

JCAT

Alternative Coatings for Fasteners on USMC- Expeditionary Fighting Vehicle

January 26, 2006

Hilton San Diego Resort
1775 East Mission Bay Drive
San Diego, CA 92109

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Presented by:

Amy Hilgeman (Sabre Systems, Inc.)

Chemist

NAVAIR

48066 Shaw Road, Bldg 2188

Patuxent River, MD 20670-1906

301-342-0986

amy.leis.ctr@navy.mil

Contributors:

Bill Nickerson (NAVAIR)

48066 Shaw Road, Bldg. 2188
Patuxent River, MD 20670-1906
301-342-8864
william.nickerson@navy.mil

Kevin Clark (GDLS)

14041 Worth Avenue
Woodbridge, VA 22192
703-490-7533
clarkk@gdls.com

Subra Bettadapur (DRPM-AAA, USMC)

14041 Worth Avenue
Woodbridge, VA 22192
703-492-3360
BettadapurSS@EFV.USMC.MIL

USMC-EFV

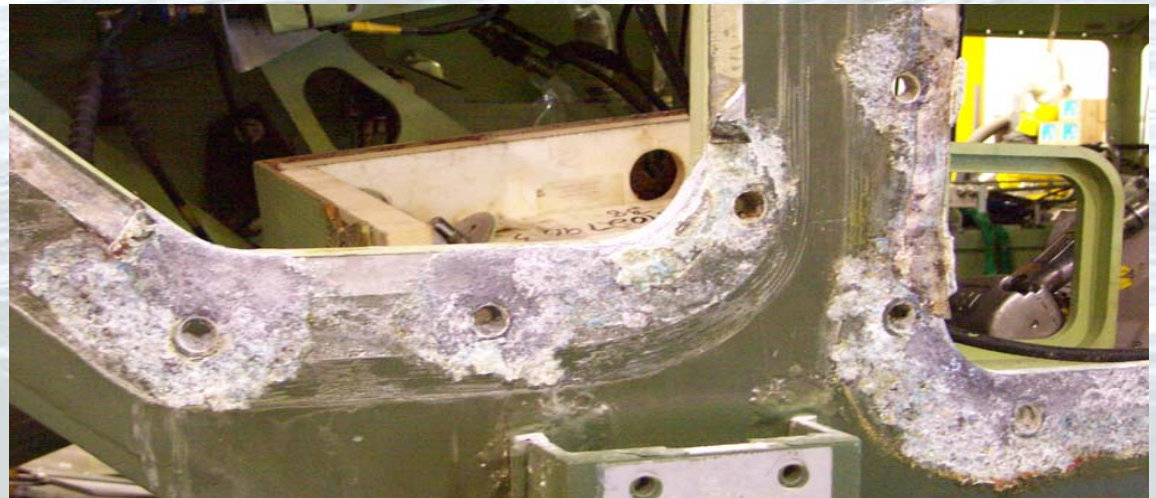
- Self-deploying, high-water-speed, armored amphibious vehicle.
- Operated by a crew of 3 Marines.
- Transports up to 17 combat equipped Marines from Naval ships beyond the visual horizon to inland objectives.

<http://www.efv.usmc.mil/>



Purpose

- Environmentally “green” program – no hexavalent chrome, no cadmium, etc.
- Original set-up – all bare fasteners contributing to severe galvanic corrosion.
- Preliminary screening of alternative fastener coatings.



Coatings

- **S4340**
 - **Cadmium** – ASTM F519, Table II, Treatment B, chromate seal, 0.5 mil (NAVAIR)
 - **Zinc Nickel** – AMS 2417F, Type II, chromate seal, 3-5 mil (AMZ)
 - **Magni 565™** - Chrome-free coating system combining an inorganic zinc-rich basecoat with an aluminum-rich organic topcoat. (Magni)
 - **Alumazite™ ZM 40** – Heat cured, corrosion inhibiting coating w/ no chromate pigments for carbon steel. (Tiodize)
 - **Bare**

Coatings (cont.)

- **SS470**
 - Cadmium
 - **Alumazite™ ZY 138** – Heat cured, inhibiting coating with no chromate pigments designed for stainless steels and titanium. (Tiodize)
 - Bare
- **Ti-6Al-4V**
 - **Titanium Anodize** – AMS 2488, Type II (Titanium Finishing Co.)
 - Bare

Test Method

- **Panel Preparation**

- AA2519-T87: 3"x6"x0.5" and 3"x8"x0.5"
- Clean – Aerowash
- Deoxidize – Ridoline™ 4450
- Pretreat – TCP

- **Prime**

- MIL-DTL-53022 (*Sherwin Williams*)
- MIL-PRF-23377, Class C2, Type I (*Hentzen*)

