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Corrosion Preventive Compounds Lifetime Testing

Topic Area: Corrosion

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Abstract:

Lifetime Testing of Corrosion Preventive Compounds (CPCs) was performed to quantify performance in the various environments to which the Space Shuttle Orbiter is exposed during a flight cycle. Three CPCs are approved for use on the Orbiter: HD Calcium Grease, Dinitrol AV-30, and Braycote 601 EF. These CPCs have been rigorously tested to prove that they mitigate corrosion in typical environments, but little information is available on how they perform in the unique combination of the coastal environment at the launch pad, the vacuum of low-earth orbit, and the extreme heat of reentry. Currently, there is no lifetime or reapplication schedule established for these compounds that is based on this combination of environmental conditions. Aluminum 2024 coupons were coated with the three CPCs and exposed to conditions that simulate the environments to which the Orbiter is exposed. Uncoated Aluminum 2024 coupons were exposed to the environmental conditions as a control. Visual inspection and Electro-Impedance Spectroscopy (EIS) were performed on the samples in order to determine the effectiveness of the CPCs. The samples were processed through five mission life cycles or until the visual inspection revealed the initiation of corrosion and EIS indicated severe degradation of the coating.

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Corrosion Preventive Compounds Lifetime Testing

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Introduction

- **Corrosion Preventive Compounds (CPCs)**
 - **Coating, oil or grease that has corrosion inhibiting properties**
- **Studies show that CPCs help prevent and/or control corrosion problems**
- **The longevity of CPCs in the environments to which the Space Shuttle Orbiter is exposed is unknown**

Orbiter Processing Flow

- **In a typical flow the Orbiter normally spends:**
 - **4 months in the Orbiter Processing Facility (OPF)**
 - **1 weeks in the Vehicle Assembly Building (VAB)**
 - **1 months at the launch pad**
 - **2 weeks in low earth orbit (vacuum)**

- **The OPF and the VAB are assumed to have no significant life-limiting effects because the environments are controlled**

Objective

- **Establish the mission life cycle of CPCs approved for use on the Orbiter**
 - **Test CPCs in Orbiter environmental exposure conditions**
 - **Temperature, Pressure, Salt Air**
 - **Performance determined through visual inspection and Electrochemical Impedance Spectroscopy (EIS)**

CPCs Approved for Use on Orbiter

CPC \ Properties	Temperature Range (where Applicable)	Lubricity	Penetration (Wicking Effect)	Appearance	Method of Application
<u>Calcium Grease</u> (Conoco, Inc.)	-250 °F to +400°F	good	fair	dark tan to brown grease	spraying, brushing, or dipping
<u>Dinitrol AV-30</u> (Oakite Products, Inc.)	-40 °F to +200 °F	poor	excellent	transparent and light brown water-displacing compound	spraying or brushing
<u>Braycote 601EF</u> (Castrol Inc.)	-112 °F to +400 °F	good	good	smooth, buttery, translucent, off-white, grease	wiping or brushing

Scope

– In Scope:

- Study 3 CPCs approved for use on Orbiter
- Use an uncoated aluminum sample for reference

– Out of Scope:

- Effect of any single environment
- Interaction on a pre-corroded sample
- Ability of aged CPC to meet qualifications set by specification
- Effect of atomic oxygen
- Effect of UV degradation
- Coating thickness

