



Aluminum-Rich Primer Development

AUGUST 2018

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ASETS Defense 2018 Workshop



Background

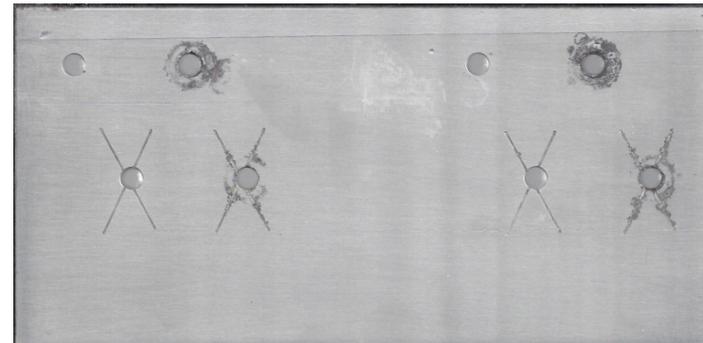
- NAWCAD has developed a non-chromated primer using an aluminum alloy pigment. This primer has exhibited corrosion performance superior to that of the current high-performance non-chromate primers the fleet is using.
- The aluminum-rich (Al-rich) primer has shown that it can perform well on aluminum and steel substrates, making it a MIL-DTL-53022 and MIL-PRF-23377 candidate. Outside of NAVAIR this primer may have benefits across the Department of Defense and in commercial applications.
- Through this research NAWCAD has found new requirements we want to add to the primer specification under the FNC to help establish more rigorous criteria for primers. (i.e. galvanic testing and dry time requirements)

Background

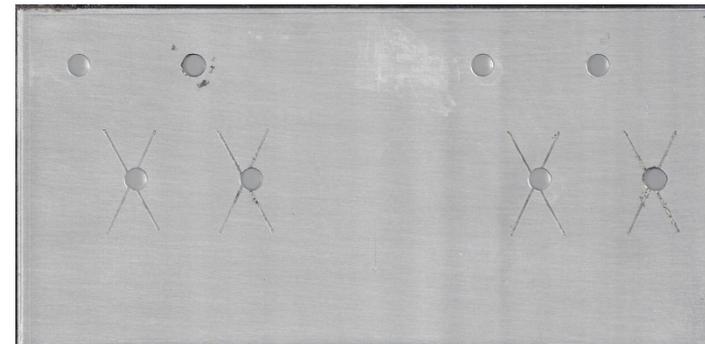
Current primers don't provide good galvanic corrosion protection in harsh naval environments. The need for better galvanic corrosion protection led to the development of the Al-rich primer.



**Problem: Harsh Marine Environment
- Extremely Corrosive**



Galvanic Performance of qualified MIL-PRF-23377 Class C primer



Galvanic Performance of Al-rich Primer



Background

- Under the ONR FNC funding is being provided to a few companies to scale up and commercially produce the primer.
- Eight companies have signed licenses with NAVAIR to produce and sell the Al-rich primer.
- In FY19, we are expecting AERMIP funding to revise the MIL-PRF-23377 specification to add the galvanic corrosion test method and include a metal rich primer class.

ONR Program Code 35

Advanced Topcoat System (ATS)

AT A GLANCE
WHAT IS IT?

A **Primer/Topcoat System** that provides enhanced durability to enable effective maintenance of aviation and amphibious platforms with high performance structural protection.

HOW DOES IT WORK?

- New topcoat **resin chemistry** to address **maintainable operation (MRO)** associated with toxic hazardous materials.
- Novel metal rich primers for improved protection of dissimilar metal structures, weight reduction versus current Al-rich pigments.

WHAT WILL IT ACCOMPLISH?

Enhanced corrosion protection

- 25% reduction in corrosion and coating maintenance costs for Naval Aviation.
- 20% reduction in maintenance cost for USMC Ground Vehicle.

Provide improved functional performance and reduced toxicity

- Reduce in health and environmental issues by eliminating 50 lbs. toxic pigments.
- Increase in water cure stability, glass transition, flexibility and erosion resistance for AV.
- Increase in resistance of chemical warfare agent resistance, and handling resistance for AV.
- Increase in flexibility by increasing flash point to 140°F VOCs to 100 g/l.