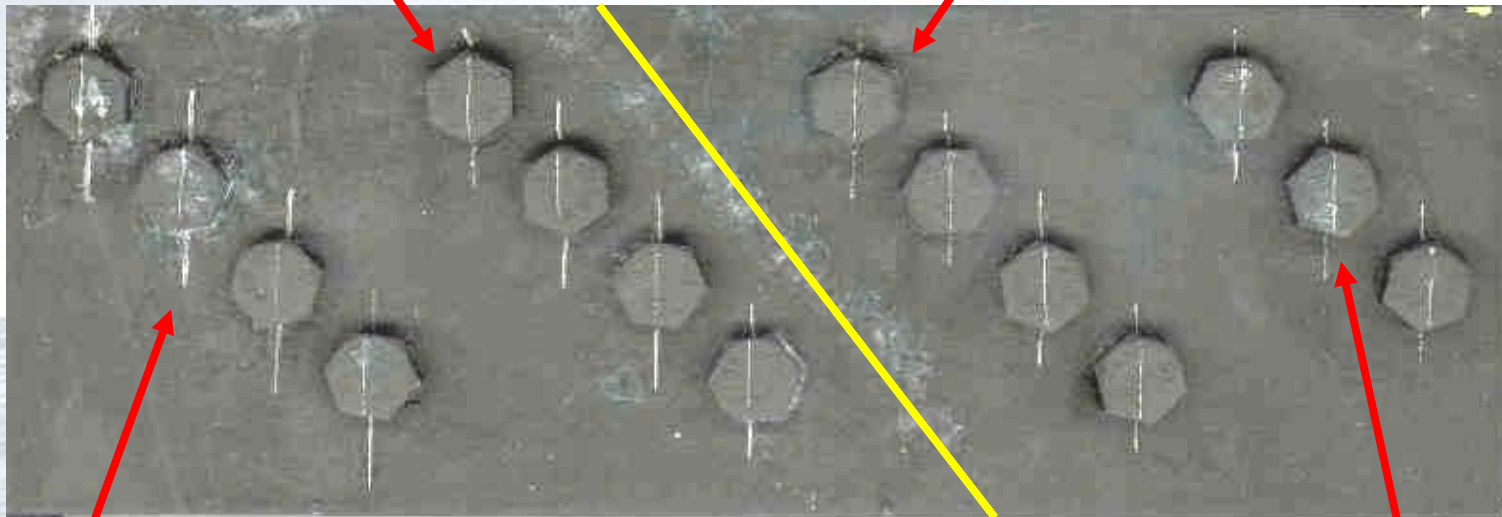
Test Method (cont.)

- **Install Fasteners (55 in. lbs)**
 - 1/4" x 1" hex head bolts
 - S4340
 - SS470
 - Ti-6Al-4V
- **Sealant Application**
 - MIL-PRF-81733D, Type II
 - PR 1775 (PS 1775)
 - Wet Install (53022 or 23377)
 - None (Loctite 242® Threadlocker)
- **Topcoat (Scribed)**
 - MIL-DTL-64159, Type II
- **GM9540P**
 - 80 cycles

Painted Corrosion Evaluation

S4340 Cd
53022

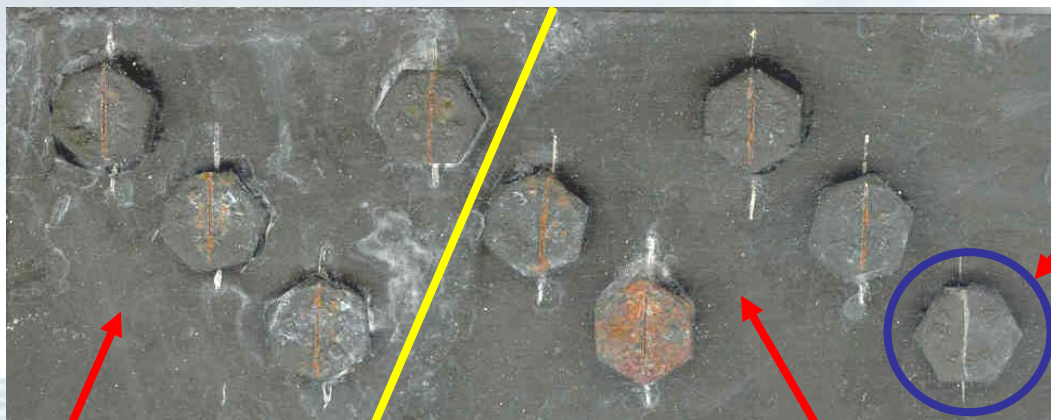
S4340 Cd
23377



S4340 ZnNi
53022

S4340 ZnNi
23377

Painted Corrosion Evaluation (cont.)