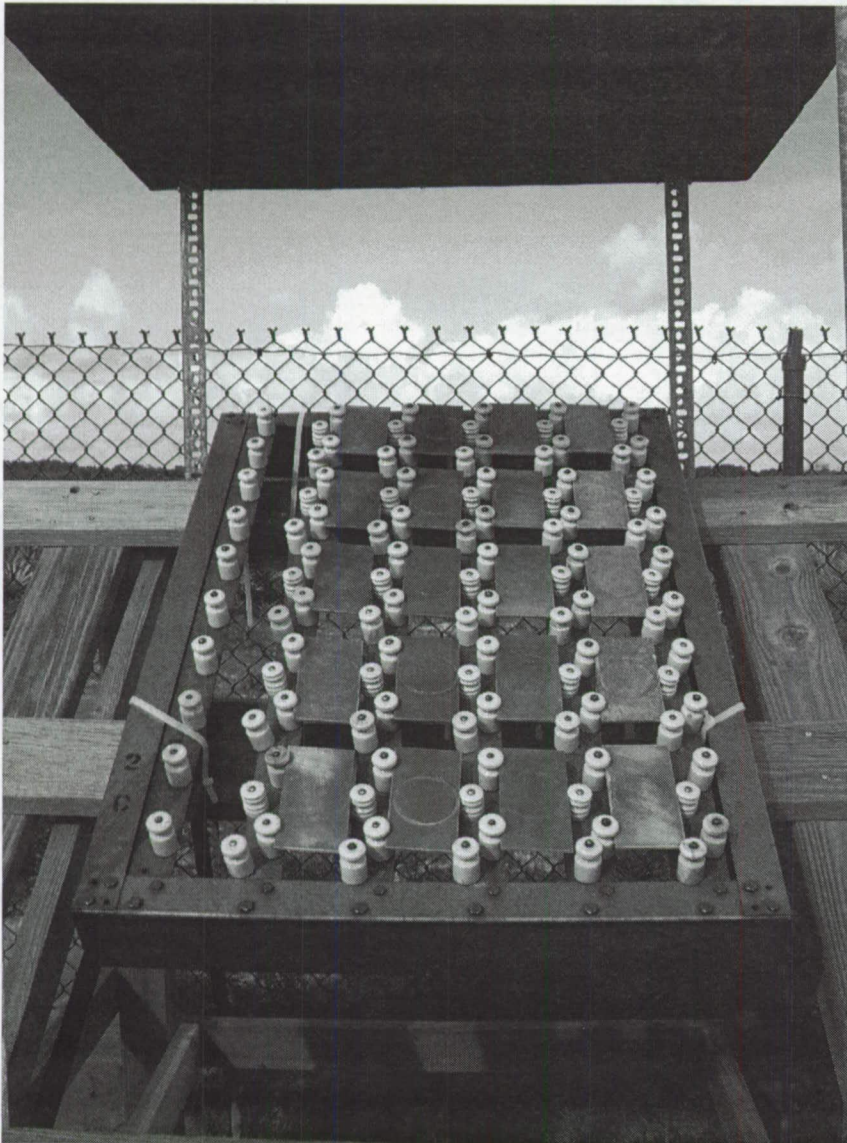
Test Plan

- 1 Mission Cycle (MC) = 1 month at beach site or 1 week in salt fog**
1 day in temperature chamber
2 weeks in vacuum chamber
- **Samples were exposed to 4 or 5 simulated mission cycles (depending on test location)**
 - **Temperature Chamber Exposure**
 - **Samples held at 0°F for 3 hours**
 - **Samples held at +185°F for 3 hours**

Test Locations at Kennedy Space Center (KSC) and Marshall Space Flight Center (MSFC)

- **Low Earth Orbit Environment:**
- **Vacuum environment at low earth orbit ~ 10^{-6} Torr**
 - **Different vacuum chamber capabilities at each test site:**
 - **KSC's vacuum chamber = 10^{-2} Torr**
 - **MSFC's vacuum chamber = 10^{-6} Torr**
- **Launch Pad Environment**
 - **MSFC performed an accelerated test using a salt fog chamber for 168 hours with a 5% salt spray solution**
 - **KSC exposed the samples at the NASA corrosion beach facility for 4 weeks**