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The Advanced Topcoat System (ATS) (Future Naval Capability (FNC) Product is developing protective coating systems with sustainably improved corrosion inhibition and reduced environmental, safety and health (ES&H) impacts for Navy and Marine Corps aviation and amphibious systems and ground and amphibious vehicle systems. To achieve this, the ATS program is developing and integrating best technologies, a state-of-the-art topcoat system for aviation (AV) and ground and amphibious vehicles (GV). Performance advancements are focused on increased corrosion protection and adhesion coating deposition, adhesion (AUV) and chemical agent resistance (CA).
The ATS products are responding to higher performance corrosion requirements with reduced ES&H impact as expressed by the fleet. In addition to substantially reducing the impact of corrosion, the ATS products will reduce the use of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) as well as have reduced flammability. All of these improvements will improve the quality of the workforce for maintenance personnel.
By improving coating system performance, ATS will ensure that the Navy and Marine Corps reduce the impact of maintenance activities world-wide while employing SOTA protection schemes which enhance sustainability over extended maintenance intervals. The ATS products enable increased fuel/airline operational health and safety, and eliminate restrictions on OTC maintenance that lead to additional costs and reduced readiness, support, durability and survivability delivery increased.

Key Technologies:
Non-isocyanate topcoats with CARC option for USMC, lower VOCs, HAPs and flammability (AV and GV) to address site-based maintenance capability gap.
Aluminum-rich primer, with capability for use on aluminum and steel, lower VOCs, HAPs and flammability, larger range of applied thickness (AV and GV) to address improved galvanic corrosion protection gap.

Research Challenges and Opportunities:

- Topcoat - novel, bio-cyclable free polymer catalysts
- Single (1K) and two component (2K) formulations
- Primer - novel galvanic protection pigments / inhibitors

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Advanced Coatings Goals

Prioritization	Requirement	Minimum	Threshold	Goal
1	Filiform corrosion	MIL-PRF-23377/85582	No filiform beyond 1/8" from scribe and majority less than 1/16" long	No filiform corrosion
	Galvanic corrosion	Equal to MIL-PRF-23377/85582 Class C control	Better than Class C control by 10%	Better than Class C control by 25%
	Scribed panel corrosion	Equal to MIL-PRF-23377/85582 Class C control	Better than Class C control by 10%	Better than Class C control by 25%
2	VOC	340 g/L	250 g/L	100 g/L
3	Flammability/Flash Point	n/a	100 F	150 F
4	Chemical Strippability	MIL-PRF-23377/85582, 90% stripped by either Method A or B	50% stripped with TT-R-2918	90% Stripped with TT-R-2918 or equivalent to Methylene chloride based paint stripper
5	Drying time	MIL-PRF-23377 (5 hr/8hr)	3 hr/8 hr	1 hr/6 hr
6	IR reflectance	MIL-PRF-23377/85582 Ty II	TBD	TBD
7	Fluid resistance	MIL-PRF-23377/85582	Minimal adhesion loss with Skydrol exposure	Current resistance + Skydrol
8	Application	MIL-PRF-23377/85582 @ 1.5 mils	MIL-PRF-23377/85582 @ 1.0 mils	MIL-PRF-23377/85582 @ 1.0 mils
9	Solvent Resistance	MIL-PRF-23377/85582	100 double rubs	200 double rubs
10	Thickness Tolerance	n/a	2x thickness (2-3 mils)	4x thickness (4-6 mils)
11	Application Method	Bulk spray (HVLP)	Brush	Aerosol spray
12	Packaging	1K or 2K	1K or 2K	1K & 2K



Key Technologies

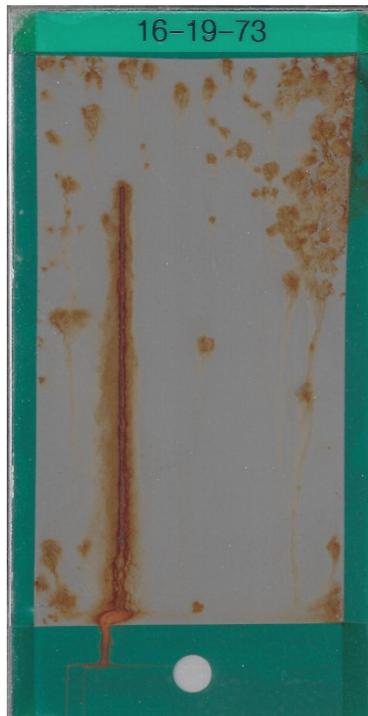
- NAWCAD developed a process for passivating the aluminum alloy pigment to give the coating greater resistance to self-corrosion and extended life to protect the substrate.
- Powder production has been scaled up to produce larger quantities and new alloys are being investigated.
- Inorganic inhibitors are being explored to further the potential of the coating to resist corrosion.
- NRL's one component polysiloxane resin systems are being used to formulate one component aluminum-rich primers.