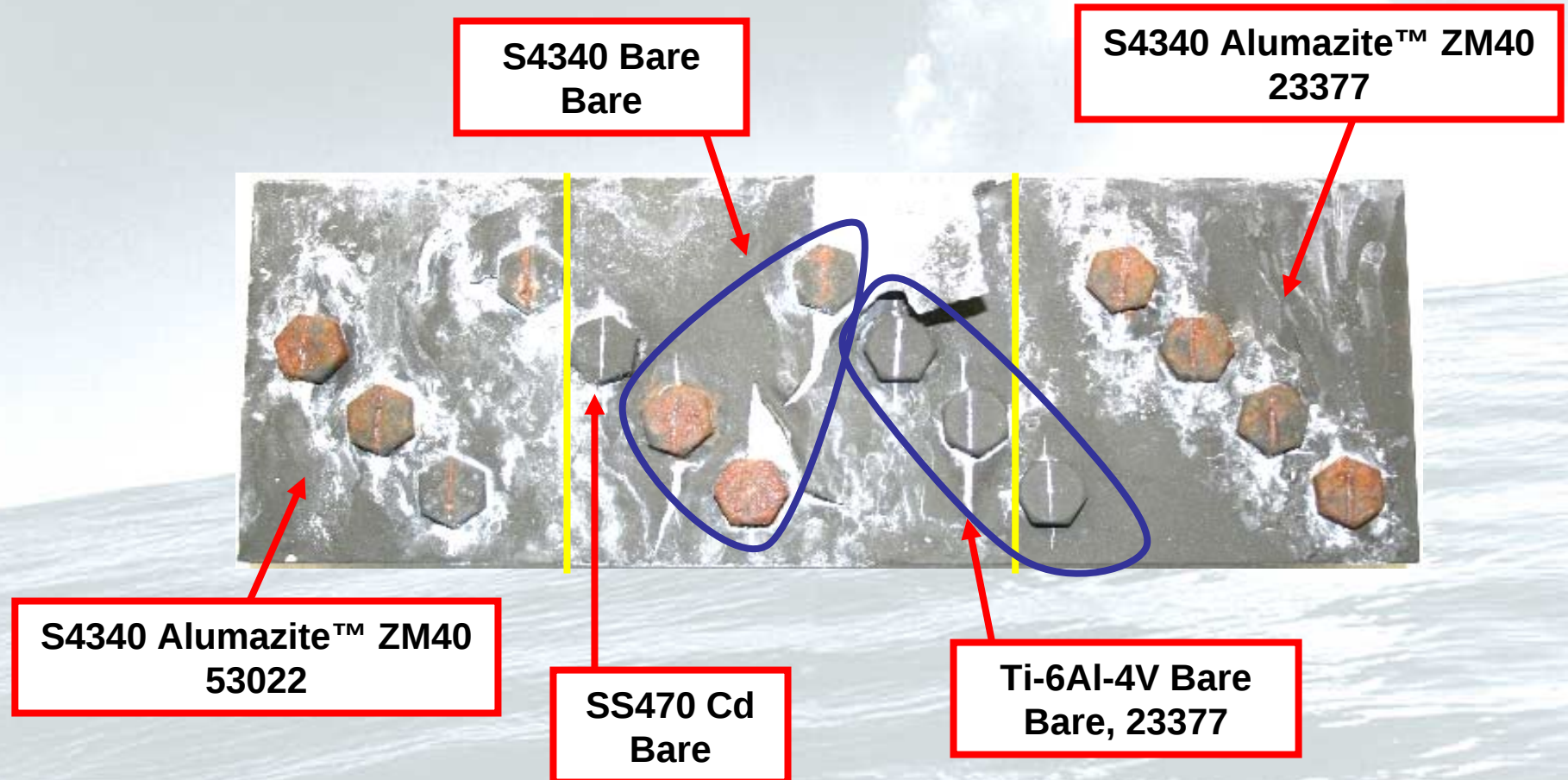


**S4340 Magni 565™
53022**

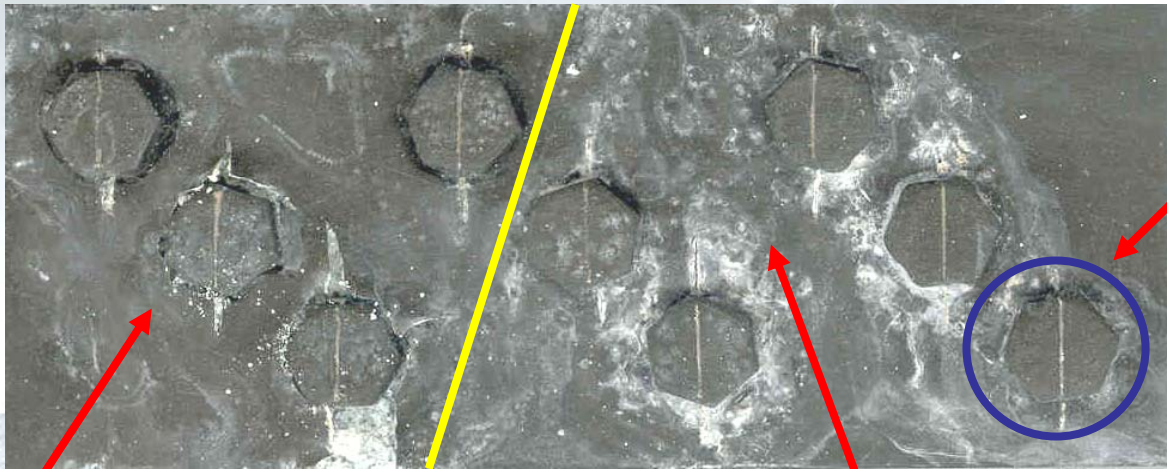
**S4340 ZnNi
23377**

**S4340 Magni 565™
23377**

Painted Corrosion Evaluation (cont.)