Launch Pad Environment



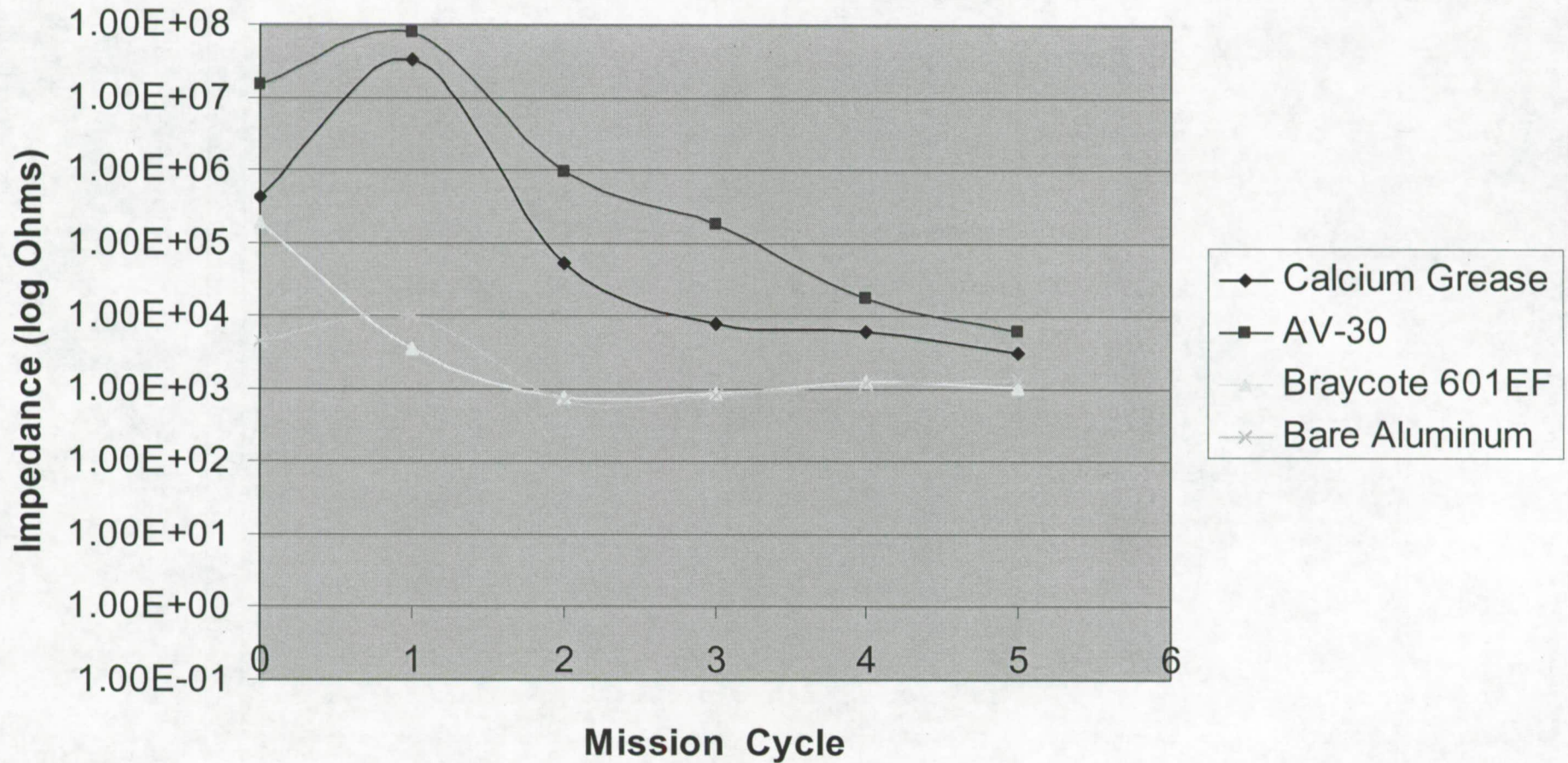
- **Sample setup at the NASA Corrosion Beach Facility at KSC. Samples were exposed to UV rays, salt air and environmental conditions**

Samples

- **20 Aluminum 2024 panels were prepared**
 - **5 with each CPC, 5 uncoated**
- **Specimens were deoxidized by mechanical abrasion and chemical etching prior to CPC application**
- **CPCs were applied using the same methods used on the Orbiters**

EIS Data from MSFC Testing

Average Impedance vs. Mission Cycle at MSFC



Conclusions from MSFC EIS Data

- **Ranking of impedance results (best to worst):
AV-30 > Calcium Grease > Braycote > Bare Aluminum**
- **All coatings exhibited a significant decline in impedance after MC 1**
- **The impedance of Braycote matches that of Bare Aluminum after MC 1**
- **The impedances of both the Calcium grease and AV30 samples were much higher than the Bare Aluminum and Braycote, so it can be concluded that they provide better protection**

Visual Inspection of MSFC Samples

- **Sample surfaces contained a thick layer of buildup from the salt fog chamber**
- **This made visual inspection of the substrate more difficult (harder to determine if corrosion had begun)**
- **Extent of corrosion was reduced on samples coated with AV30 and Calcium Grease.**

