Environmentally Friendly Coating Systems for Department of Defense Applications

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# Environmentally Friendly Coating Systems for Department of Defense Applications

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- Same as Report (SAR)
Evaluation of New Technologies

Commercial Coatings and Pretreatments

Department of Defense Needs
Programs

E-Coat for Munitions
Modernization

Environmentally Friendly
Zirconium Oxide
Pretreatment

http://www.theodoregray.com/PeriodicTable/
“Electrocoat for Munitions Modernization”

Coatings for munitions modernization
- Project originally targeted acrylic electrocoat development
- Expanded to powder coatings and other environmentally friendly treatments for munitions applications
Coatings for Munitions Modernization

• Current commercial munitions coatings
  – Alkyd Enamels (Mil-E-52891, Mil-DTL-11195)
  – Applied by spray or dip process
  – Salt-spray resistance requirement, 150 hrs
  – Possible aesthetic drawbacks (runs, drips, sags, etc.)

• Coatings for munitions modernization
  – Acrylic electrocoat and polyurethane powder
  – Higher work efficiency/simplified process
  – Durability > 750 WOM
  – Salt-spray resistance > 400 hrs
  – High transfer efficiency (approach 95-100%)
  – Low or no VOC
  – Widely used industrially
Coatings for Munitions Modernization (Systems Approach)

- Development of complementary coating systems for munitions applications
  - Opportunity to evaluate E-Coat and powder on munitions substrates
  - Systems approach for asset protection and enhancement
  - Aluminum, magnesium, and titanium
  - Stainless steel and high-strength steel (armor applications)
Systems Approach (Commercial Pretreatments with Powder Coating)

- Cold-rolled steel
- 2 mil Polyurethane powder coating
- Pretreated samples had < 1/4” scribe creep after 20 cycles GM9540P

![Bar chart showing scribe creep comparison among Clean Only, Commercial ZrOx pretreatment, and Zn Phosphate.

- Clean Only: Bar reaches up to 14 mm
- Commercial ZrOx pretreatment: Bar reaches up to 2 mm
- Zn Phosphate: Bar reaches up to 1 mm

![Images of scribe creeps for Clean Only, Commercial ZrOx pretreatment, and Zn Phosphate samples.]}
Systems Approach (Commercial Pretreatments with Powder Coating)

400 hr Salt Spray

- Cold-rolled steel
- 2 mil Polyurethane powder coating
- Pretreated samples had < 1/4” scribe creep after 400 Salt-Spray

scribe creep, mm

6.36 mm = ¼ in.

<table>
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<tr>
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<th>scribe creep, mm</th>
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<tbody>
<tr>
<td>clean only</td>
<td>6.00</td>
</tr>
<tr>
<td>ZrOx</td>
<td>2.00</td>
</tr>
<tr>
<td>Zn phosphate</td>
<td>6.36</td>
</tr>
</tbody>
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Images of samples showing different pretreatments and their effects on scribe creep.
Systems Approach (Commercial Pretreatments with Powder Coating)

1000 hr Salt Spray

- **Commercial ZrOx**
  - Average: 3.00 mm
  - Maximum: 5.00 mm

- **Zn Phosphate**
  - Average: 4.00 mm
  - Maximum: 6.00 mm

**Images**
- Zr-based pretreatment
- Zn phosphate

**Legend**
- Blue: Average
- Red: Maximum
• 2 mil film build specification for polyurethane powder coatings
• ZrOx outperforms commercial Zn Phosphate
• Scribe creep specification met at all film thicknesses for ZrOx
Systems Approach (Commercial Pretreatments with Powder Coating)

- 2 mil film build specification for polyurethane powder coatings
- Better adhesion at all coating thicknesses for the ZrOx pretreatment
Conclusions

- Polyurethane powder/commercial pretreatment coating systems perform well in the testing outlined in Mil-E-52891 and Mil-DTL-11195, with several added environmental benefits over alkyd systems.