Painted Corrosion Evaluation (cont.)



SS470 Cd
23377

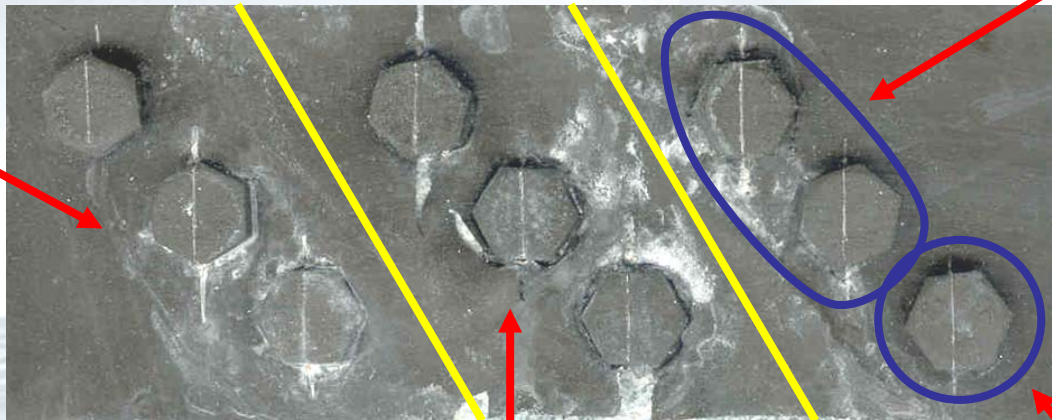
SS470 Alumazite™ ZY138
53022

SS470 Alumazite™ ZY138
23377

Painted Corrosion Evaluation (cont.)

SS470 Cd
53022

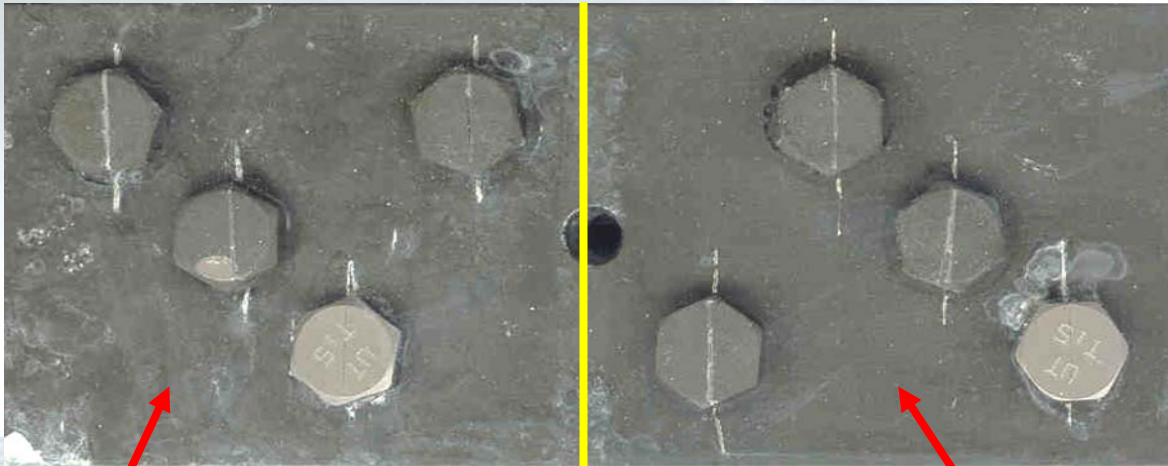
SS470 Cd
23377



SS470 Bare
Bare

S4340 ZnNi
23377

Painted Corrosion Evaluation (cont.)



**Ti-6Al-4V Anodize
53022**

**Ti-6Al-4V Anodize
23377**

S4340 Wet Install

<u>Coating</u>	<u>Primer</u>	<u>Wet Install</u>
ZnNi	23377	23377
Cd		
ZnNi	53022	53022
Cd		
Magni 565™	23377	23377
	53022	53022
Alumazite™ ZM40	23377	23377
	53022	53022
Bare	Bare	53022

SS470 Wet Install

<u>Coating</u>	<u>Primer</u>	<u>Sealant</u>
Cd	23377	23377
	53022	53022
Alumazite™ ZY138	23377	23377
	53022	53022
Bare	Bare	53022

Ti-6Al-4V Wet Install

<u>Coating</u>	<u>Primer</u>	<u>Wet Install</u>
Titanium Anodize	23377	23377
Titanium Anodize	53022	53022
Bare	53022	53022

Overall Wet Install

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>	<u>Wet Install</u>
S4340	ZnNi	23377	23377
	Cd		
SS470	Cd		
Ti-6Al-4V	Anodize	53022	53022
S4340	ZnNi		
	Cd		
SS470	Cd		
Ti-6Al-4V	Anodize	53022	53022
S4340	Magni 565™	23377	23377
SS470	Alumazite™ ZY 138	23377	23377
SS470	Alumazite™ ZY 138	53022	53022
S4340	Magni 565™	53022	53022

Overall Wet Install (cont.)