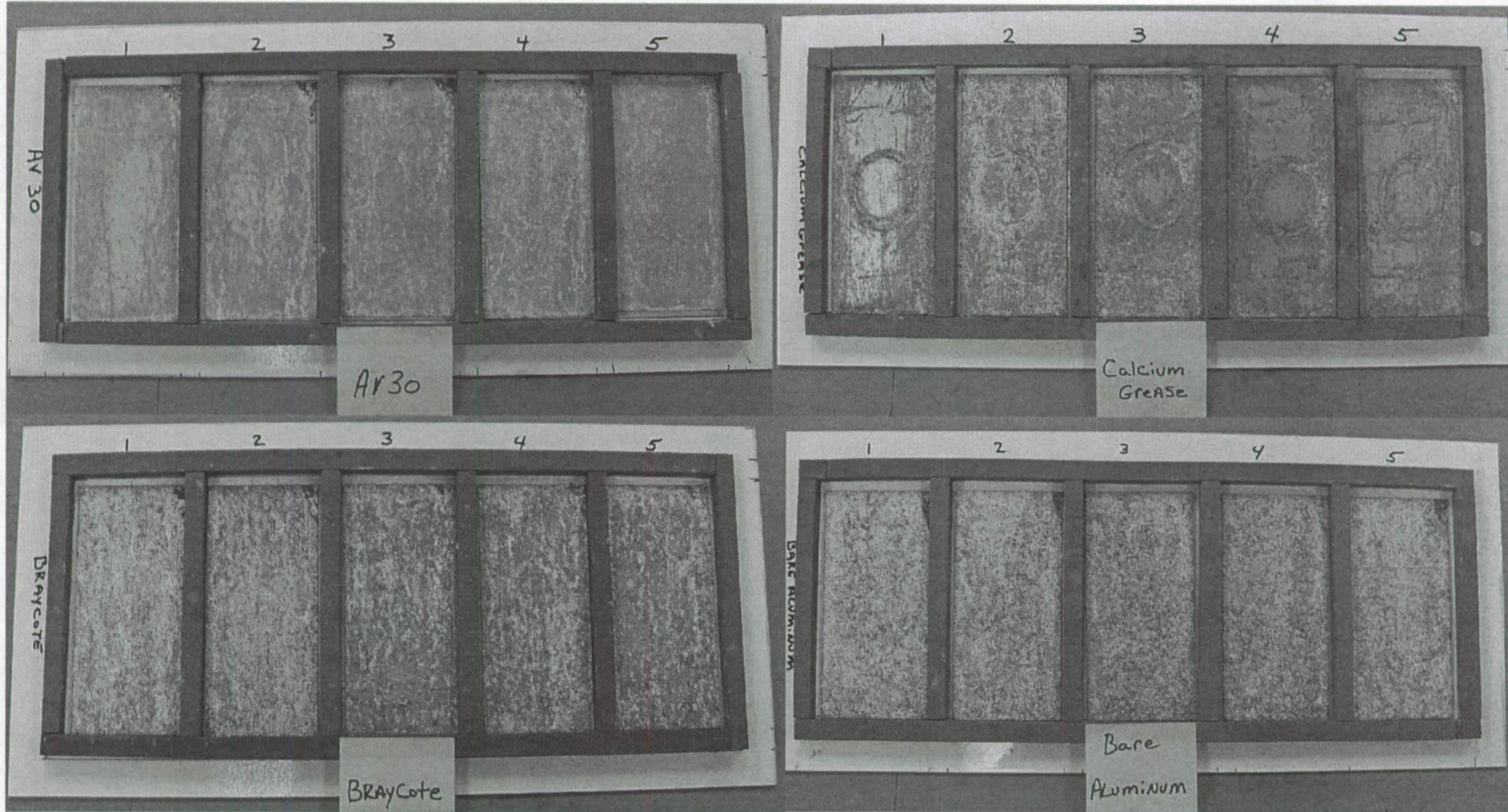
MSFC Samples After MC 1



MSFC Samples After MC 3



MSFC Samples After MC 5

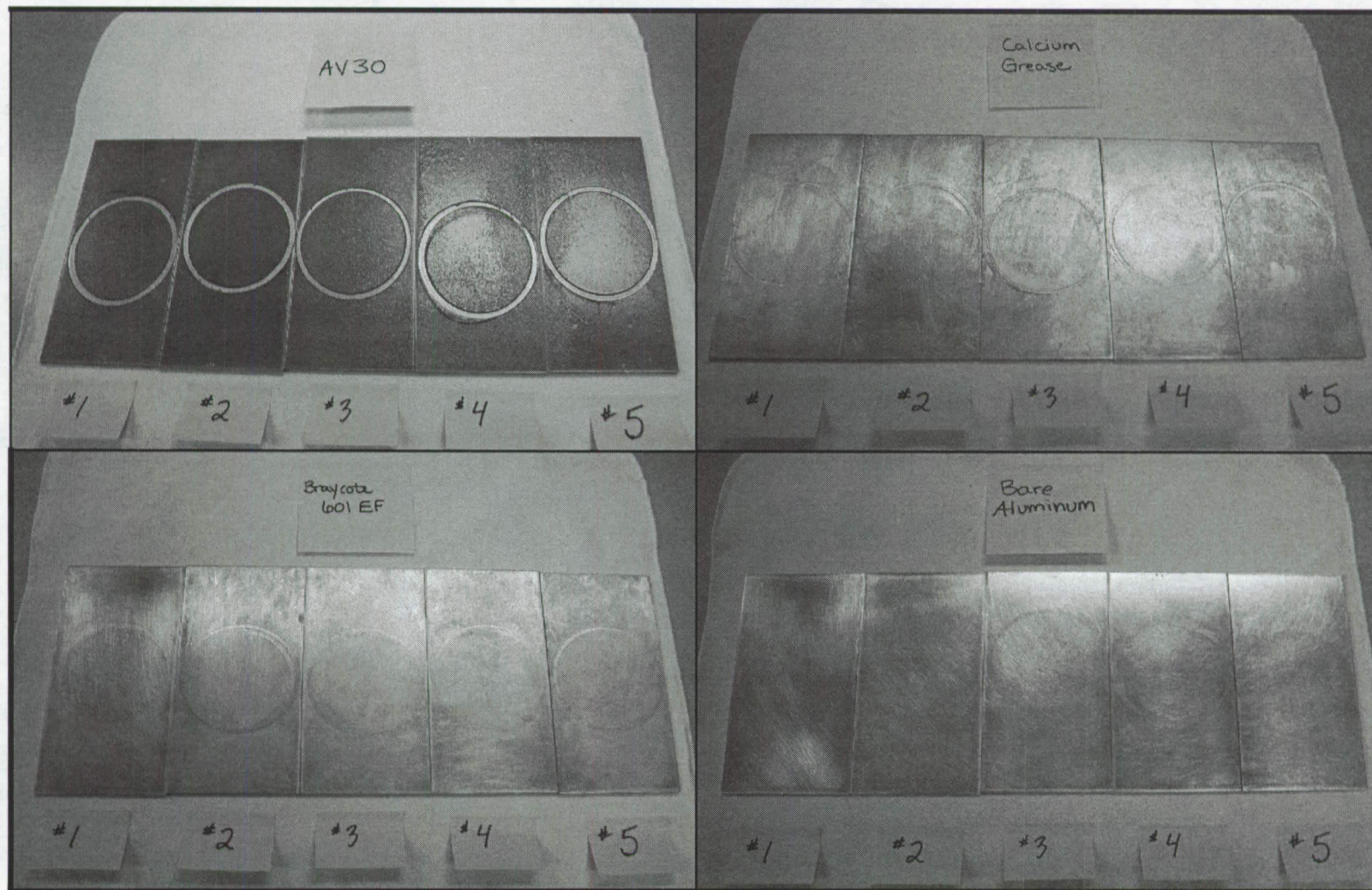


Visual Inspection on KSC samples

- **Ranking of specimen condition (best to worst):
AV-30 > Calcium Grease > Braycote > Bare Aluminum**