Technical Accomplishments

- Progressed on magnesium-free compositions.
 - A variety of inhibitor packages have been assessed and the performance of the primer with the inhibitors has come close to the performance of the primer with magnesium in aluminum, and surpassed on steel and for mixed metals.
 - Alternative, Zn-free, alloys that were atomized are being assessed.
- Testing scaled-up products produced by NAVAIR licensees and providing the licensees with feedback.
- Successfully scaled up to larger batch of powder being atomized (10,000lbs). This is increasing the supply and reducing the cost per pound.
- Demonstration efforts with Army, Marine Corps, and Navy underway.

Performance on Phosphated Steel



Control Al-Rich
Primer (no Mg)



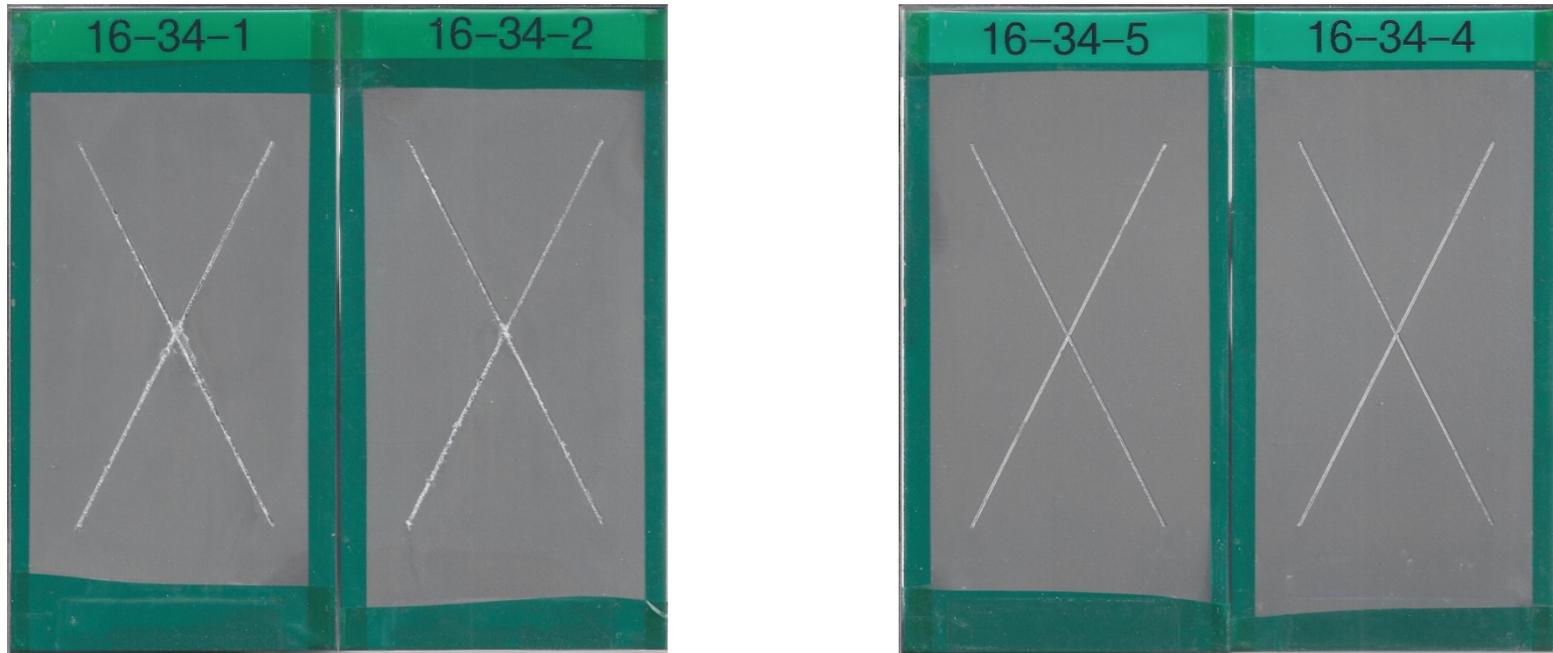
Control Al-Rich Primer
(with Mg)