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>	<u>Wet Install</u>
S4340	Alumazite™ ZM 40	23377	23377
S4340	Alumazite™ ZM 40	53022	53022
Ti-6Al-4V	Bare	Bare	53022
SS470	Bare	Bare	53022
S4340	Bare	Bare	53022

Overall 81733D

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>
S4340	ZnNi	53022
	Cd	53022
		23377
	ZnNi	23377
SS470	Cd	23377
Ti-6Al-4V	Anodize	23377
SS470	Alumazite™ ZY138	23377
		53022
S4340	Magni 565™	23377
		53022
Ti-6Al-4V	Anodize	53022
SS470	Cd	Bare
S4340	Alumazite™ ZM 40	23377
		53022

Overall PR1775

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>
SS470	Cd	53022
S4340	ZnNi	23377
	Cd	23377
Ti-6Al-4V	Anodize	23377
SS470	Cd	23377
S4340	Cd	53022
SS470	Alumazite™ ZY 138	23377
S4340	Magni 565™	53022
S4340	ZnNi	53022
S4340	Magni 565™	23377
Ti-6Al-4V	Anodize	53022
SS470	Alumazite™ ZY 138	53022

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>
S4340	Alumazite™ ZM 40	23377
S4340	Alumazite™ ZM 40	53022
Ti-6Al-4V	Bare	Bare
SS470	Bare	Bare
S4340	Bare	Bare

Overall No Sealant

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>
S4340	Cd	23377
	ZnNi	53022
		23377
	Cd	53022
Ti-6Al-4V	Anodize	23377
S4340	Magni 565™	53022
SS470	Alumazite™ ZY 138	23377
		53022
Ti-6Al-4V	Anodize	53022
S4340	Magni 565™	23377

<u>Fastener</u>	<u>Coating</u>	<u>Primer</u>
Ti-6Al-4V	Bare	23377
S4340	Alumazite™ ZM 40	23377
		53022
SS470	Bare	Bare
S4340	Bare	Bare

Overall S4340

<u>Coating</u>	<u>Primer</u>	<u>Sealant</u>
ZnNi	23377	PR1775
		23377
	53022	81733D
Cd	23377	PR1775
		23377
		None
	53022	81733D
	23377	
ZnNi	23377	81733D
	53022	None
		53022
Cd	53022	PR1775
ZnNi	23377	None
Cd	53022	53022
		None

Overall S4340 (cont.)

<u>Coating</u>	<u>Primer</u>	<u>Sealant</u>
Magni 565™	53022	PR1775
ZnNi		
Magni 565™	23377	81733D
	53022	81733D
	23377	PR1775
		23377
	53022	None
		53022
	23377	None

Overall S4340 (cont.)

<u>Coating</u>	<u>Primer</u>	<u>Sealant</u>
Alumazite™ ZM40	23377	81733D
	53022	
	23377	PR1775
	53022	
	23377	53022
	53022	23377
	23377	None
	53022	
Bare	Bare	53022
		PR1775
		None

S4340 Fasteners

**Cd
53022**

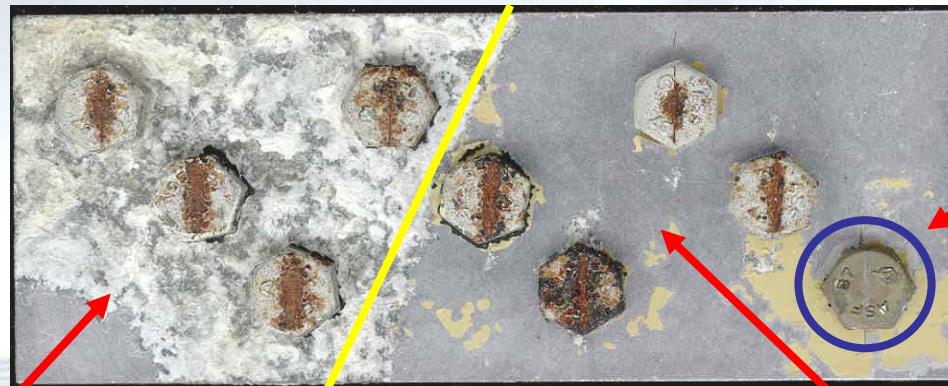
**Cd
23377**



**ZnNi
53022**

**ZnNi
23377**

S4340 Fasteners (cont.)



