Laboratory Validation and Demonstrations of Non-Hexavalent Chromium Conversion Coatings for Steel Substrates

NEW ORLEANS
February 8-10, 2011

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<table>
<thead>
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<th>1. REPORT DATE</th>
<th>2. REPORT TYPE</th>
<th>3. DATES COVERED</th>
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<td>00-00-2011 to 00-00-2011</td>
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13. SUPPLEMENTARY NOTES
ASETSDefense 2011: Sustainable Surface Engineering for Aerospace and Defense Workshop, February 7 - 10, 2011, New Orleans, LA. Sponsored by SERDP/ESTCP.
Outline

✓ ESTCP WP 200906

✓ Background

✓ Laboratory Validation
  • Test Methodology
  • Results

✓ Ongoing and Scheduled Demonstrations
  • Stryker
  • MRAP

✓ Summary
Total of 3 Technology Areas Being Demonstrated

1) Demonstration of Conversion Coatings for Armor Steel
   - Stryker (ANAD) - Jim Swann/Patty Dodson
   - MRAP (Camp Lejeune) - Daniel Cooper CWO5 (ret)

2) Demonstration of Phosphate Sealers
   - Anniston Army Depot – Patty Dodson

3) Demonstration of Non-chromate primer and ZVOC Topcoat
   - Cherry Point – Jacob Waller
Background

AR 750-12, requires all Army ground equipment coated with full (CARC) system.

- The CARC system is defined in MIL-DTL-53072B:
  a) A conversion coating or pretreatment in direct contact with a properly prepared substrate
  b) Followed by an epoxy primer
  c) Lastly, a polyurethane based topcoat MIL-DTL-53039 or MIL-DTL-64159.

- Coating exception/variation was granted to Stryker manufacturers and extended to MRAP giving permission to omit the pretreatment/conversion coating step.

Examples of Direct-to-Metal Processes

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Background

Pretreatment /conversion coatings omitted:
- Hex-chrome pretreatments prohibited for new ground vehicles
- Hydrogen embrittlement concerns
- Viable alternatives have not been fully field tested

No pretreatment makes process robustness diligence dependent:
- Type and condition of the blast media
- SP 10? 6? 7? degrades to? before applying inhibitor and painting
- The true dry film thickness (DFT)?

Poor coating practices leads to premature failures

Pretreatments will make process more robust
Steel Conversion Coatings

Candidate Conversion Coatings for HHA

- SurTec 650 - ChromitAL TCP
  - Trivalent Chrome Pretreatment Developed by NAVAIR for Aluminum.
- Chemetall Oxsilan 9810/2
  - Non-chrome Organo-silane
- PPG Zircobond 4200
  - Non-chrome Zirconium-based steel conversion coating

Baseline Steel Pretreatments:

- PPG Cheminhib 420
  - Flash rust inhibitor used on Stryker
- DOD-P-15328
  - Chromate Wash primer

Control Samples:

- Untreated abrasive blasted surfaces
Substrates: All pretreatments applied by manufacturer
  • High Hard Armor MIL-A-46100
  • Charpy’s
  • Low Carbon Steel A366

Corrosion Tests:
  • Neutral Salt Fog – B117
  • Cyclic Corrosion – GM9540P
  • Flash Rust – Modified ASTM D 1735
  • Humidity – ASTM D 2247-87
  • Outdoor Exposure (Cape Canaveral)

Adhesion Test:
  • Pull-Off Adhesion – ASTM D 4541
  • Wet Adhesion – ASTM D 3359 Method A

Stress Corrosion Cracking:
  • Rising Step Load – ASTM F 1624-95

Chip Resistance:
  • Gravelometer – SAE-J400
Humidity Test Results on Bare Abrasive Blasted HHA

- Modified version of ASTM D 1735
  - 90% RH at 100 Degrees F
- Used 3M pressure sensitive tape to capture flash rust

Results:
- No flash rust observed on either Oxsilan or SurTec 650
- Not clear if material pulled off Zircobond is corrosion or product residue
- Similar results through 96 hours of exposure
Laboratory Validation Results

ASTM-B117 results for pretreated steel panels and 53022/53039 CARC system

B117 test results indicate TCP, Oxsilan and Zircobond all perform well on abrasive blasted HHA
Laboratory Validation Results

