Combating Corrosion in Magnesium Using New Generation Alloys and Modern Coatings such as Tagnite
Common Magnesium Concerns

- Surface Corrosion
- Galvanic Corrosion
- Low Abrasion Resistance
- Paint Adhesion
Finishing Options

Typical for Magnesium

Conversion Coatings
- Dow 7, created in the 1940’s
- Dow 9, created in the 1940’s
- Chrome Manganese, created in the 1940’s

Anodize Coatings
- Dow 17, created 1942
- HAE, created 1955
- Tagnite®, created 1992
HAE

HAE, named after inventor Harry A. Evangelides, was patented in 1952. The very high alkaline solution has a pH of approximately 14 and should be operated between 70 and 86°F Fahrenheit.

<table>
<thead>
<tr>
<th>CHEMICAL</th>
<th>Concentration (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroxide <em>(extremely caustic)</em></td>
<td>120</td>
</tr>
<tr>
<td>Fluoride</td>
<td>35</td>
</tr>
<tr>
<td>Potassium Permanganate <em>(strong oxidizer)</em></td>
<td>20</td>
</tr>
<tr>
<td>Aluminum Hydroxide</td>
<td>34</td>
</tr>
<tr>
<td>Sodium Phosphate</td>
<td>35</td>
</tr>
</tbody>
</table>
Dow 17

The Dow Chemical Company invented Dow 17 in the mid-1940’s. The electrolyte has a pH of approximately 5 and should be operated at or above 160°F Fahrenheit.

<table>
<thead>
<tr>
<th>CHEMICAL</th>
<th>Concentration g/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium BiFluroide</td>
<td>360</td>
</tr>
<tr>
<td>Sodium Dichromate (hazardous chemical)</td>
<td>100</td>
</tr>
<tr>
<td>Phosphoric Acid</td>
<td>97</td>
</tr>
</tbody>
</table>
Developed in the 1990’s with the Clean Air & Clean Water Act in mind, Tagnite® was designed as a replacement coating for Dow 17 and HAE. The electrolyte’s pH range is 12.8-13.2 and operates below room temperature (40-60°F).

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Concentration (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroxide</td>
<td>4 - 8</td>
</tr>
<tr>
<td>Fluoride</td>
<td>5 - 10</td>
</tr>
<tr>
<td>Silicate</td>
<td>15 - 25</td>
</tr>
</tbody>
</table>

No Chromates or Heavy Metals.
Chemical Composition as a Percentage of Water

- **TAGNITE®**: 5% * chemical concentration
- **HAE**: 25% * chemical concentration
- **Dow 17**: 56% * chemical concentration

*Approximations

HAE contains heavy metals; Dow 17 contains heavy metals and chromium
Coating Morphology

All photos shown at 500x magnification.
Corrosion Testing
Superior Corrosion Resistance

TAGNITE®, HAE & Dow 17 (Type I) on magnesium alloy ZE41 after 168 hours in salt spray

Only Tagnite Provides Inherent Corrosion Resistance
Superior Galvanic Corrosion Resistance

AZ91E sand cast magnesium test plates assembled using cadmium plated steel bolt/washer & placed in salt spray (ASTM B117) for 1000 hours.

TAGNITE® 8200  HAE  DOW 17
Galvanic Corrosion - HAE

Cadmium-Plated Steel Bolt

Cadmium-Plated Steel Washer

AZ91E Test Panel Coated with HAE
Galvanic Corrosion – Dow 17

Cadmium-Plated Steel Bolt

Cadmium-Plated Steel Washer

AZ91E Test Panel Coated with TAGNITE®
Galvanic Corrosion – Tagnite

- Cadmium-Plated Steel Bolt
- Cadmium-Plated Steel Washer
- AZ91E Test Panel Coated with Tagnite
Environmentally Clean

Tagnite has been carefully studied and reviewed and by the EPA’s Design for the Environment Program and has been granted the status of Partner Formulator

Tagnite Contains

- No Chromium(VI)
- No Heavy Metals
- No Sulfuric Acid
- No Nitric Acid
- No Hydrofluoric Acid
Tagnite Process Overview

Degreaser → Rinse → Alkaline Etch → Rinse → Fluoride Pretreatment → Rinse → Final Rinse → Dry → Surface Neutralization Post Treatment → Rinse → Tagnite 8200

Approximately 120 Minutes From Entering Degrease Station to Entering Drying Station
View of Magnesium Intermediate Case For a Jet Engine – Approximately 75 Square Feet of Surface Area
Magnesium Transmission Housing

Magnesium Oil Pan

Magnesium Gearbox

Magnesium Jet Engine Gearbox
• Last B-52 was built in 1962
• Air Force wants to keep them going until 2040
• The B-52 utilizes many magnesium components including several in the pilot yoke/Steering column
• These 48 year old castings still look good, and show few signs of corrosion
• By today’s standards, the magnesium alloys used on the B-52 corrode at a very high rate
• Tagnite is on average 10 times more corrosion resistant than what was first used to protect these 48 year old castings
Tagnite is regularly applied to used magnesium castings on the B-52.
48 Year Old+ Magnesium Castings

Corrosion Has Not Taken Them Out of Service
48 Year Old+ Magnesium Castings
48 Year Old+ Magnesium Castings

Corrosion Has Not Taken Them Out of Service
• Last KC-135 Was built in 1965
• Air Force wants to keep them going until 2040
• The KC-135 utilizes many magnesium components including several in flap drive system
• These 45+ year old castings look good, and while some are scraped due to corrosion, many are cleaned and put back into service
• By today’s standards, the magnesium alloys used on the KC-135 corrode at high rate
• Tagnite is on average 10 times more corrosion resistant than what was first used to protect these 45+ year old castings
Magnesium Housings Used For Flap Drive Gearboxes
Do these look like 49 year old magnesium castings?

Old magnesium castings cleaned and then Tagnite anodized.
45 Year Old+ Magnesium Castings Corrosion Has Not Taken Them Out of Service
45 Year Old+
Magnesium Castings Ready to Return to Service
Neptune Aviation has a fleet of P-2V's which they use as Fire Bombers. The aircraft's magnesium wheels are scheduled to be replaced in 2011.
There is a Long History of Successful Use of Magnesium in Aviation

• Properly protected, magnesium can provide years of trouble free service

• Today’s magnesium alloys have a much lower corrosion rate than many of magnesium components that are presently in service

• Today’s coatings prevent magnesium corrosion far better than what has historically been used

The Bottom Line: You Can Use Strong, Lightweight Magnesium With Confidence