**Magni 565™
53022**

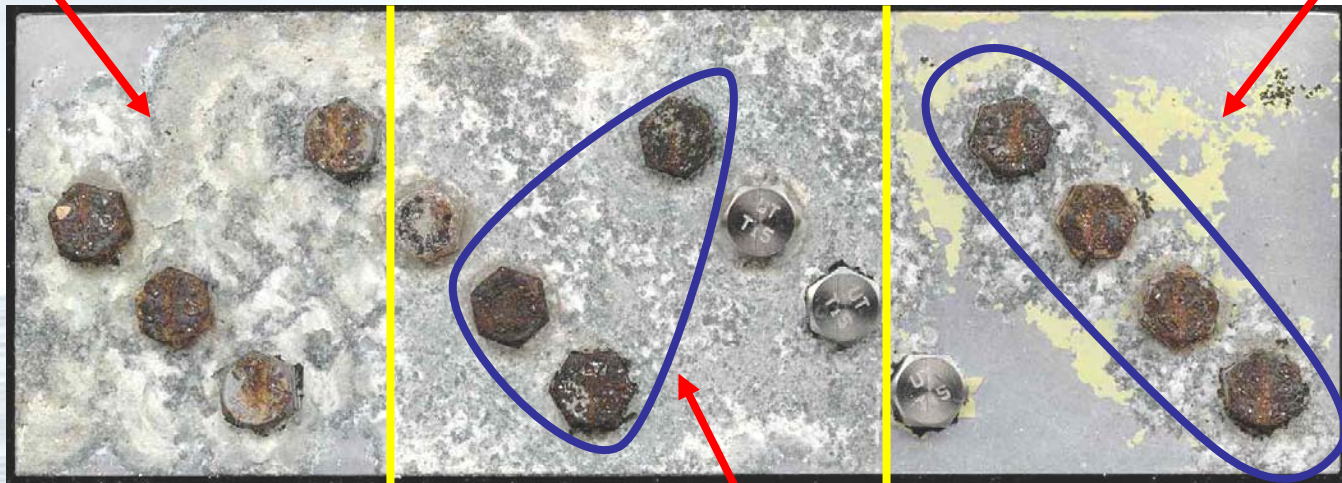
**ZnNi
23377**

**Magni 565™
23377**

S4340 Fasteners (cont.)

Alumazite™ ZM40
53022

Alumazite™ ZM40
23377



Bare
Bare

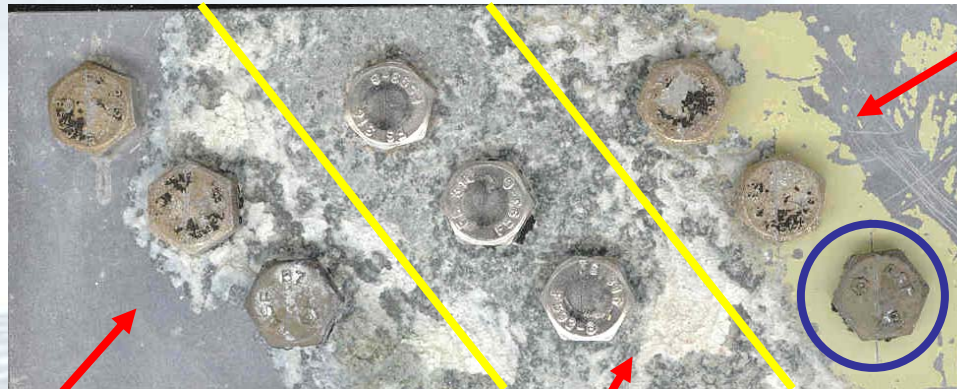
Overall SS470

<u>Coating</u>	<u>Primer</u>	<u>Sealant</u>
Cd	53022	PR1775
	23377	23377
	53022	53022
	23377	PR1775
	23377	81733D

Overall SS470 (cont.)

<u>Coating</u>	<u>Primer</u>	<u>Sealant</u>
Alumazite™ ZY138	23377	81733D
	53022	
	23377	PR1775
	53022	53022
	23377	23377
	23377	None
	53022	
Cadmium	Bare	81733D
Alumazite™ ZY138	53022	PR1775
Bare	Bare	PR1775
		53022
		None

SS470 Fasteners



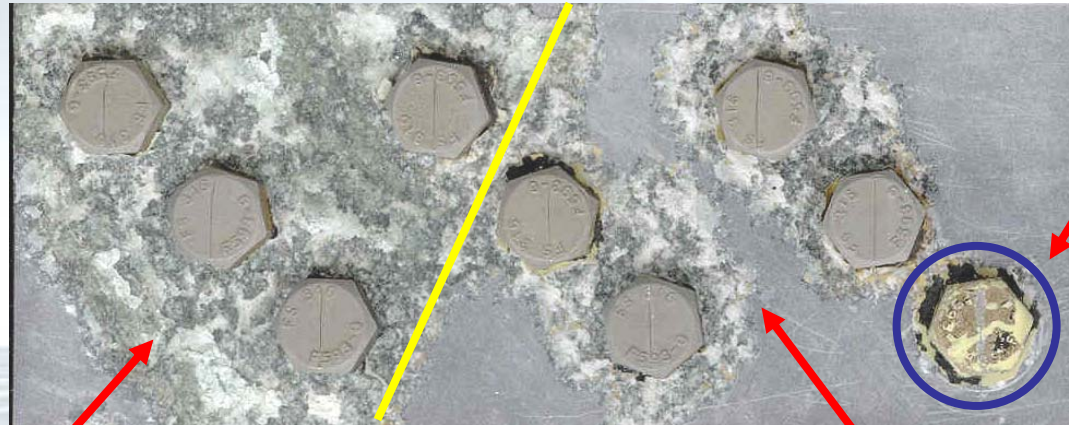
**Cd
53022**

**Cd
23377**

**Bare
Bare**

**ZnNi
23377**

SS470 Fasteners (cont.)