Abrasive Blasted
HHA @ 750 hours of B117 with MIL-DTL-53022 / MIL-DTL-53039

<table>
<thead>
<tr>
<th>Pretreatment</th>
<th>AVG Ratings</th>
</tr>
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<tbody>
<tr>
<td>Abrasive Blast</td>
<td>5</td>
</tr>
<tr>
<td>PPG 420</td>
<td>4.2</td>
</tr>
<tr>
<td>MIL-P-15328</td>
<td>4.8</td>
</tr>
<tr>
<td>SurTec 650</td>
<td>6.6</td>
</tr>
<tr>
<td>Chemetall Oxsilan</td>
<td>6</td>
</tr>
<tr>
<td>PPG Zircobond 4200</td>
<td>6.2</td>
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</table>
## Laboratory Validation Results

### Cyclic Corrosion Test on HHA

<table>
<thead>
<tr>
<th>Panel</th>
<th>Pretreatment</th>
<th>GM 9540P Cycles</th>
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<tbody>
<tr>
<td></td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
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<tr>
<td>3</td>
<td>7</td>
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</table>

**Baselines**

- Abrasive Blast Only
- PPG Cheminhib 420
- DOD-P-15328
- Gardobond 24T + FH-3 (zinc phos/Cr6+)

**Candidates**

- SurTec 650 (TCP)
- Chemetall Oxsilan
- PPG Zircobond 4200

- **ASTM 1654 Ratings through 80 cycles of GM9540P**

- All candidate conversion coatings outperformed DOD-P-15328 Wash Primer
Laboratory Validation

ASTM D 4541 results for pretreated steel panels with 3 paint systems

- Pull off values considered artificially low on CARC Beaded versions.
  - Suspected glue/bead interaction
- Wash primer low point baseline (1200 psi)

**ASTM D 4541 Pull-Off Adhesion for LCS**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Adhesion Strength (PSI)</th>
</tr>
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<tbody>
<tr>
<td>Abrasive Blast</td>
<td>3500</td>
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<tr>
<td>PPG Cheminhb #20</td>
<td>3000</td>
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<tr>
<td>DOD-P-15528 WP</td>
<td>2500</td>
</tr>
<tr>
<td>Zinc Phos/Cr6+</td>
<td>2000</td>
</tr>
<tr>
<td>Surtec 650 (TCP)</td>
<td>1500</td>
</tr>
<tr>
<td>Chemetal Oxidan</td>
<td>1000</td>
</tr>
<tr>
<td>PPG Zircobond 4200</td>
<td>500</td>
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</table>

**ASTM D 4541 Pull-Off Adhesion for HHA**

<table>
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<tr>
<th>Treatment</th>
<th>Adhesion Strength (PSI)</th>
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<tr>
<td>Abrasive Blast</td>
<td>3500</td>
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<tr>
<td>PPG Cheminhb #20</td>
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<td>1000</td>
</tr>
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<td>PPG Zircobond 4200</td>
<td>500</td>
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</tbody>
</table>
**Laboratory Validation**

Wet tape adhesion results for pretreated steel panels

- Only DOD-P-15328 with MIL-DTL-64159 had a complete failure on HHA.
- All alternatives provided good wet tape adhesion on HHA.

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**Low Carbon Steel 96 hours ASTM D 3359A WTA**

- Abrasive Blast
- PPG A2O
- DOD-P-15328
- Zn/Phos/Cr6+
- SuTec 650
- Ovallan
- Zircobond

- Graph showing adhesion results with different treatments.

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**High Hard Armor 96 hours ASTM D 3359A WTA**

- Abrasive Blast
- PPG A2O
- DOD-P-15328
- Zn/Phos/Cr6+
- SuTec 650
- Ovallan
- Zircobond

- Graph showing adhesion results with different treatments.

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**PPG ChemInhib 420, LCS 96 hrs WTA (0)**

- Image of wet tape adhesion test results.

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**DOD-P-15328 WP, HHA 96 hrs WTA (0)**