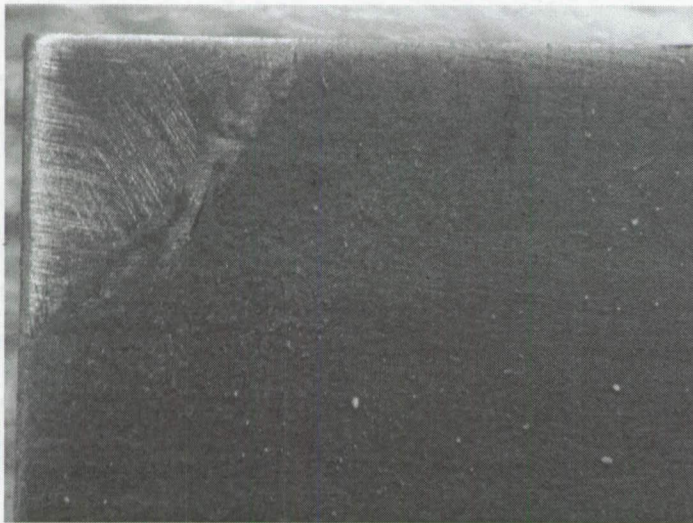
- **AV30 samples did not show any initiation of corrosion and coating was still in excellent condition after MC4**
- **Corrosion did not initiate on the Calcium grease coated coupon until ~ MC3**
- **Corrosion had initiated on the Braycote and Bare Aluminum samples after MC2**