Al-Rich with Inhibitor
Package (no Mg)

After 500 hours (21 cycles) in cyclic corrosion testing

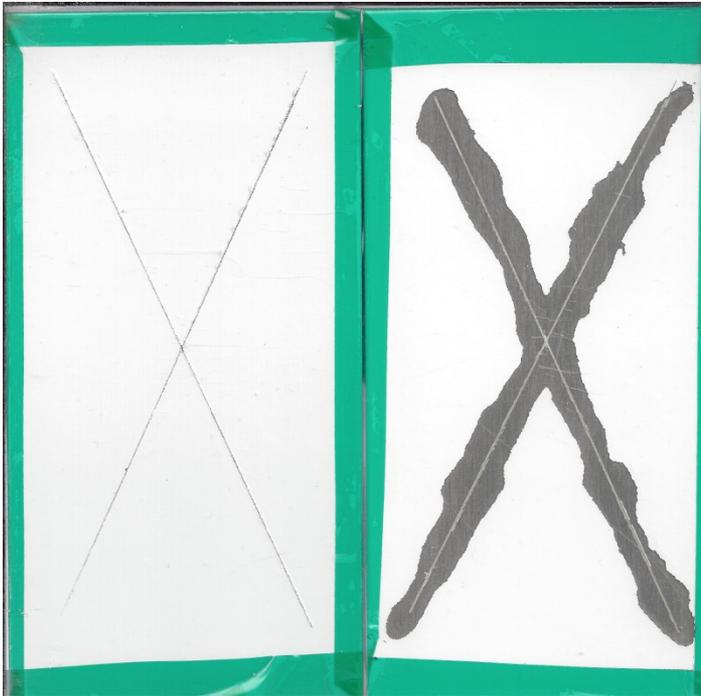
Performance on Aluminum



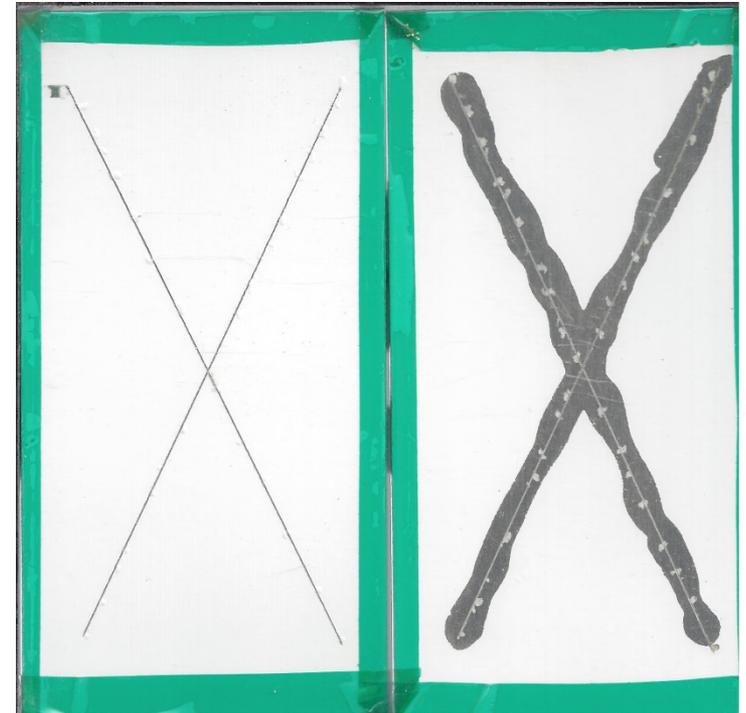
Al-rich primer (L) 2000 hours NSF and (R) 2000 hours cyclic testing with inhibitor package in place of magnesium powder

Performance on Aluminum

The Al-rich primer protects against filiform corrosion better than the MIL-PRF-23377 qualified chromate primer.



Al-Rich Primer



Qualified 23377 Chromate Primer

Completed filiform test (1000 hrs.) per MIL-PRF-23377. Right-hand panel in each set shows chemically stripped scribe area.



