Non-Chromate Primer Transition

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Brenna Skelley, NAVAIR Organic Coatings Team
Initial Driving Force for this Effort: 2009 DoD Memorandum

The Under Secretary of Defense

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS

SUBJECT: Minimizing the Use of Hexavalent Chromium (Cr⁶⁺)

Cr⁶⁺ is a significant chemical in numerous Department of Defense (DoD) weapons systems and platforms due to its corrosion protection properties. However, due to the serious human health and environmental risks related to its use, national and international restrictions and controls are increasing. These restrictions will continue to increase the regulatory burden and life-cycle costs for DoD and decrease material availability. OSD, DoD Components, and industry have made substantial investments in finding suitable replacements for Cr⁶⁺ for many of the current DoD applications. In particular, a number of defense-related industries are minimizing or eliminating the use of Cr⁶⁺ where proven substitutes are available that provide acceptable performance for the application.

This is an extraordinary situation that requires DoD to go beyond established hazard materials management processes. To more aggressively mitigate the unique risks to DoD operations now posed by Cr⁶⁺, I direct the DoD Military Departments to take the following actions:

- Invest in appropriate research and development on substitutes.
- Ensure testing and qualification procedures are funded and conducted to qualify technically and economically suitable substitute materials and processes.
- Approve the use of alternatives wherever they can perform adequately for the intended application and operating environment. Where Cr⁶⁺ is produced as a by-product from use or manufacture of other acceptable chromium oxides, explore methods to minimize Cr⁶⁺ production.
- Update existing technical documents and specifications to authorize use of the qualified alternatives and, therefore, minimize the use of materials containing Cr⁶⁺.
- Document the system-specific Cr⁶⁺ risks and efforts to qualify less toxic alternatives in the Programmatic Environment, Safety, and Occupational Health Evaluation for the system. Analyses should include any environmental risks and life cycle cost comparisons among alternatives. Life cycle comparisons should address material handling and disposal costs and system overhaul cycle timetables due to any differences in corrosion protection.
- Share knowledge derived from research, development, testing and evaluations (RDT&E) and actual experiences with qualified alternatives.

- Invest in appropriate research and development on substitutes.
- Ensure testing and qualification procedures are funded and conducted to qualify technically and economically suitable substitute materials and processes.
- Approve the use of alternatives where they can perform adequately for the intended application and operating environment. Where Cr⁶⁺ is produced as a by-product from use or manufacture of other acceptable chromium oxides, explore methods to minimize Cr⁶⁺ production.
- Update all relevant technical documents and specifications to authorize use of the qualified alternatives and, therefore, minimize the use of materials containing Cr⁶⁺.
- Document the system-specific Cr⁶⁺ risks and efforts to qualify less toxic alternatives in the Programmatic Environment, Safety, and Occupational Health Evaluation for the system. Analyses should include any cost/schedule risks and life cycle cost comparisons among alternatives. Life cycle comparisons should address material handling and disposal costs and system overhaul cycle timetables due to any differences in corrosion protection.
- Share knowledge derived from research, development, testing and evaluations (RDT&E) and actual experiences with qualified alternatives.
• Subpart 223.73 – Minimizing the Use of Materials containing Hexavalent Chromium
  • 223.7301 – ‘It is DoD policy to minimize hexavalent chromium (an anti-corrosive) in items acquired by DoD (deliverables and construction material), due to the serious human health and environmental risks related to its use. Executive Order 13423, section 3, paragraph (a) requires that the heads of agencies reduce or eliminate the acquisition and use of toxic or hazardous chemicals. Executive Order 13514 requires that the heads of agencies are responsible for “reducing and minimizing the quantity of toxic and hazardous chemicals and materials acquired, used, or disposed of.”’
NAVAIR, Policy Guidance FRCSE (2013)

- **FRCSEINST 5103.15**
  - FRCSE Responsibilities
  - “Do not introduce new sources of heavy metals into repair, overhaul or modification processes…”

- **COMFRCINST 7500.1**
  - FRC Responsibilities
  - Reduced Exposure
  - Revision Requested