KSC Samples Prior to Testing



AV-30 at KSC

- Coating was removed from corner of samples for inspection
- After MC2 and MC4, surface still in pristine condition and no evidence of corrosion noted
- Coating was easier to remove after MC 4 compared to MC 2



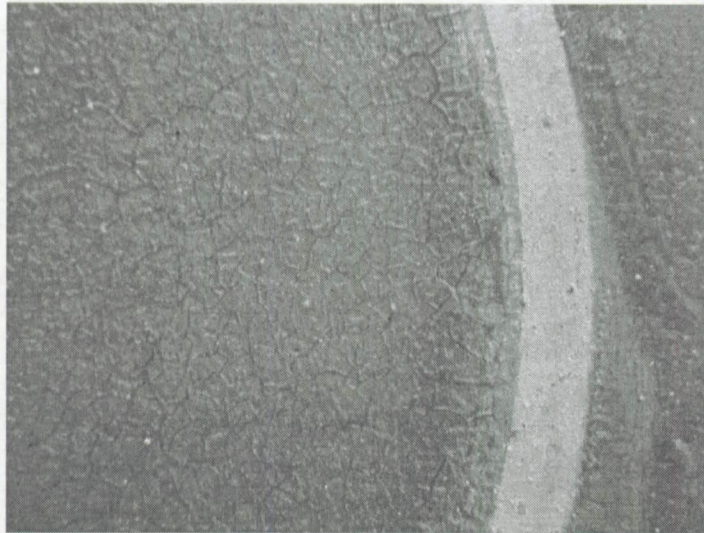
Close up after MC 2



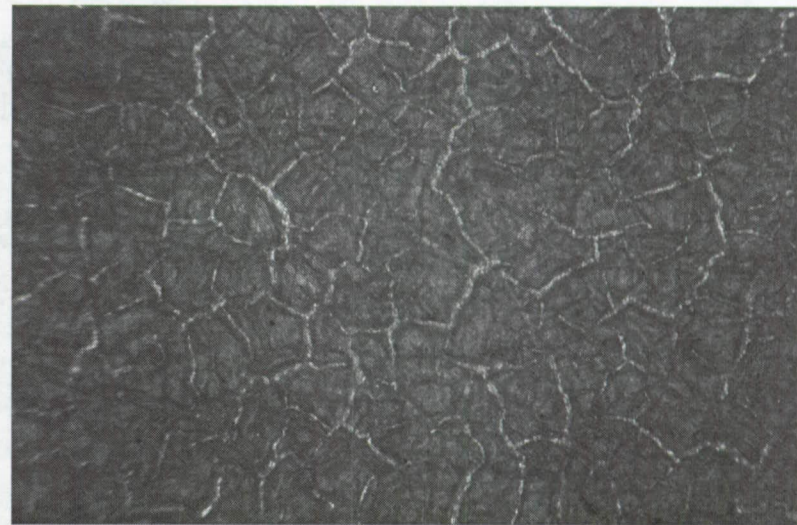
After MC 4 @ 30X

AV-30 at KSC

- The AV-30 began exhibiting a crazing effect as early as MC 2
- Crazing did not appear to expose the substrate
- Crazing more severe after 4 cycles