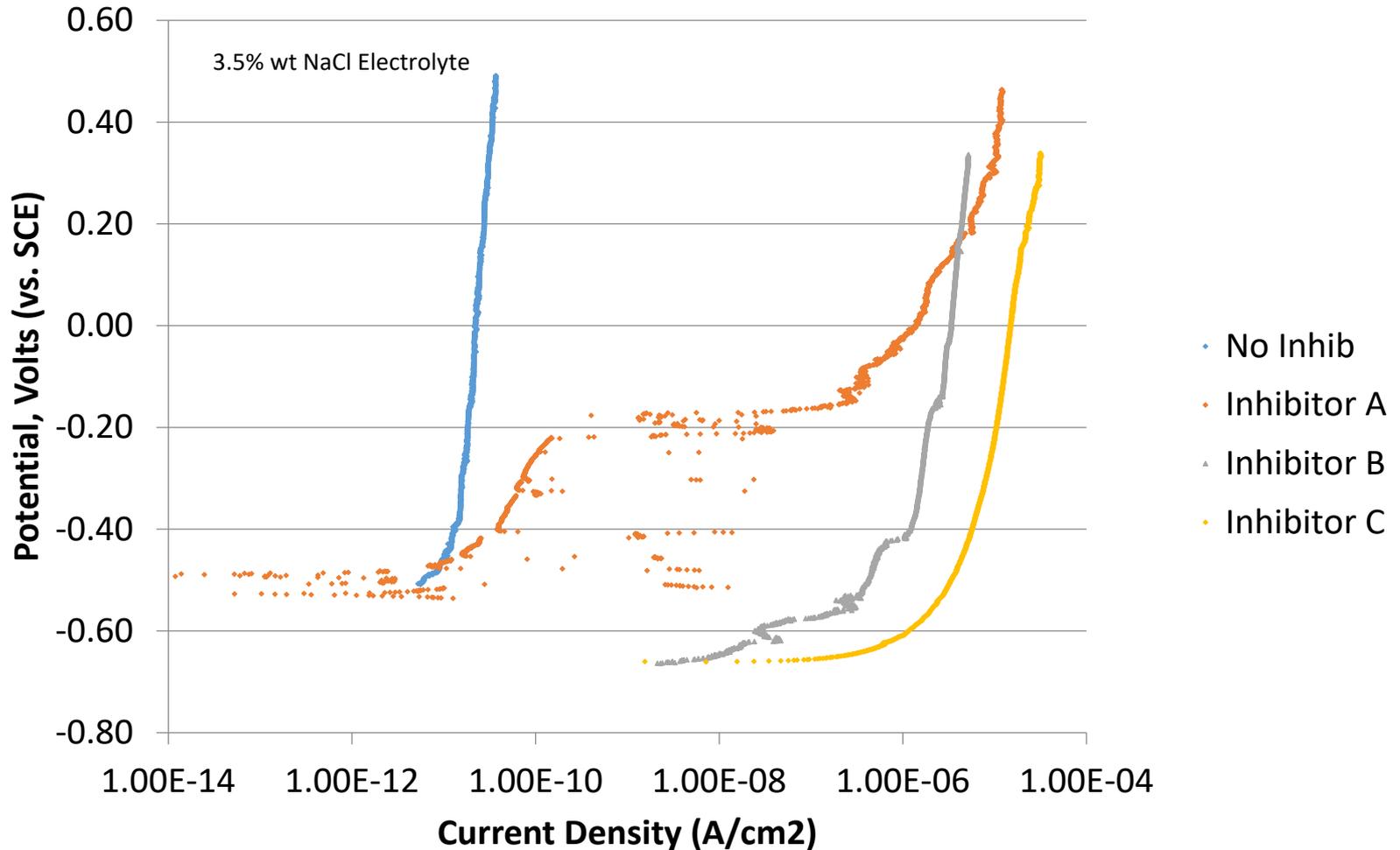
Performance on Aluminum - Inhibitors

- Under the ONR DNI program, NAWCAD has been researching supplemental corrosion inhibitors.
- Solutions with these inhibitors were made and electrochemistry analyses were performed on the solutions to determine the effects of the inhibitors.
- The promising inhibitors were then formulated into the Al-rich primer.



Performance on Aluminum - Inhibitors

Al-Rich Primer- Effects of Added Inhibitors





Alternative Aluminum Alloys

- Currently, work is being done to find an alternative aluminum alloy that does not contain zinc for use in the Al-rich primer.
- A zinc-free alloy could have broader applications, such as zinc free anodes.
- This work is being funded through a NAVAIR internal 219 funding effort.
- In 2017, a new patent application was filed for alternative aluminum alloys.



