Chemical Agent Resistant Coating (CARC)
How the US Marine Corps Paints their Tactical Equipment

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US MARINE CORPS CORROSION PREVENTION AND CONTROL (CPAC) PROGRAM
Corrosion Prevention and Control
Mandate/Governance

Title 10 USC, Section 2228 - Requires DoD to take a number of specific actions to prevent or mitigate corrosion on the Department's equipment and infrastructure:

- Designation of a Director of Corrosion Policy and Oversight
- Development and execution of a long-term strategy for corrosion prevention and mitigation
- Establishes guidance on policy
- Requires review of corrosion-related funding levels


DFARS (12 October 2004) – DFARS Part 207 was amended to incorporate the requirement to address corrosion and other maintainability issues within the acquisition plan. Specifically Part 207.105 (b),13), Logistics consideration, states "Performance based logistics that optimize total system availability while minimizing costs and logistics footprint should be considered. Trade-off decisions involving cost, useful service, and effectiveness shall consider corrosion prevention and mitigation"

DoD Directive 4151.18, Maintenance of Military Materiel - Establishes policies and assigns responsibilities for the performance of DoD materiel maintenance, including maintenance of weapon systems. Paragraph 3.3.7 states: "Corrosion prevention and control programs and preservation techniques shall be established throughout the system life cycle."

DoDI 5000.67 - Assigns responsibilities for the DoD Corrosion Executive and the Secretaries of the Military Departments. The Secretaries of the Military Departments shall oversee and coordinate efforts throughout their respective Military Departments to prevent and mitigate corrosion of military equipment and infrastructure.

MCO 4790.18B - Requires the implementation of the Marine Corps CPAC Program, and assigns management responsibility to MCSC on existing assets and new acquisitions.

MISSION. To establish an effective CPAC program to extend the useful life of all Marine Corps tactical ground and ground support equipment.

OBJECTIVE. Mitigate the impact of corrosion on USMC assets through a comprehensive CPAC program:

- **Existing Assets**: Identify, Correct, and Maintain

- **New Procurements**: Implement corrosion control throughout the acquisition as part of Systems Engineering: Corrosion Planning, Contract Wording, Design Analysis, and Performance Testing

- **Research and Development / Engineering**: Better products and processes to combat corrosion

The key to Operations and Sustainment of Existing Assets – Identify, Correct, Maintain

**IDENTIFY** - CPAC developed Corrosion Category Codes (CCC) and database to assess the condition of fleet and determine required level of repair.

**Corrosion Category Codes:**

**Category 1:** Item requires no corrosion repair or preservatives and has been assessed within the past 6 months.

**Category 2:** Item requires surface preparation, spot paint, and preservation at the operator and/or organizational level.

**Category 3:** Item requires maintenance performed beyond the operator level. The item must be inducted to the C3 program for repair. The goal is to return the item to category 1 condition.

**Category 4:** Item requires repair to sheet metal, major frame components, paint, blasting, and undercoating (e.g., replacement or repair of components such as doors, fenders, chassis frame rails, or battery boxes due to corrosion). The goal is to return the item to a category 1 condition.

**Category 5:** The item is degraded to a degree that requires depot level repair and replacement based on the deterioration caused by corrosion.

**Snapshot of USMC Fleet in 2004**
### Organizational

**Corrosion Service Teams (CST)**
- Preventative Maintenance and minor corrective actions IAW TM-4795-OR/1A
- Centrally managed by CPAC Program Office with 9 CST teams
- Equipment serviced on established Service Intervals (9, 12, 15, 18 Months)
- Focused on Corrosion Cat Code 1 & 2 and sustainment of CCC 3 & 4 (ROI 19:1)
- Preventive actions keep equipment from progressively getting worse
- CST's perform assessments to determine Cat Codes and funding requirements across USMC with consolidated management

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#### Field Level Activities

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#### Depot Level Activities

- Complete rebuild of vehicle including replacement of major sub-components
- Consolidated program ensures compliance during repairs and upgrades

#### Field Level Costs

- Corrosion Service Teams (CST)
  - $200

#### Intermediate Level Activities

- Intermediate Maintenance—blast, repair and repaint IAW TM-4750-OD/1
- Four (4) separate CRFs with Government management and contracted services
- Consolidated Program FY14 changed contracting and repair practices
- Up to three (3) MCRFs supporting remote areas
- Focused on repair of Corrosion Cat Code (3 & 4) priority 1 assets