- The powder/commercial zirconium pretreatment system provides performance superior to Zn phosphate, in adhesion and corrosion testing (ASTM B117 and GM9540P), at lower applied powder thickness.

Path forward

- Pretreatment systems for Ti, Mg, and Al alloys
- Study the electrocoat system with commercial ZrOx pretreatments
Environmentally Friendly Zirconium Oxide Pretreatment

SERDP WP-1676

ARL Personnel
John Escarsega
Fred Lafferman
Daniel Pope
Pauline Smith
Technical Background

Do We Need Pretreatment?

Electrocoated steel panels after GM 9540 cyclic corrosion testing

No pretreatment

Zinc phosphate pretreatment
Environmentally Friendly Zirconium Oxide Pretreatment

Environmental/Health Impact

- DoD Wash Primer systems
  - 7.1% zinc chromate
  - 6.5 lb/gal of VOCs
- Yearly est. usage of 21,000 gal
  - 12,600 lb of zinc chromate
  - 35,700 gal of package/thinner solvents
- Environmental concerns and EPA regulatory issues associated with solvent emissions
- Worker safety and OSHA compliance issues related to the presence of regulated metals
CARC Topcoat
Epoxy Primer
Substrate

Wash Primer/Pretreatment

- Chemical Agent Resistant Coating (CARC) specification, MIL-C-53072, requires metal surfaces be treated to improve coating adhesion and corrosion resistance

- Zinc phosphate pretreatment required for Original Equipment Manufacturers

- Hexavalent Chrome (Cr\(^{6+}\)) containing wash primer required for Depot and Repair operations
• Develop an environmentally friendly pretreatment system for multi-material DoD applications
  – Free of hexavalent chromium (Cr$^{6+}$)
  – No volatile hazardous air pollutants (HAPs)
  – Ease of application using existing infrastructure
  – Equal or better corrosion performance to current (Cr$^{6+}$) wash primers
  – Broad substrate/topcoat compatibility
  – Cost effective
Zirconium-Based Pretreatments

- **Commercial Zirconium-Based Pretreatment**
  - No regulated metals in pretreatment
  - Reduced energy cost for pretreatment application
  - Reduced water consumption for pretreatment application
  - Reduced pretreatment waste
  - No HAPS or VOC in pretreatment system

- **Do commercial zirconium-based immersion pretreatments meet DoD specifications?**
  - Confirm/determine that existing formulas meet DoD standards
  - Modify to meet DoD needs as necessary
  - Early experiments suggest Automotive OEM formula may not be directly applicable to DoD substrates/coating systems
**Task 1:** OEM Pretreatment Development

- Immersion-applied ZrOx
- Spray-applied ZrOx

**Task 2:** Depot Pretreatment Development

- Sanding
- Spray-Gun applied
- Wand applied
- Wipe-on

**Task 3:** Repair Pretreatment Development
Task 1: OEM Pretreatment Development

- Evaluate commercial immersion formulae with DoD substrates and coatings - reformulate as needed (Mil-Spec testing at ARL).

- Investigate and optimize lab prototype formula with a range of spray application conditions (Mil-Spec testing at ARL).
Task 2: Depot Pretreatment Development

- Visit DoD depot facilities to benchmark application process/conditions
- Determine compatibility of OEM spray formula with depot equipment.
- Characterization and limited Mil-Spec testing
- Formula optimization
- Comprehensive Mil-Spec testing
Environmentally Friendly Zirconium Oxide Pretreatment

Task 3: Repair Pretreatment Development

- Sanding
- Spray-Gun applied
- Wand applied
- Wipe-on

- Surface characterization.
- Evaluate optimized ZrOx spray formulation
- Limited Mil-Spec testing
- Reformulate
- Characterize
- Comprehensive Mil-Spec testing
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Questions?

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Zirconium-Based Pretreatment

Steel Substrate

Me → Me^{2+} + 2e^-

Micro anode

2e^- + 2H_2O → 2 OH^- + H_2

Micro cathode

Coating thickness: 20-200 nm.