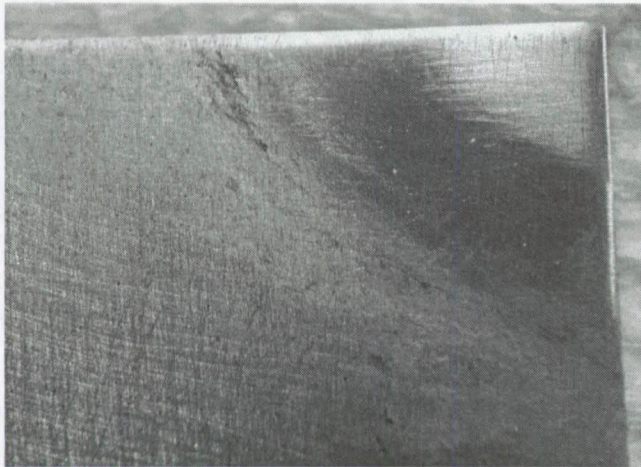
Close up after MC 2



Close up after MC 4

Calcium Grease at KSC

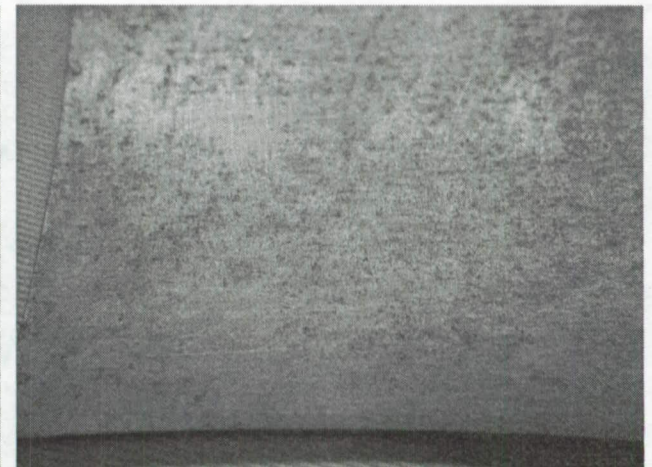
- Grease was removed from corner of samples for inspection
- After MC2 surface still in pristine condition and no evidence of corrosion noted
- Initial pitting was present after MC3
- Grease still adhered to the surface, areas with a heavier application were in better condition



Close up after MC2



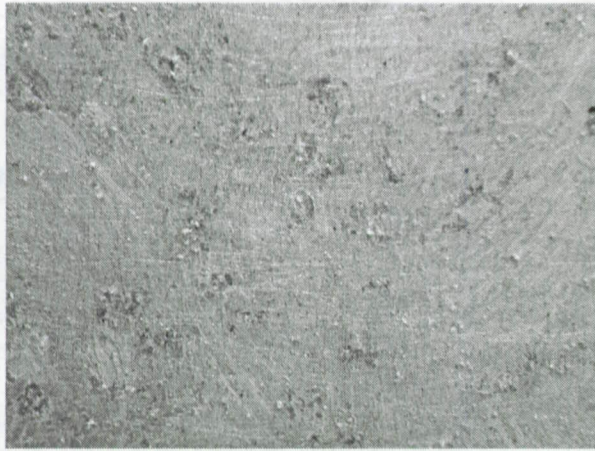
After MC2 @ 30X



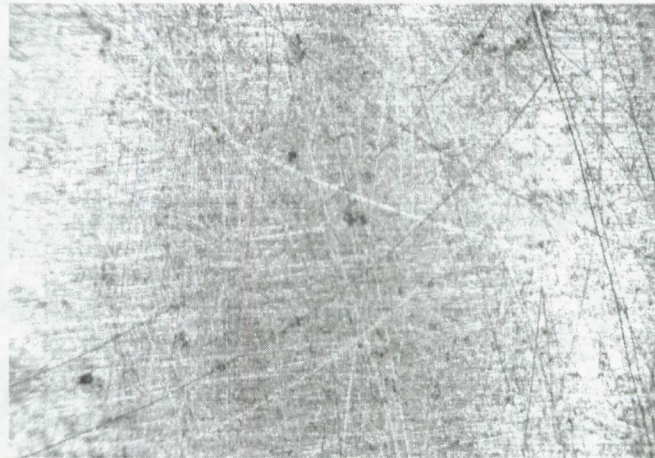
Close up after MC4

Braycote 601EF at KSC

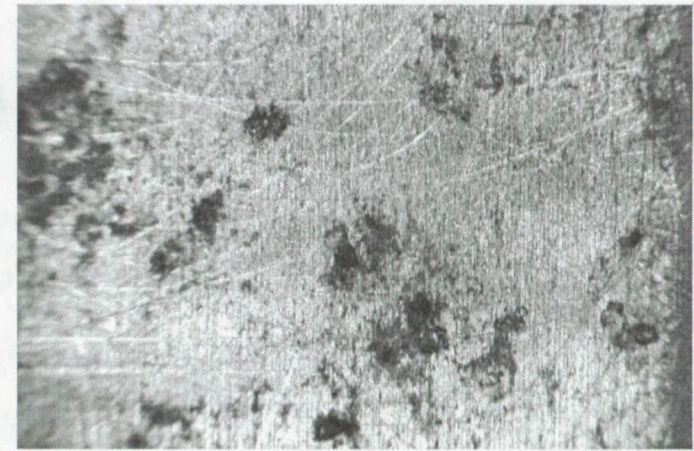
- After MC2 grease was still evident on the surface
- Contamination was stuck to the grease
- After MC2 initial pitting evident when inspected @ 30X
- Pitting was more severe after MC4