Aluminum Alloy Compositions

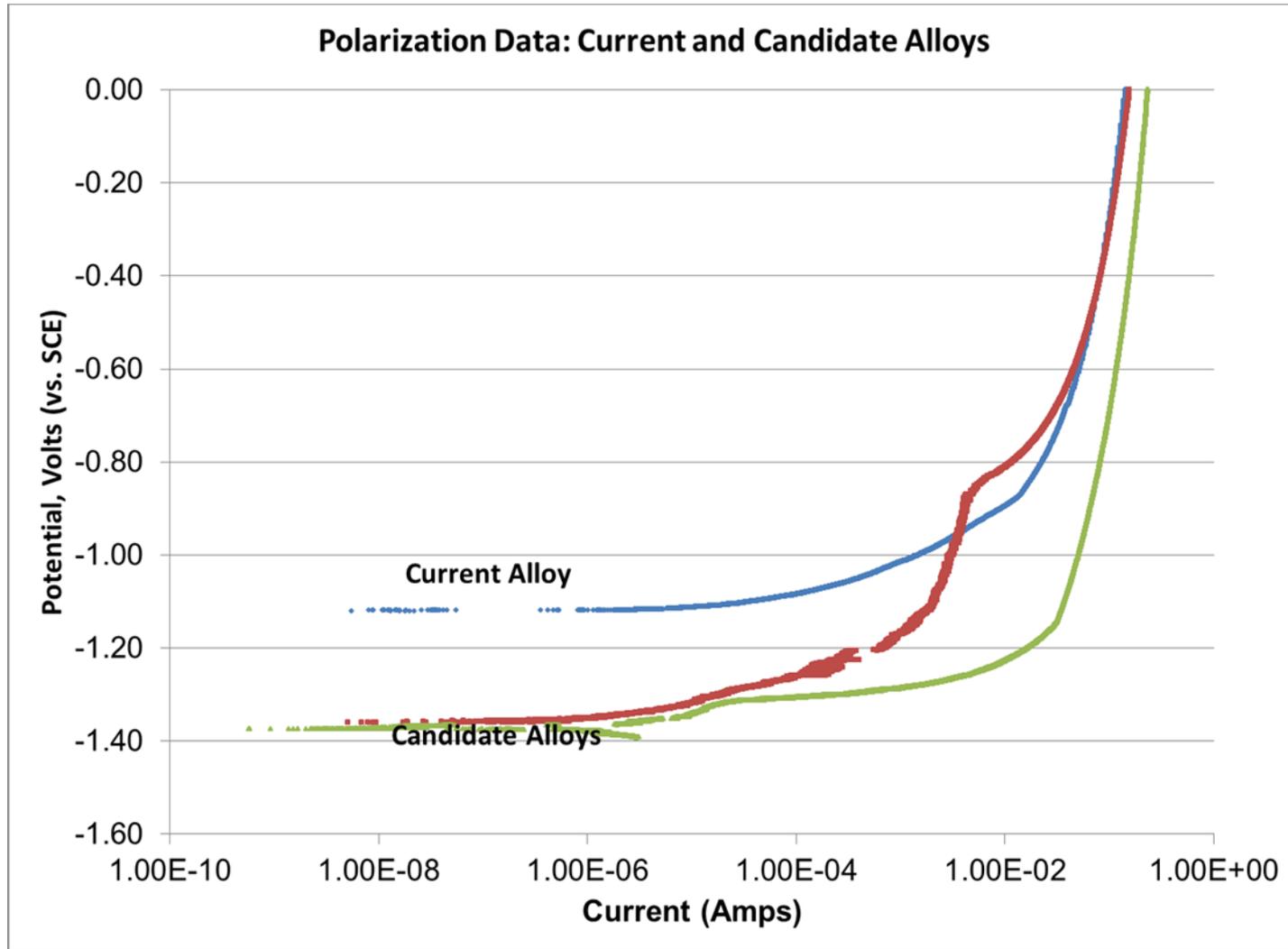
Alloy Composition	Density (gm/cc)	Efficiency (%)	Current Capacity (Amp-hr/kg)	Open Circuit Potential (V vs SCE)
Alloy A	2.704	46.4¹	1383¹	-1.43
Alloy B	2.702	55.5 ¹	1653 ¹	-1.43
Alloy C	2.701	72.5	2160	-1.35
Alloy D	2.701	79.9	2381	-1.36
Alloy E	2.701	92.6 ¹	2759 ¹	-1.04
Alloy F	2.700	91.4 ¹	2623	-1.09
Zinc ²	7.14	~98%	820	-1.05
Magnesium ²	1.74	~60%	1320	-1.60
Alloy G	2.923	91.0¹	2613¹	-1.12

