
Identification Of Corrosion Protective Greases

Summary of Phase 1 & Recommendations For Phase 2

M&P PRT

9/06

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ISSUE:

- Available budget dictates that the list of 30 candidate greases should be narrowed down to the best 5

OBJECTIVE:

- Review phase 1 evaluation of a wide variety of greases & CPCs
- Provide rationale on why testing of 6 products should continue into phase 2



This Effort Addresses Two Grease-Related Concerns

BACKGROUND:

Issue #1

- **Conoco HD-2 grease is being discontinued by the manufacturer & no alternative is currently approved for Orbiter use**
 - Orbiter uses this product as a corrosion prevention compound (CPC)

Issue #2

- **The HD-2 is location limited because it is not vacuum stable**
 - The M&P community believes that a more vacuum stable (improved) version of the Conoco could be developed

Is there a CPC that is vacuum stable?

Products Screened For Stability & Corrosion Protection

BACKGROUND (Continued):

- **Testing of greases was funded in July using corrosion control budget**
- **Phase 1 effort evaluated the following properties;**
 - Weight loss
 - After 7 days ambient exposure
 - After 24 hours at 250F
 - After 24 hours at 450F
 - Physical properties at 400F (after .5, 1, 2, 5, 8, 10, 14, 20, & 44 hours)
 - Physical properties at 450F (after 24 hours)
 - Salt fog performance (1, 2, & 3 week exposures – except scribed panels)
 - 2024-T3 deoxidized aluminum panels covered with 5 mils of grease
 - 2024 deoxed Al panels w/5 mils of grease & baked 1 hr @ 400F
 - 2024 deoxed Al panels w/5 mils of grease & scribed (1 week test)
 - 2024 deoxed Al panels w/5 mils of grease & baked 1 hr @ 400F & scribed
 - Thermal cycling (separation test) 250F to -40F

27 Products (& 2 Controls) Were Evaluated in Phase 1

Sample #	Manufacturer	Product Code
1	Castrol	Conoco HD-2
2	Castrol	Braycote 194
3	Castrol	Braycote 601E/F
4	Castrol	GXL 682
5	Castrol	GXL 683
6	Castrol	GXL 684
7	Chemetall Oakite	Dinitrol AV 30
8	Christo-Lube	MCG 603
9	Christo-Lube	MCG 609AC
10	Christo-Lube	MCG 108RP
11	Christo-Lube	MCG 136
12	Christo-Lube	MCG 155
13	Dow Corning	DC 112
14	Dow Corning	Molykote 41
15	Dow Corning	High Vacuum Grease

Sample #	Manufacturer	Product Code
16	Dupont	Krytox LVP 228
17	Dupont	Krytox 240AC
18	Dupont	Krytox KDP-4666
19	Dupont	Krytox KDP-4667
20	Dupont	Krytox KDP-4668
21	Exxon Mobil	Mobilith SHC 220
22	Lear Chemical	ACF-50
23	Lektro-Tech	Super Corr A
24	MG Chemicals	846-80G
25	MG Chemicals	8463-7G
26	Nye	Rheolube 2000
27	PPG Aerospace	CA1000
28	Zip Chem/Andpak	Cor-Ban 35
29	Zip Chem/Andpak	D5029NS
30	Empty	None

Weight Loss Test Results Suggest Vacuum Stability

- 6 of the candidates performed as well or better than the Braycote 601 control
- Another 5 products were close to meeting the performance of the Braycote
- The remaining 16 products are not expected to meet vacuum stability