**Alumazite™ ZY138
53022**

**Alumazite™ ZY138
23377**

**Cd
23377**

Overall Ti-6Al-4V

Coating	Primer	Sealant
Titanium Anodize	23377	23377
		PR1775
		None
		81733D
Titanium Anodize	53022	53022
		PR1775
		81733D
		None
Bare	23377	None
	Bare	53022
	Bare	PR1775

Ti-6Al-4V Fasteners



**Anodize
53022**

**Anodize
23377**

Ti-6Al-4V Fasteners (cont.)



**Bare
Bare**

Conclusions

- **S4340**
 - Cadmium and Zinc Nickel ranked at the top.
 - Magni 565™ ranked in the mid-level.
 - Alumazite™ ZM 40 and Bare were clearly at the bottom.
- **SS470**
 - Cadmium was a definite first.
 - Alumazite™ ZY138 is a better alternative than bare but not close to Cadmium.
- **Ti-6Al-4V**
 - Titanium anodize is a much better option than bare.

Recommendations

- **S4340** – Zinc Nickel is the best option as cadmium alternative. Further evaluation recommended.
- **SS470** – Alumazite™ ZY138 is a better option than the current set-up using bare fasteners.
- **Ti-6Al-4V** – Titanium anodize is a better option than the current set-up using bare fasteners.

Additional Information

Additional Information

- AA2519-T87 – High-copper, aluminum armor alloy (sig. weight reduction vs. 5083)
- S4340 – Ni-Cr-Mo high-strength steel
- SS470 – Work-hardened 316 stainless steel alloy
- Ti-6Al-4V – Titanium alloy, 6% aluminum and 4% vanadium.

Additional Information

- Aerowash – Mildly alkaline, all-purpose maintenance cleaner (Henkel)
- Ridoline™ 4450 – Phosphate-free, dilute citric/acetic acid deoxidizer (Henkel)
- TCP – Trivalent chromium conversion coating for aluminum and its alloys (NAVAIR)

Additional Information

- MIL-DTL-53022 – Solvent-borne, non-chromated epoxy primer (Sherwin Williams)
- MIL-PRF-23377, Class C2, Type I – High-solids, solvent-borne, chromated epoxy primer (Hentzen)
- MIL-DTL-64159, Type II – Water-reducible, CARC topcoat (Hentzen)

Additional Information

- MIL-PRF-81733D, Type II – Two-component, room temp curable, polysulfide sealant with a hexavalent chrome inhibitor to prevent corrosion.
- PR 1775 – Two-component room temp curable, polysulfide sealant with a non-chromate inhibitor to prevent corrosion.

Additional Information

- GM9540P – Accelerated, cyclic corrosion test. Three stages repeated for each cycle:
 - 8 hr ambient with 4 salt mist applications every 90 min (40%-50% RH, 25C)
 - 8 hr humidity (100% RH, 49C)
 - 8 hr dry (<30% RH, 60C)

Additional Information

- Zinc Nickel – Plating performed in accordance with AMS 2417F Type II at a thickness of 0.0003" - 0.0005" - post-treated with hexavalent chrome (AMZ)
- Cadmium – Plating performed in accordance with ASTM F519, Table II, Treatment B, chromate seal, 0.5 mil (NAVAIR)
- Magni 565™ – Chrome-free duplex fastener coating system that combines an inorganic zinc-rich basecoat with an aluminum-rich organic topcoat.

Additional Information

- Alumazite™ ZM40 – Heat cured, corrosion inhibiting coating with no chromate pigments for carbon steel (Tiodize)
- Alumazite™ ZY138 – Heat cured inhibiting coating with no chromate pigments designed for stainless steels and titanium(Tiodize)
- Titanium Anodize – Anodized in accordance with AMS 2488, Type II (Titanium Finishing Company)