- Image of wet tape adhesion test results.
### Laboratory Validation Results

#### Chip Resistance SAE-400J Gravelometer

<table>
<thead>
<tr>
<th>Abrasive Blasted HHA</th>
<th>53022/53039</th>
<th>53022/64159</th>
<th>23377/85285 ZVOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasive Blasted HHA</td>
<td>6 A/B</td>
<td>5 B/A</td>
<td>5 B</td>
</tr>
<tr>
<td>PPG Chem Inhib 420 HHA</td>
<td>5 B</td>
<td>5 B</td>
<td>5 B</td>
</tr>
<tr>
<td>DOD-P-15328 HHA</td>
<td>4 B/A</td>
<td>4 B</td>
<td>5 B</td>
</tr>
<tr>
<td>Gardobond 24T+FH-3 HHA</td>
<td>5 B/A</td>
<td>5 B/A</td>
<td>5 B/A</td>
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<tr>
<td>Gardobond 24S + CS100 + FH-3 HHA</td>
<td>4 A</td>
<td>4 B/A</td>
<td>4 B/A</td>
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<tr>
<td>Surtec 650 HHA</td>
<td>5 A</td>
<td>4 B/A</td>
<td>5 B/A</td>
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<tr>
<td>Chemetall Oxsilan HHA</td>
<td>5 B</td>
<td>5 B</td>
<td>5 B</td>
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<tr>
<td>PPG ZircoBond 4200 HHA</td>
<td>5 B/A</td>
<td>5 B</td>
<td>5 B/A</td>
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</table>

<table>
<thead>
<tr>
<th>Milled Finish Low Carbon Steel</th>
<th>53022/53039</th>
<th>53022/64159</th>
<th>23377/85285 ZVOC</th>
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<tbody>
<tr>
<td>Abrasive Blasted LCS</td>
<td>4 B</td>
<td>4 B</td>
<td>5 B</td>
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<tr>
<td>PPG Chem Inhib 420 LCS</td>
<td>5 C</td>
<td>4 C</td>
<td>5 B</td>
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<tr>
<td>DOD-P-15328 LCS</td>
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<td>5 C</td>
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<tr>
<td>Gardobond 24T+FH-3 LCS</td>
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<td>4 B</td>
<td>4 B</td>
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<tr>
<td>Surtec 650 LCS</td>
<td>4 C/D</td>
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<td>5 C/D</td>
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<td>Chemetall Oxsilan LCS</td>
<td>5 B</td>
<td>4 B/A</td>
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<tr>
<td>PPG ZircoBond 4200 LCS</td>
<td>5 B</td>
<td>5 B</td>
<td>5 B</td>
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Alternative conversion coatings demonstrate better-than or equal-to chip resistance than baselines.

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Demonstrations

Demonstration of Steel Conversion Coatings on HHA

- **Stryker Vehicles:**
  - Stryker Demonstration Plan and JTP submitted Oct 18, 2010
  - Demonstration of steel conversion coatings on Stryker initiated at ANAD Sept 2010

- **MRAP Vehicles:**
  - Received signed Letter of Support from PMO MRAP
  - Demonstration Plan submitted on January 31, 2011
Stryker Demonstration

Demonstration: Steel Conversion Coatings

Stryker Components Used in Demonstrations
Stryker Demonstration

Demonstration: Steel Conversion Coatings

Masking spall liner prior to abrasive blasting of high hard hatches

Application of chemical pretreatments

<table>
<thead>
<tr>
<th>Component</th>
<th>Stryker Demonstration Vehicle Identification</th>
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<tbody>
<tr>
<td></td>
<td>MEV-76</td>
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<tr>
<td>Power Entry Panel (PEP) Hatch</td>
<td>SurTec 650 (TCP)</td>
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<tr>
<td>Front Access Hatch</td>
<td>PPG Zircobond 4200</td>
</tr>
<tr>
<td>Side Egress Hatch</td>
<td>Chemetall Oxsilan</td>
</tr>
</tbody>
</table>
Hatches shown immediately after pretreatment.

Only Zircobond had a noticeable color change, a pinkish hue that turned yellow at the edges.
Treated hatches after 19 hours ambient “shop” exposure. Weather conditions in Anniston Lo=51F Hi=81F @ 60-70% RH

SurTec 650 TCP

Oxsilan 9810/2

Zircobond 4200
• Received PMO Support (Nov 2010)
• Demonstration will be initiated at Camp Lejeune
• Meeting at Camp Lejeune (Jan 5, 2011)
  • Met with CWO5 Mark Schmidt
  • Obtained 2 complete MRAPs for Demonstration
  • Non-chrome conversion coating more desirable
• Demonstration Plan submitted to ESTCP on (Jan 31, 2011)
• Propose demonstration start date April 1, 2011
Summary

- Early indications are that all candidate conversion coatings will provide:
  - Better than baseline flash rust inhibition
  - Enhanced corrosion protection for HHA and LCS vs. DTM and wash primer DOD-P-15328
  - Improved adhesion of CARC vs. current DTM and wash primer
  - Equal or better chip resistance vs. baselines
- No additional step required vs. current processes used at OEM