Close up after MC2



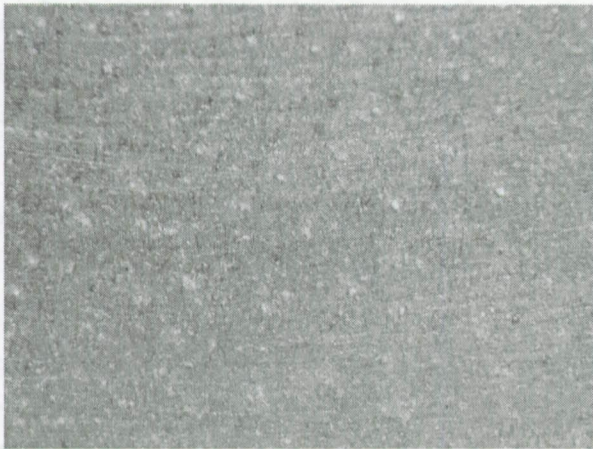
After MC2 @30X



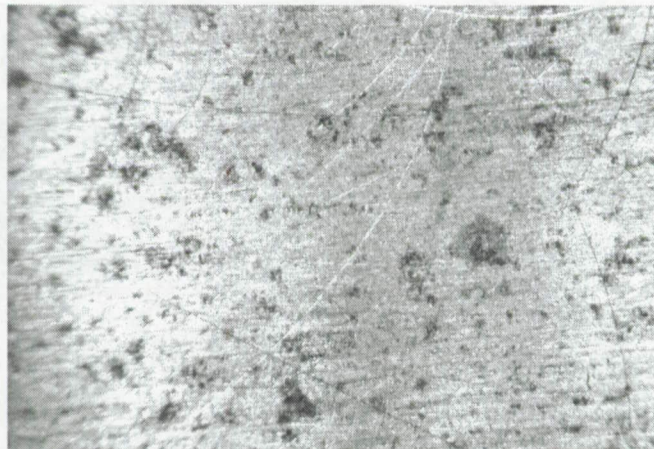
After MC4 @30X

Bare Aluminum at KSC

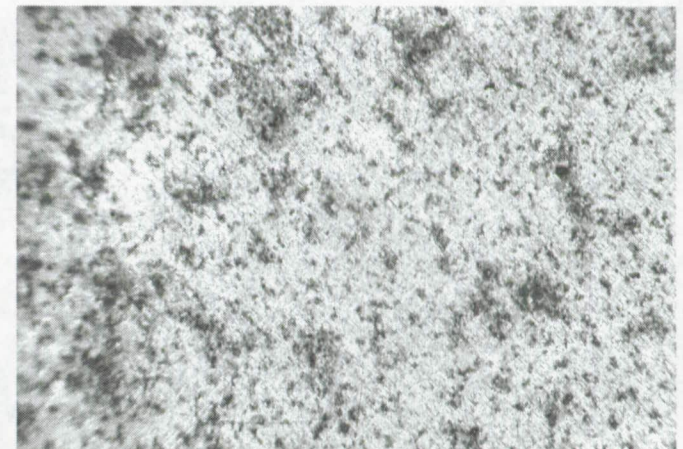
- Sand and dirt accumulated on the surface due to harsh beach environment
- Debris could also be Aluminum Oxide corrosion product
- Closer look of a cleaned corner taken @ 30X revealed pits forming during MC2, which became more severe after MC4



Close up after MC2



After MC2 @ 30X



After MC4 @ 30X

Conclusions

- Reapplication of CPCs after every mission is not necessary for AV-30 and Calcium Grease
- Based on MSFC EIS data and KSC visual inspections, AV30 was the best performing CPC
- AV-30 was effective in protecting against corrosion for 3 mission cycles
- Calcium Grease was effective in protecting against corrosion for 2 mission cycles
- Vacuum pressure environment does not appear to affect the level of protection provided by CPCs

Future Actions

- Implement a reapplication schedule to be used for each CPC based on testing results

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