1- Average of two specimens

2 - Reference anode material



Aluminum Alloy Compositions

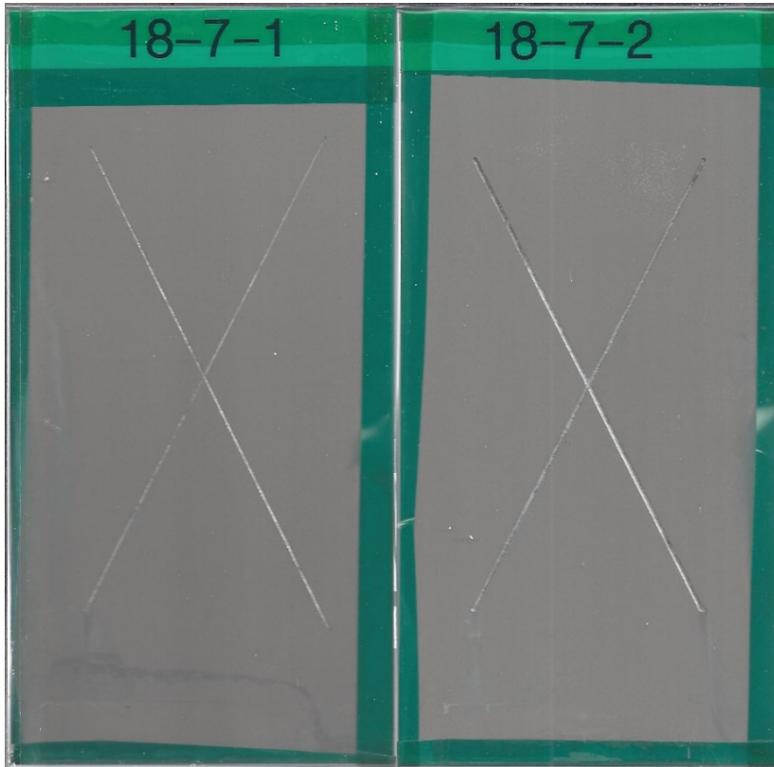




One Component Al-Rich Primers

- Currently, the products qualified to the TT-P-1757 spec are 1K alkyds which don't have strong corrosion performance. Frequently, these 1K alkyds are used in corrosion prone areas such as wet installation of fasteners.
- As a solution, we are looking at NRL's one component polysiloxane resin to formulate a one component Al-rich primer to meet TT-P-1757.
- The polysiloxane resin Al-rich primer has shown such potential in corrosion testing that it is also being formulated as a 1K primer that meets MIL-PRF-23377.