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Effect of Hexavalent Chromium Management: NAVAIR FRC

Daily Break Room Cleaning

<table>
<thead>
<tr>
<th>SECTION I: BASIC INFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. GMT</td>
</tr>
<tr>
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</table>

<table>
<thead>
<tr>
<th>SECTION II: A SHIFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. CLEAN ALL SURFACES OF THE FOLLOWING ITEMS (initial each block DAILY once completed):</td>
</tr>
<tr>
<td>a. Interior &amp; exterior parts of doors (including handles &amp; knobs)</td>
</tr>
<tr>
<td>b. All food preparation surfaces</td>
</tr>
<tr>
<td>c. Tables/chairs/benches (including legs)</td>
</tr>
<tr>
<td>d. Refrigerators, coffee pots, toasters, ice machine</td>
</tr>
<tr>
<td>e. Vending machines (including key pads &amp; doors)</td>
</tr>
<tr>
<td>f. Microwave ovens (including handles &amp; keypad)</td>
</tr>
<tr>
<td>g. Shelving/Cabinets</td>
</tr>
<tr>
<td>h. Televisions, radios, fan guards &amp; blades</td>
</tr>
<tr>
<td>i. All other horizontal surfaces (molding, chair rails, window/door &amp; picture frames, pipe/stands/duds, bulletin boards etc.) (6 feet &amp; below)</td>
</tr>
<tr>
<td>j. Map floor - HCPA vacuum if necessary, DO NOT DRY SWEEP</td>
</tr>
<tr>
<td>k. Ensure sticky mats are still effective</td>
</tr>
</tbody>
</table>

Effect of Hexavalent Chromium Management: NAVAIR FRC

**Approximately $1M/year labor/materials for HM daily cleaning at each FRC**
Effect of Hexavalent Chromium Management: USAF

OSHA Inspections (2009-2011)

- Warner Robins 2009-10 result in 13 Citations
  - 11 Serious / 2 Willful resulting in Settlement Agreement
  - Over $20.2 Mil in abatement with increasing costs
- Hill inspections result in 4 Citations with 79 items
  - 70% are Hex-Chrome, 20% is Cadmium, 10% safety-noise
  - Over $24.8 Mil in abatement with increasing costs
- Tinker no citations but same depot processes
  - Over $22.4 Mil in abatement with increasing costs
  - Significant investment in Safety and Health
    - 77 active housekeeping plans
    - 2,000+ employees on Medical Surveillance program
    - Downdraft tables, sanding booths, portable and central vacs
    - Wing Service Abatement contracts

AFSC Cost: $67.4 Mil

January 2017
WP-201132 History

- Initiated in FY11, leveraged support from NESDI during effort
- **Goal:** Identify, test, validate and implement non-chromate primers which are as broad in capabilities and performance as the current highest performing chromate primers.
- **Stakeholders:** NAVAIR, ARL, AMCOM, AFCTIO, AFCPCO, USCG, NASA
  - **In-Kind Stakeholders:** Lockheed Martin, Boeing
• Majority of \( \text{Cr}^{6+} \) usage across DoD is in coatings
• All a/c exteriors are repainted every 6-10 years, depending on the platform, which requires REMOVAL and REAPPLICATION of chromate primers
Technical Objective

Document Current Usage (Cr6+ and non-Cr6+)

Implement Non-Chromate Primers/Revise Spec

Mature Low TRL Primers

Demonstrate Non-Chromate Primers

Identify Mature Non-Chromate Primers

Validate Primer Performance/Establish Acceptance Criteria

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Risk of Implementing NC Primer

All DoD branches chose to focus on low-risk/high-reward strategy:

Exterior of the Air Vehicle
(Outer Mold Line)

**Note:** Factors such as platform/component operational environment and inspection intervals must be considered and may justify adjustment to the risk analysis level. Ex. Trainer aircraft operate in a less severe environment than ship-based aircraft.

