 with MIL-PRF-23377:

- Left: 2 panels removed at 101.5 hrs
- Right: 3 panels after 123 hrs exposure

TCP with MIL-PRF-23377:

- Left: 1 panel removed after 46 hrs
- Middle: 1 panel removed after 69.5 hrs
- Right: 3 panels removed after 71.5 hrs

ZE41 after 123 hrs @Salt Fog
Brush Tagnite Qualification: Outdoor Exposure

Beach Front Outdoor Exposure after 3 months:
- QE22 Magnesium Coupons
- Painted with MIL-PRF-23377 Primer

Above: Brush Tagnite pretreatment with no evidence of corrosion

Above: DOW 19 pretreatment with some evidence of corrosion

Left: TCP pretreatment with some evidence of corrosion

**Conclusion:** Brush Tagnite is performing much better than currently used conversion coatings!