#### Intermediate Level Costs

- Corrosion Repair Facilities (CRF)
  - ~$5,000 (CCC-3)/$7,000 (CCC-4)

- **Distribution Statement A**: Approved for public release: distribution unlimited.
Research and Engineering – CERM

• Corrosion Engineering For Reduced Maintenance (CERM) – Finding Solutions for highest cost drivers, problems coming from the Marines
• All products are subjected to rigorous test plan that includes laboratory and Field Testing before implementation
• USMC – CPAC program office has authority to create and modify Military Specifications
• CPAC program manages all Marine Corps Technical Manuals for Corrosion and can implement rapid changes
• OSD Corrosion Policy and Oversight (CPO) has provided matching funding for multiple projects due to high ROI and cross service solution

Spray-on Bedliners  Single Component Coatings  Zinc-Rich Primers

Process Improvements – Facility Upgrades

Automated Wash Racks  Portable Wash Racks  Blast Recovery System

Drying Facility  Paint Booth Upgrades  Paint Sprayer Improvements

Program Goal: Identify, Correct, and Maintain

August 2017

5,323 Assets Serviced and Assessed:
- Cat 1: 0.1%
- Cat 2: 29.2%
- Cat 3: 57.0%
- Cat 4: 13.5%
- Cat 5: 0.1%

* Prior to 2008, no DNS items identified.

101,401 Assets Serviced and Assessed:
- Cat 1: 26.2%
- Cat 2: 50.9%
- Cat 3: 21.8% (DNS 11%)
- Cat 4: 0.8%
- Cat 5: 0.2%

- DNS items are major cost avoidance contributor since 2008 – Doing "more with the same"
PAINTING WITHIN THE US MARINE CORPS
The CARC (Chemical Agent Resistant Coating) System is the most commonly used paint on tactical wheeled vehicles. This system provides specific performance requirements:
- Chemical agent resistance / decontamination
- IR signature
- Camouflage
- Corrosion resistance

Changes are continually made to the governing specifications as improvements are made.
Current Specification Versions

- MIL-DTL-53072E – 31 May 2017
- MIL-DTL-53022E – 19 January 2012
- MIL-DTL-53030D – 14 September 2016
- MIL-DTL-53084B – 3 December 2015
- MIL-PRF-32348 – 16 December 2013
- MIL-DTL-53039E – 16 May 2014
- MIL-DTL-64159B – 16 November 2015

CARC System

- CARC is more than just the topcoat
- The CARC system includes:
  - Surface preparation methods
  - Pre-treatments
  - Primers
  - Topcoats

- There are many options for this system

- The selection and proper application will ultimately impact overall performance
General Considerations

• Steel (ferrous) substrates
  – Utilize zinc-rich primers direct to metal

• All substrates
  – Utilize primer materials with enhanced corrosion properties
    • Enhanced corrosion versions of MIL-DTL-53022/53030
    • Electrodeposition coating (e-coat)
    • Powder coating
  
  – Require 3-5 mils of primer
    • 2-3 times thicker than specified in MIL-DTL-53072
Zinc-rich Paints

- Covered in CID A-A-59745 and new Metal-rich Spec
  - MIL-PRF-32550

- MIL-DTL-53072E lists use as follows
  - 3.2.1 – available alternative to hexavalent chromium pre-treatment on blasted steel
  - 3.3.6 – available pre-treatment on blasted steel with a Rockwell C Hardness (HRC) above 39 (chromated wash primer prohibited)
  - 3.3.6 – for blasted steel HRC above 42 contracting officer must approve use of zinc-rich paint
  - 3.4 – requires the use of MIL-DTL-53022 or MIL-DTL-53030 over zinc-rich

- Demonstrated corrosion benefits in USMC applications
“Enhanced” Corrosion Resistance

• What does the USMC get from these enhanced products?

• More stringent corrosion requirements for the liquid epoxy primers
  – MIL-DTL-53022 Type IV
  – MIL-DTL-53030 Type II primers

• Similar criteria for the e-coat and the powder primers
  – MIL-DTL-53084 e-coat
  – MIL-PRF-32348 Types I and II
    • Type II for interior use untopcoated
Corrosion Comparison of Primers

Comparison of ASTM B117 Test Durations for Steel Panels

- MIL-DTL-53022 Type IV & V also has a 40 cycle GMW14872 requirement
  - Type II is being sun-setted
- MIL-DTL-53030 Types II & III also have a 40 cycle GMW14872 requirement
- MIL-PRF-32348 has a 60 cycle GMW14872 requirement

Topcoat Materials

- Often referred to/thought of as “CARC”, but this is just part of the CARC system

- The topcoat provides IR and camouflage properties as well as UV resistance

- IR signature is not a stand-alone function of the topcoat and can be affected by the color of the primer used
  - Minimum thickness requirements aids in alleviating these concerns
Topcoat Weathering

Elimination of silica-based flattening agents has improved mar resistance and UV stability for all CARC topcoats.