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## Implementation Strategy per DoD Branch

<table>
<thead>
<tr>
<th>NAVAIR</th>
<th>ARMY</th>
<th>USAF</th>
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<tr>
<td>Implement NC primers per MIL-PRF-23377/ MIL-PRF-85582</td>
<td>Implement NC primers per MIL-PRF-23377/ MIL-PRF-85582</td>
<td>Implement NC primers per MIL-PRF-32239</td>
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</table>
Environmentally Friendly Coatings

Coating Performance

Ease of Use
Validation Testing Timeline

- 2011: Project initiated
- Evaluate commercially available NC primers
- 2014: JTP & Dem Plan submitted
- Demonstration of commercially available NC primers
- Develop and execute joint service Al-rich primer evaluation
- Demonstration of commercial Al-rich primer formulations
- 2015: JTR submitted
- 2016: Final report in progress

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## Maturity Index for Non-Chromate Primers
### FY11

<table>
<thead>
<tr>
<th>Product</th>
<th>Relevant Specification(s)</th>
<th>Technical Development Status (TRL)</th>
<th>Commercial Availability (MRL)</th>
<th>Qualified</th>
<th>NSN</th>
<th>Project Supporting</th>
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<td>8- med risk a/c exterior, 9- low risk a/c exterior</td>
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<td>Deft 44GN098</td>
<td>MIL-PRF-85582 Class N Type I</td>
<td>7/8- high risk to low risk a/c (F-35)</td>
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<tr>
<td>Hentzen 16708TEP/16709C EH</td>
<td>MIL-PRF-23377 Class N Type I</td>
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<td>yes</td>
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<tr>
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<tr>
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<td>Akzo Nobel MgRP003</td>
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<td>7</td>
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<td>PPG Aerocron 1100 (e-coat)</td>
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<td>X</td>
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<tr>
<td>Zn-Ni Nano Layer Coating</td>
<td>ASTM WK 29468 (Draft)</td>
<td>6-med risk on high strength gun base bolts</td>
<td>6</td>
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<td></td>
</tr>
</tbody>
</table>

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Lower Performing Primers Evaluated During Project

• **Crosslink Primer**
  • Novel non-chromate inhibitor package
  • Unable to meet corrosion performance at the time of evaluation

• **Magnesium Oxide Primers**
  • USAF/NAVAIR evaluation to validate Boeing Commercial data justifying switch from chromate primer to non-chromate primer per BMS10-72
    • Mg Oxide Primers were **not equivalent** to chromate primer tested
      • Drove decision to keep chromate primer on exterior of P-8A & KC-46

  • US Army/NAVAIR evaluation to evaluated MgOxide & Metal rich primers for mixed substrate D-level repair operations
    • Metal rich primers **performed as well as chromate** for mixed substrate rework
Demonstrated Non-Chromate Primers: NAVAIR

- **PPG-DEFT 02GN084**
  - E-2C (4 a/c)
  - P-3C (1 a/c)
  - Trainers

- **Hentzen 17176KEP**
  - H-46 (3 a/c)
  - MV-22*
  - H-53 (6 a/c)
  - F-18A-D (17 a/c)

- **Hentzen 16708CEH**
  - Trainers (on-going)
As a result of the successful E-2C & Trainer demonstrations, NAVAIR signed an authorization letter for the use of PPG-DEFT 02-GN-084 on the OML:

“...PPG, Inc. – Deft 02-GN-084 is a non-chromate primer qualified to reference (f). References (g) and (h) contain results from both laboratory and outdoor exposure testing. References (i) through (l) contain results from an E-2C demonstration/validation on the OML of four aircraft. Based upon this data, NAVAIR authorizes the use of PPG, Inc. – Deft 02-GN-084 over conversion coatings qualified to MIL-DTL-81706, Type I, Class 1A when used in conjunction with a gloss topcoat qualified to MIL-PRF-85285.”

It is not authorized for use over non-chromate conversion coatings or extended to the use of PPG, Inc.–Deft 02-GN-084 with semi-gloss or camouflage (flat) topcoats qualified to MIL-PRF-85285, nor other application areas such as inner moldlines, radomes, components, weapons, or ground support equipment.

