Magnesium-Rich Coatings

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### Title and Subtitle

**Magnesium-Rich Coatings**

### Performing Organization Name(s) and Address(es)

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### Abstract

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### Name of Responsible Person

unclassified
Introduction

• Hexavalent chromium compounds (chromates)
  – “Gold” standard in corrosion prevention
    • Regulatory, environmental and health issues

• Hexavalent chromium elimination efforts
  – Can simplify paint/depaint, decrease the cost
  – Have led to increased corrosion failures

• Much work has been done on chromate-free protection systems
  – No non-chromated primer equivalent performance
Introduction

[Diagram showing layers: Aluminum Substrate, Conversion Coating Layer, Mg-Rich Primer Layer, Topcoat Layer, with various materials indicated: Graphite, Platinum, Gold, Titanium, 300 Stainless Steel, Silver, Lead, 400 Stainless Steel, Manganese Bronze, Admiralty Brass, Lead-Tin Solder, Copper, Brass, Aluminum Bronze, Steel, Cast Irons, Cadmium, Aluminum Alloys, Zinc, and Magnesium]
Test Plan

• Substrates
  - AA2024-T3
  - AA7075-T6
  - AA2219-T87
  - AA2024 Al clad

• Conversion Coatings
  - MIL-DTL-81706 Type I
  - MIL-DTL-81706 Type II
  - None (Scotchbrite™ abraded)

• Primers
  - Mg-Rich (Multiple Formulations)
  - MIL-PRF-23377 Class C2
  - MIL-PRF-23377 Class N
  - MIL-PRF-85582 Class N

• Tests
  - Beach-Front Exposure
  - Salt Fog Exposure
  - Filiform Corrosion
Beach-Front Testing

Kennedy Space Center
Beach Corrosion Test Site
100 feet from mean high-tide
Panels racked 30º from horizontal
Accelerated Testing

ASTM Standard Test Methods
B 117: Neutral Salt Fog
G 85, Annex 4: SO$_2$ Salt Fog
Accelerated Testing
First Generation Test Results

AA2024-T3 (4000 hours B117) – MgRich Primer-only

MIL-DTL-81706 Type I – Alodine 1200S

No Chemical Pretreatment Scotchbrite Abrade

MIL-DTL-81706 Type II – Alodine T5900
First Generation Test Results

AA2219-T87 (4000 hours B117) – MgRich Primer-only

MIL-DTL-81706 Type I – Alodine 1200S

MIL-DTL-81706 Type II – Alodine T5900

No Chemical Pretreatment
Scotchbrite Abrade
First Generation Test Results

AA2024-T3 (1200 hours G85 A4) – MgRich Primer-only

MIL-DTL-81706 Type I – Alodine 1200S

No Chemical Pretreatment Scotchbrite Abrade

MIL-DTL-81706 Type II – Alodine T5900
Second Generation Test Results

AA2024-T3 (1200 hours G85 A4) – MgRich Primer-only
Second Generation Test Results

Primer-only panels (5000 hours B117)

<table>
<thead>
<tr>
<th>Mg-Rich Primer</th>
<th>MIL-PRF-23377, Class C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA2024-T3</td>
<td>AA2024-T3</td>
</tr>
<tr>
<td>AA7075-T6</td>
<td>AA7075-T6</td>
</tr>
</tbody>
</table>
Second Generation Test Results

MIL-PRF-85285 topcoated Mg-Rich panels (ASTM B117)

AA2024-T3  AA7075-T6

1 Week
(170 hours)
Second Generation Test Results

MIL-PRF-85285 topcoated Mg-Rich panels (ASTM B117)

AA2024-T3                AA7075-T6

12 Weeks
(2000 hours)
Second Generation Test Results

MIL-PRF-85285 topcoated Mg-Rich panels (ASTM B117)

AA2024-T3  AA7075-T6

30 Weeks
(5000 hours)
Second Generation Test Results

MIL-PRF-85285 topcoated Mg-Rich panels (ASTM B117)

AA2024-T3  AA7075-T6
Second Generation Test Results

AA7075-T6 (336 hours G85 A4) – MgRich Primer-only

MIL-DTL-81706 Type II

Mg-Rich Primer  
MIL-PRF-23377 Class N  
MIL-PRF-85582 Class N  
MIL-PRF-23377 Class C2
Second Generation Test Results

AA7075-T6 (1500 hours G85 A4) – MgRich Primer-only

MIL-DTL-81706 Type II
Second Generation Test Results

Mg-Rich Primer

Non-Chromium Primer (Deft 084)

MIL-PRF-85582 Class N
Non-Chromium Primer

MIL-PRF-23377 Class C2
Hexavalent Chromium Primer
Second Generation Test Results

MIL-PRF-85285, (1500 hours G85 A4)

MIL-DTL-81706 Type II

Mg-Rich Primer

MIL-PRF-23377 Class N

MIL-PRF-85582 Class N

MIL-PRF-23377 Class C2
Second Generation Test Results

AA2024-T3 Galvanic panels – Primer-only – 4 month KSC Beach

Aluminum test panels with titanium, stainless steel and aluminum bolts.

Mg-Rich Primer

Class N Control
Second Generation Test Results

Filiform corrosion test (1000 hours) – MIL-DTL-81706 Type II

Mg-Rich Primer

MIL-PRF-85285 Topcoat  
MIL-DTL-53039 Topcoat

MIL-PRF-23377 Class C2

MIL-PRF-85285 Topcoat  
MIL-DTL-53039 Topcoat
Third Generation Test Results

AA2024-T3 (2000 hours B117) – MgRich Primer-only
Third Generation Test Results

AA2024-T3 (2000 hours B117) – MgRich/MIL-PRF-85285
Modifications to Second Generation Mg-Rich

AA7075-T6 (1000 hours G85 A4) – MgRich Primer-only

NAVAIR Non-chromium pretreatment
Modifications to Third Generation

AA7075-T6 (1000 hours G85 A4) – MgRich Primer-only

MIL-DTL-81706 Type II
Summary & Conclusions

• No single, universal test for corrosion prevention
  – Multiple alloys, test methods and configurations

• Promising performance – MgRich does well
  – Primer only in neutral salt fog (5000 hours)
  – Topcoated in SO$_2$ salt fog (1500 hours)
  – Filiform corrosion tests (1000 hours)

• Challenges – MgRich issues not seen with Class N controls
  – Topcoated in neutral salt fog
  – Primer only in SO$_2$ salt fog
  – Downglossing of High-gloss topcoats
  – Performance degradation on non-2000 series alloys
  – Poor corrosion performance on steel
  – Validation over anodize, Cd, ZnNi, IVD-Al, phosphate, etc.
Summary & Conclusions

• Under certain conditions
  – Mg-Rich primer performs comparably to chromate primers
  – Overall it is not equivalent to chromated OR non-chromated control primers

• Modifications have increased performance over various substrates
  – Fewer ruptures through the coating and blisters
    • Compared to the baseline early generation MgRich primers
  – Fewer blisters and corrosion products in the scribe
Path Forward

• Testing the fourth generation is underway
  – Commercial MgRich product
  – NAVAIR modified MgRich
  – Test Plan
    • Variety of substrates
    • Variety of exposure conditions
      – Beach, ASTM B117, ASTM G85 Annex 4, filliform, galvanic test panels
  – Go/No-Go Criteria
    • Must be better than the best non-chromate coating system
      – Currently available and transitioned
      – Before implementation will be authorized for Navy and Marine Corps assets
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