S4340 Fasteners

Cd
53022

Cd
23377



ZnNi
53022

ZnNi
23377

S4340 Fasteners



Magni 565™
53022

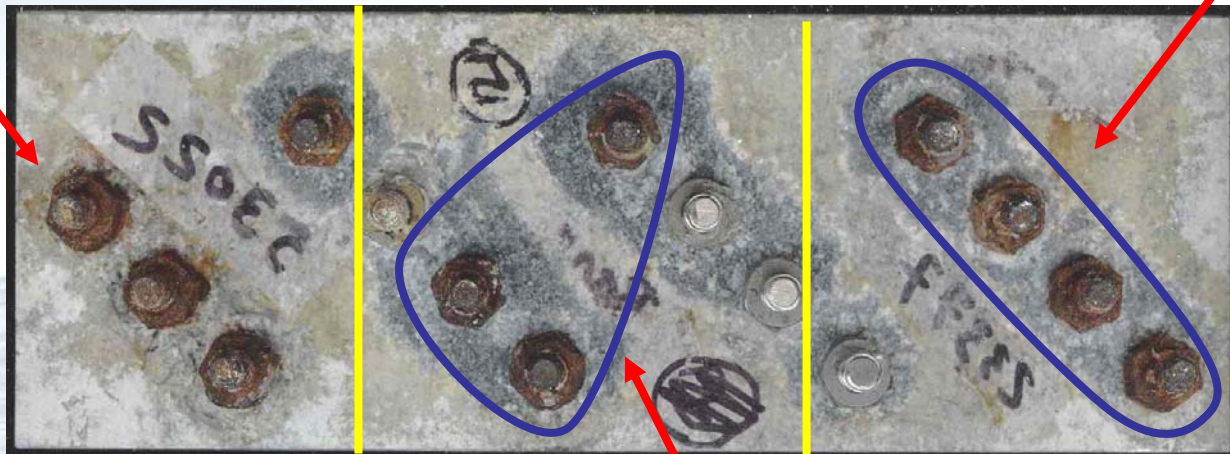
ZnNi
23377

Magni 565™
23377

S4340 Fasteners

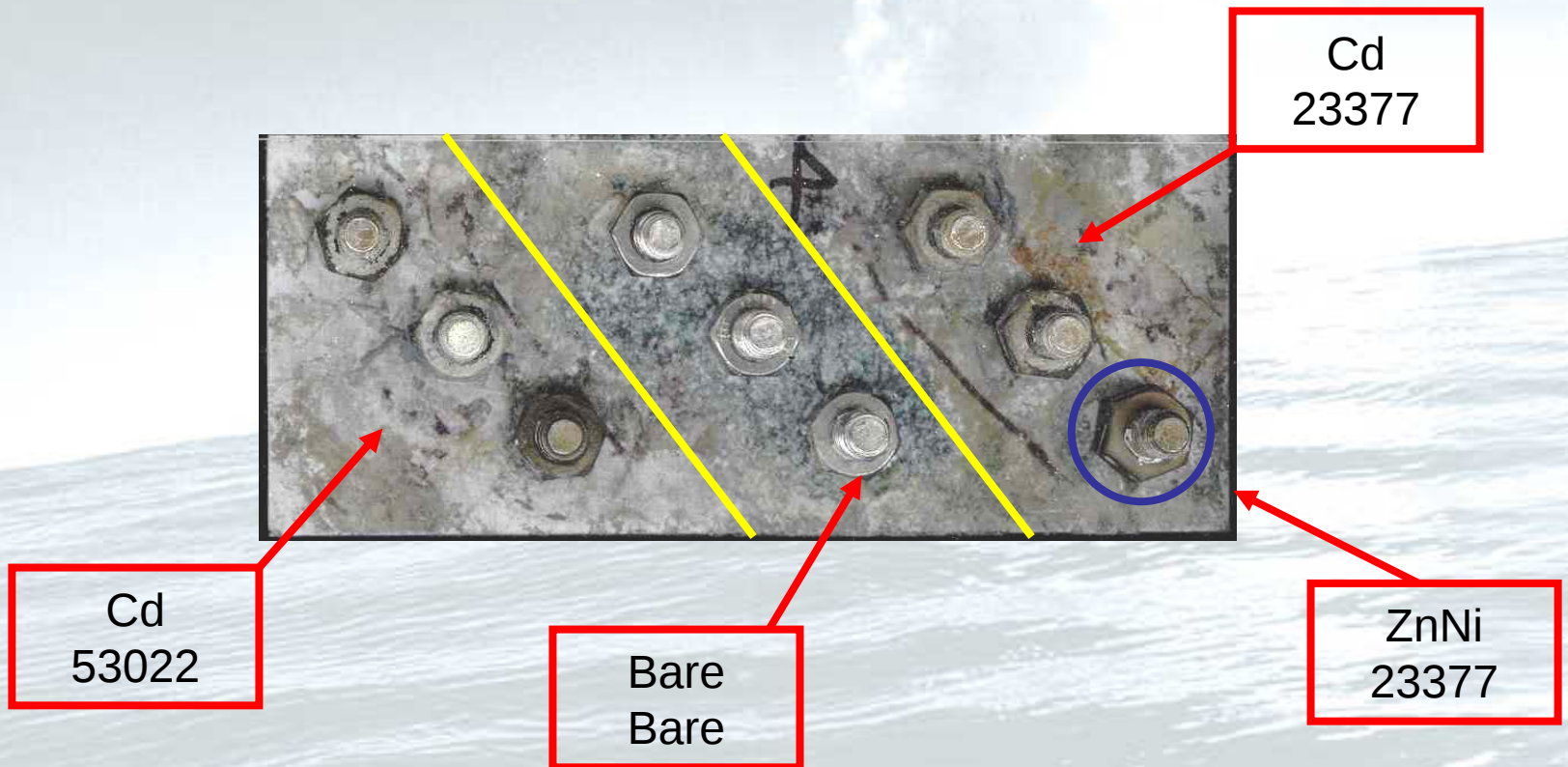
Alumazite™ ZM40
53022

Alumazite™ ZM40
23377



Bare
Bare

SS470 Fasteners



SS470 Fasteners



Alumazite™ ZY138
53022

Cd
23377

Alumazite™ ZY138
23377

Ti-6Al-4V Fasteners



Anodize
53022

Anodize
23377

Ti-6Al-4V Fasteners



Bare
Bare