ARL plot (TARDEC Paint Forum, Feb 2011) showing change in color ($\Delta E$) during accelerated weathering. Higher value = more color change.

New Acquisition

- Original Equipment Manufacturers (OEMs) primarily following MIL-DTL-53072
  - Provides an overview of the application of the CARC system
  - Includes cleaning, pre-treatment, primer and topcoat application materials/methods
  - Includes methods of “examination”, which include QA methods (Table IV)
  - Provides recommended thicknesses for each coating (Table V)
    - Liquid epoxy primer thickness to 1.5 ±0.2 mils DFT
    - Specifies 2.0 mils (or greater) if using black e-coat
  - Includes repair methods

- CPAC Program validates their implementation and application of this specification
  - Review of proposal/process documents
  - Evaluation of process controls and quality assurance testing
  - Review of process and wait times to ensure no undue impact to paint
  - Independent verification of quality and workmanship performed on behalf of the Program Manager (PM)

Maintenance Activities

• Follow the requirements of TM 4750-OD/1
  - Based upon the requirements in MIL-DTL-53072
  - Add in USMC-specific requirements
    • Increased primer thickness requirements
    • Use of specific types of materials
  - Includes additional coatings to enhance the CARC system
    • Bedliner/abrasion resistance coatings
    • Underbody coatings

• Repainting done at various maintenance levels
  - Organizational (O) level touch-up and spot painting
  - Intermediate (I) level complete repaint, limited disassembly
  - Depot (D) level complete repaint, may or may not be disassembled
    • Depended on repair
  - The use of qualified materials and proper techniques are specified at each level of repair
Availability of “rattle can” touch-up products

- Approved coatings in spray cans
- Complete liquid system
  - Epoxy primer
  - Polyurethane topcoat
- Provides color match as well as restoration of functional CARC system properties
Performance of CARC Aerosols

• Use of approved products and full CARC system provides

• Better UV protection/ color match
• Improved corrosion performance
• Maintains the functional properties of the CARC system

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Non-CARC Topcoat</th>
<th>CARC System Repair</th>
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</thead>
<tbody>
<tr>
<td>3 Months</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
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<tr>
<td>6 Months</td>
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<td>9 Months</td>
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<tr>
<td>12 Months</td>
<td><img src="image7.png" alt="Image" /></td>
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I-/D-level Maintenance Update

- Increased use of powder coating materials
  - Benefits on material usage (reclaim/recycling)
  - Benefits on coverage and consistency of application
  - Observed incompatibility with water-reducible topcoats
  - Defects will significantly impact production
• Defects were found to be a result of the water used during thinning
  – Thinning at/near the maximum threshold allowed by the manufacturer increased likelihood of defects
  – Higher humidity also increased sensitivity (even at lower thinning amounts)
• Modification to process to thin to minimum amount mostly eliminated this issue
• Solvent-based products were unaffected and could be used as-thinned
USMC Implementation of the CARC System

• The CARC system includes many options for preparation, pre-treatments, primers and topcoats
• The USMC utilizes the options that they have found to work best within their industrial base and provide the best performance
• New materials and application methods have promise
• Need to be evaluated before implementation
  – Overall benefit to the USMC
  – Ability to be used within industrial based without significant modifications
Parting Thoughts

• The CARC system is part of the corrosion control system
  – Not a replacement for one

• The CARC system is a functional coating system
  – UV, IR and camouflage

• Corrosion resistance comes from
  – Base materials (substrates),
  – Pre-treatments and other processes
  – Coating System

• Good painting practices applies to the CARC system just like any other coating
• Currently there are 6 different specifications for CARC primers with a total of 15 unique types
• Currently there are 4 different specifications for CARC topcoats with a total of 12 unique types
• This gives a 15 x 12 matrix of combinations or
  180 primer/topcoat combinations
  – Does not consider substrates, cleaning, pretreatments, supplemental coatings, etc.
• Selecting the product(s) that best suit the USMC can be a challenge