Upon release, each applicable Program had the option to implement the primer at OEM and depot level.
Implemented Non-Chromate Primers: NAVAIR

• MV-22
  • Implemented Hentzen 17176KEP (MIL-PRF-23377, TY N, CLASS 2) as tiecoat on OML

• Trainers
  • NAS Meridean and NAS Kingsville implemented PPG-Deft 02GN084 as a final primer on the OML of all USN trainers
Demonstrated Non-Chromate Primers: USAF

<table>
<thead>
<tr>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016-17</th>
</tr>
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<tbody>
<tr>
<td>Finish Laboratory Qualification Testing and Outdoor Exposure Testing (External Funded)</td>
<td>Update MIL-PRF-32239</td>
<td>Modify Tech Orders (-23s) on Low Corrosion Prone Aircraft for Non-Chrome Coating Systems</td>
<td>Charaterize and Assign Corrosion Severity Indexes to Aircraft and Base Locations (AFRL, OSD)</td>
<td>Develop a Family of Test Samples for Testing Protection Schemes that Replicate Aircraft Structure and Stresses (AFRL, FAA, AFLCMC, OSD)</td>
</tr>
</tbody>
</table>

Develop a Laboratory Corrosion Test Method and Protocol that Accurately Replicates Real World Environments (OSD SERDP AFRL) AFRL Prediction and Behavior RM P1
Demonstrated Non-Chromate Primers: USAF

- **C-130 – 4 Aircraft – Complete coverage**
  - 2 aircraft – PPG-DEFT RECC/02GN093/99GY013
  - 2 aircraft - Prekote/ AE2100 (Mg Rich Primer)/AE 5000

- **F-16 – 2 Aircraft – Split down middle**
  - 1 aircraft
    - PPG-DEFT RECC/02GN093/99GY013 – Left side
    - Prekote/ AE2100 (Mg Rich Primer)/AE 5000 – Right Side
  - 1 aircraft
    - PPG-DEFT RECC/02GN093/99GY001 – Left Side
    - Prekote/ AE2100 (Mg Rich Primer)/Special Topcoat – Right Side

- **E-3 – 2 Aircraft – Top of both wings**
  - 2 aircraft
    - Prekote/ AE2100 (Mg Rich Primer)/ PPG-DEFT 99GY013 – one wing
    - Prekote/ AE2100 (Mg Rich Primer)/AE 5000 – other wing

- **KC-135 – 2 Aircraft – Complete coverage of both wings**
  - 2 aircraft
    - Prekote/ AE2100 (Mg Rich Primer)/DEFT 99GY001 – one wing
    - Prekote/ AE2100 (Mg Rich Primer)/AE 5000 – other wing

- **HH-60 – 4 Aircraft – Belly panels**
  - 4 aircraft - Prekote/ AE2100 (Mg Rich Primer)/AE 5000

- **ICBM – 2 Trailers**
  - Prekote/ AE2100 (Mg-Rich)/AE 5000

As of Feb 2016

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Implemented Non-Chromate Primers: USAF

- **PPG-DEFT RECC/02GN093/99GY013**
  - USAF F-15 – Jan 2012

- **Prekote/ AE2100 (Mg Rich Primer)/AE 5000**
  - Norwegian Air Force – Jan 2012
  - Germany Approval – May 2012
    - Specification TL8010-0046
    - Used on Tornado and P3-C Orion
  - Italian Air Force – July 2012
    - 30 C-130s to be painted (Entire Fleet)
  - Dutch Air Force – 2013
  - Gulfstream and Cessna - 2015
  - Duncan Aviation – 2015
  - Belgium Air Force – 2015
  - Israeli Air Force - 2015

WWW.AF.MIL
Implemented Non-Chromate Primers: OEM

New aircraft (primer applied during production)