One Component Al-rich Primers



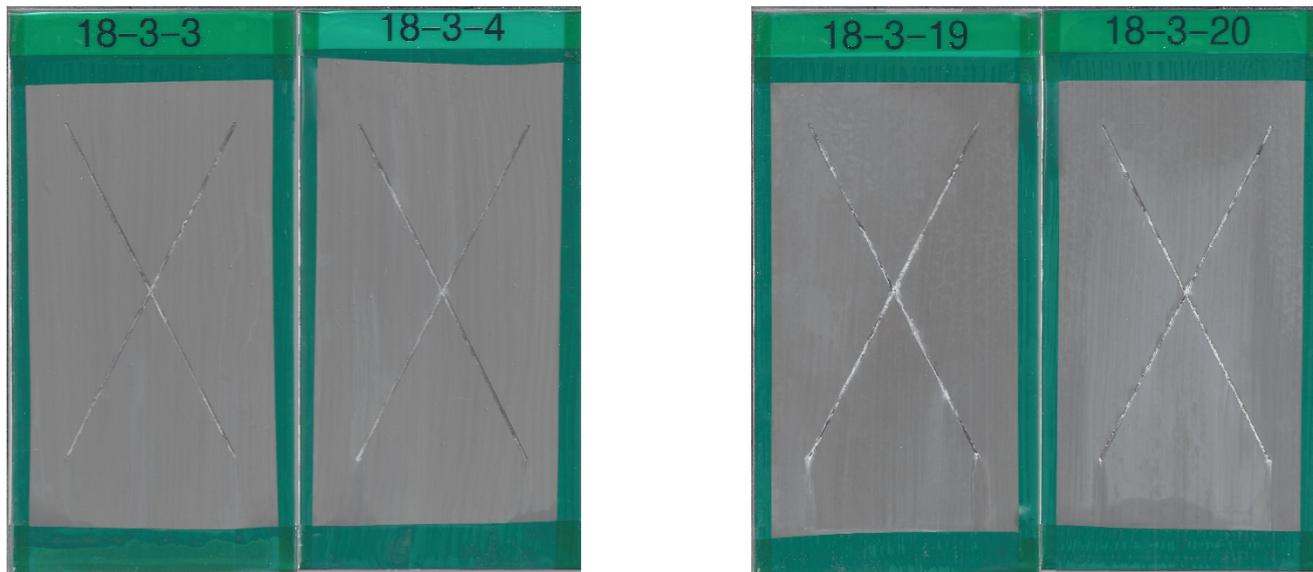
Benefits:

- Eliminates mixing
- Allows for easy touch-up applications
- Environmentally friendly / non-chromate
- Strong corrosion prevention

1500 hours in B117 - Formulation made with passivated aluminum pigment, contains no inhibitors. (L) hand scribe (R) machine scribe

One Component Al-rich Primers

One component resin, with passivated and un-passivated aluminum pigment.



1500 hour B117 exposure of polysiloxane resin Al-rich primer. Panels at the left contain passivated powder, and at the right contain untreated powder.



Aluminum-Rich Primer Demonstrations

Aluminum-Rich Primer

January 2017 – MIL-DTL-53022 version of Al-rich primer was applied to a NET-4 trailer at NAS Oceana. At the one year inspection, the Al-rich primer was performing slightly better than the control.



Tow bar primed with Al-rich



Tow bar and axle primed with Al-rich primer



Tow bar and axles topcoated with polyurethane topcoat



Aluminum-Rich Primer

February 2017 – Army H-60 demonstration at TASM-G in Groton, CT. Parts of an H-60 Black Hawk were painted with MIL-PRF-23377 version of Al-rich primer.



H-60 Cargo Door



H-60 Stabilator



Aluminum-Rich Primer

Fall 2016 – U.S. Coast Guard painted two H-60 tail booms at their facility in Elizabeth City, NC. One H-60 deployed to Kodiak, AK and the other went to Clearwater, FL. At the one year inspection, both H-60s were performing well and were comparable to the control.



Aluminum-Rich Primer

May 2017 – Al-rich demonstration over grit blasted steel on spotting dolly that will be deployed on the U.S.S. Stennis.



Fully assembled spotting dolly



Al-rich on chassis of spotting dolly



Painter spraying Al-rich primer

Aluminum-Rich Primer

August 2017 – Al-rich demonstration over grit blasted steel on P-25 Fire Truck that was deployed on the U.S.S. Eisenhower in April 2018.



Fully assembled Fire Truck



Frame after being primed with Al-rich primer



Aluminum-Rich Primer

- Demonstration Feedback

- Painters would like a tinted color so the Al-rich primer is not the same color as the metal and there is improved contrast. As a result, two licensees have provided tinted primers recently for evaluation.
- Ground support equipment community would like dry to topcoat time reduced to 2 hours or less





Aluminum-Rich Primer

- Future Research Efforts
 - Type II Al-rich – initial proof of concept has been started
 - Tint the primer to color that stands out against the camo grey topcoat
 - Optimize one-component polysiloxane formulations
 - Re-evaluate pigment passivation process and look for improvements that can be made to the process to increase efficiency



Aluminum-Rich Primer

- Transition Efforts
 - ONR Future Naval Capabilities project is supporting the scale up of Al-rich primer by licensees.
 - Under the FNC, companies are required to produce 50 gallon batches in the next few months and then scale up to 150 gallon batches within the next 18 months.
 - Demonstrations on small scale assets and low risk areas will continue, while test plans for large scale demonstrations are being planned with V-22 and H-53. These demonstrations are supported by the ONR FNC.



Questions?

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