- PPG-Deft 02GN098 (MIL-PRF-85582 Type I, Class N) on F-35B and F-35C aircraft
- PPG-Deft 02GN084 (MIL-PRF-23377 Type I, Class N) on MQ-8B Firescout test/LRIP aircraft
  - A/C already operating from ship during testing
- PPG-Deft 02GN084 (MIL-PRF-23377 Type I, Class N) on H-60R Seahawk production aircraft
  - On low risk interior surface per SIC/UT risk assessment method
- Hentzen 17176 (MIL-PRF-23377 Type II, Class N) on EA-18G production aircraft
  - Overcoat application during production final assembly, chromated primer on detail parts
Lessons Learned: NAVAIR

• PPG-DEFT 02GN084
  • Recoat window critical for intercoat adhesion between primer and topcoat, especially on larger a/c, such as P-3C (shown below)
  • Issue was not experienced on E-2C, since the primer was scuff sanded prior to topcoating
Lessons Learned: USAF
Training
Aluminum Rich Primer
Aluminum Rich Primer

• NAWC-AD has developed a non-chromated primer using an aluminum alloy pigment. This primer has exhibited corrosion performance superior to that of the current high-performance non-chromate primers the fleet is using.

• The Aluminum rich (Al-rich) primer has shown that it can perform well on aluminum and steel substrates, making it a MIL-DTL-53022 and MIL-PRF-23377 candidate. Outside of NAVAIR's intended Navy aerospace and ground vehicle formulation work, this primer may have benefits across the Department of Defense and in commercial applications.

• **Key Technology**: NAWC-AD has developed a process for passivating the aluminum alloy pigment to give the coating greater resistance to self-corrosion and extended life to protect the substrate.
Demonstration of Aluminum Rich Primer: Navy Support Equipment

January 2017-- Al-rich primer was applied to a NET-4 trailer at NAS Oceana.
Demonstration of Aluminum Rich Primer: Navy Support Equipment

**May 2017** – Demonstration over grit blasted steel on **Spotting Dolly** that will deploy on U.S.S. Stennis

Fully assembled spotting dolly

Painter spraying aluminum-rich primer

Aluminum-rich on chassis of spotting dolly
August 2017 – Demonstration on P-25A firetruck at FRC Solomons that will deploy aboard TBD

Fully assembled P-25A firetruck

Al-rich on exterior panels, suspension springs and suspension arms

Al-rich on planetary drive gears
February 2017 -- Demonstration at TASM-G in Groton, CT. Parts of an H-60 Black Hawk were painted with Al-rich primer.
Demonstration of Aluminum Rich Primer: Feedback

- Painters would like a tinted color so the Al-rich primer is not the same color as the metal.

- Ground support equipment community would like dry to topcoat time reduced to 2 hours or less.

- Technical Data sheet should specify that a 1.8mm spray gun tip is needed for Al-rich primer.
Demonstration of Aluminum Rich Primer: Planned

• Future Plans/Demonstrations

  • Fall 2017 - Marine Corps mobile facilities will be sprayed with Al-rich primer at the Marine Corps Base in Albany, GA

  • Fall 2017 – Al-rich primer will be applied in Gulfport, MI and demonstrated on Army H-60 parts

  • Spring/Summer 2018 – anticipate NAVAIR fleet aircraft demonstrations; exact T/M/S TBD
Aluminum Rich Primer: Path Forward

• ONR Future Naval Capabilities project is supporting the scale up of Al-rich primer by licensees

• This summer, draft MIL-PRF-23377 specifications for a new class of primer to include the Al-rich, are being drafted

• Demonstrations on small scale assets and low risk areas will continue, with the goal of larger scale demonstrations in the near future
Looking ahead…
Future of Non-chromate Primer Implementation

• Transitioning to non-chromate primer is complex
  • Aversion to replacing chromate primer in high risk locations or on CSIs

• WP-201132 focused on the low hanging fruit
  • Replacing non-chromate primer on OML – highest opportunity of worker exposure

• Variety of commercial non-chromate primers are available, most do not perform as well as chromate

Our challenge is to adhere to DoD policy, driving forward the implementation of non-chromate alternatives without sacrificing corrosion protection and other performance properties.
QUESTIONS?

Back up Slides
OSHA Field Manual / AFI 91-202
Prioritized Steps for Abatement

1. ENGINEERING CONTROLS: The first and best strategy is to control the hazard at its source. Engineering controls are based on the following principles:
   - If feasible, design the facility, equipment, or process to remove the hazard or **substitute** something that is not hazardous.
   - If removal is not feasible, **enclose the hazard** to prevent exposure in normal operations.
   - Where complete enclosure is not feasible, establish barriers or local ventilation to reduce exposure to the hazard in normal operations.
Project Team

Co-PIs:
Julia Russell and
Brenna Skelley, NAVAIR

Aviation/Light Metal
Lead Org: NAVAIR

Julia Russell,
NAVAIR

Paul Robinson,
AMCOM

Joni Richards,
NASA-TEERM

Mike Spicer,
AFRL

Sam Benavides,
USCG

Tony Phillips,
Lockheed Martin

Lesly Ntanyi,
Sikorsky

Bruce Griffin,
Boeing

OEM

Fred Lafferman,
ARL
# Non-Chromate Primer Usage

<table>
<thead>
<tr>
<th>AV EXTERIOR</th>
<th>Coatings</th>
<th>Air Force</th>
<th>Navy</th>
<th>USCG</th>
<th>Army Aviation</th>
<th>NASA</th>
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<tbody>
<tr>
<td>Pretreatments</td>
<td>5541, Cl 1A, Ty I (Alodine 1200S, Turco Alumigold, Alodine 600)</td>
<td>81706, Cl 1a (Turco Alumigold, Alodine 600, Iridite 14-2, Alodine 1201)</td>
<td>81706, Ty I, Class 1A</td>
<td>81706, Class 1A, Ty I (Turco Alumigold, Alodine 1201S, Iridite 14-2)</td>
<td>81706, Ty I, Cl IA (Iridite 14-2, Alodine 1200S/1201)</td>
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<td>Deft RCC 1015+3021</td>
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<td>Primers</td>
<td>Deft 02GN093</td>
<td>23377C2, TY 1 &amp; 2 (ANAC 10P20-12/-13)</td>
<td>85582C, Ty II (Deft 44GN8)</td>
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<td>85582C1, Ty I (Deft 44GN7)</td>
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<td>23377C2, Ty I (Akzo Nobel)</td>
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<td>85582C1, Ty II (DEFT 44GN8A)</td>
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<td>TT-P-1757 (WASH PRIMER: PRC DESOTO 515X346)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deft 02Y040B (23377C, Ty I/II)</td>
<td>23377N, Ty I (Deft 02GN084)</td>
<td></td>
<td></td>
<td>Carbon Steel Powder Coating - Zinc Primer Epoxy</td>
<td></td>
</tr>
<tr>
<td>Topcoat</td>
<td>85285, Ty IV</td>
<td>85285, Ty I</td>
<td>85285, Ty I, Class H</td>
<td>85285, Ty I, Class H</td>
<td>85285, Ty I</td>
<td></td>
</tr>
<tr>
<td></td>
<td>85285, Ty IV</td>
<td>85285, Ty I</td>
<td></td>
<td>85285, Ty I, Class H</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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NAVAIR Public Release 2017-970. Distribution A – “Approved for public release; distribution is unlimited.”
Aluminum Rich Primer over Grit Blasted Steel

LP formulation of Al-rich Primer with 53039 Type IV Topcoat DFT: 3-5 mils

MIL-PRF-24441 Steel Control with 53039 Type IV Topcoat DFT: 3-5 mils

After 2000 hours in Cyclic GMW 14872

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Aluminum Rich Primer over Phosphated Steel

Below illustrates the effect of supplemental inhibitors:

- Control Al-rich Primer
- Al-rich with non-chromate inhibitor package

After 500 hours (21 cycles) in Cyclic corrosion testing

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Aluminum Rich Primer on pretreated aluminum

Below illustrates the effect of supplemental inhibitors:

Al-rich primer (L) 2000 hours NSF and (R) 2000 hours Cyclic with non-chromate inhibitor package