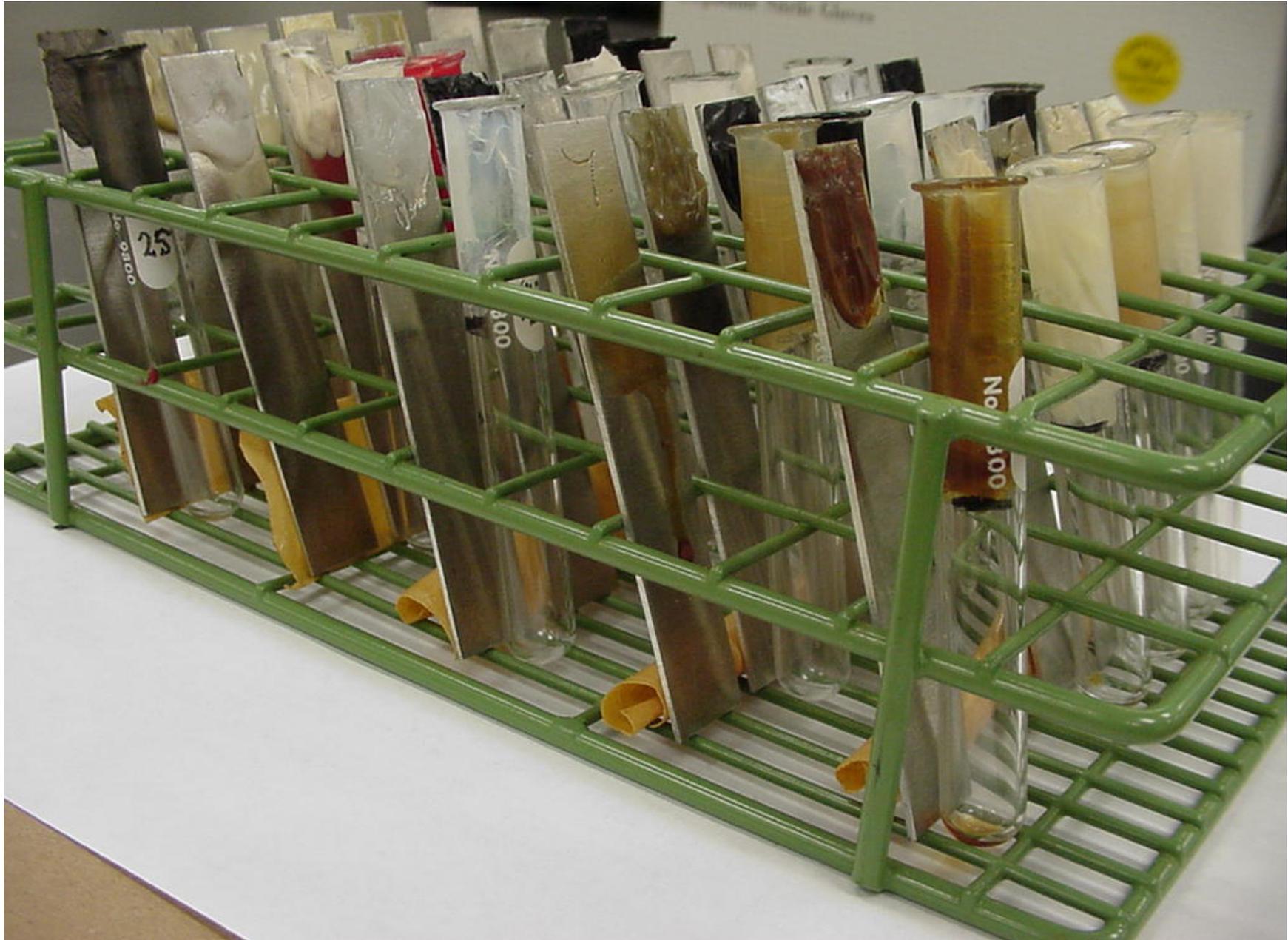
**Products that were
As good or better than the
Braycote 601 control**

**Christo Lube MCG 108RP
Christo Lube MCG 136
Christo Lube MCG 155
DuPont Krytox LVP 228
DuPont Krytox KDP-4666
DuPont Krytox KDP-4668**

**Products that performed
Slightly worse than the
Braycote 601 control**

**Dow Corning DC 112
Dow Corning High Vac Grease
DuPont Krytox 240AC
DuPont Krytox KDP-4667
MG Chem 8463-7G**

Thermal Cycle Oil Separation Test



Over Half The Products Resisted Oil Separation

- 9 of the candidates performed better than the Braycote 601 control
 - No oil separation after 10 cycles from -40F to 250F
- Another 8 products equaled the performance of the Braycote
 - First oil separation observed after 10 cycles from -40F to 250F
- The remaining products separated before 10 complete cycles

Products that were Better than the Braycote 601 control

Castrol GXL682
Castrol GXL683
Castrol GXL684
Christo Lube MCG603
Christo Lube MCG 609AC
Christo Lube MCG 108RP
DuPont Krytox LVP 228
Exxon Mobilith SHC220
PPG CA1000

Products that performed Slightly the same as the Braycote 601 control

Christo Lube MCG 136
Christo Lube MCG 155
DuPont Krytox KDP-4666
DuPont Krytox 240AC
DuPont Krytox KDP-4667
DuPont Krytox KDP-4668
MG Chem 846-80G
MG Chem 8463-7G

At Least 8 Products Can Handle 400F

- Candidate should not harden or separate out oil when exposed to 400F
 - 8 Products performed as well or better than the Conoco HD-2
 - 12 Products separated out oil
 - 7 Products hardened more than the HD-2

Products that performed As good or better than the Conoco HD-2 control

Castrol GXL682
Castrol GXL683
Castrol GXL684
Christo Lube MCG603
Christo Lube MCG 609AC
DuPont Krytox KDP-4668
MG Chem 8463-7G
MG Chem 846-80G

These products Separated out oil

Braycote 601
Christo Lube MCG 108RP
Christo Lube MCG 155
Christo Lube MCG 136
NYE Rheolube 2000
Dow Corning DC 112
DC Molykote 41
DuPont Krytox 240AC
DuPont Krytox LVP 228
DuPont Krytox KDP-4666*
DuPont Krytox KDP-4667
Exxon Mobilith SHC220

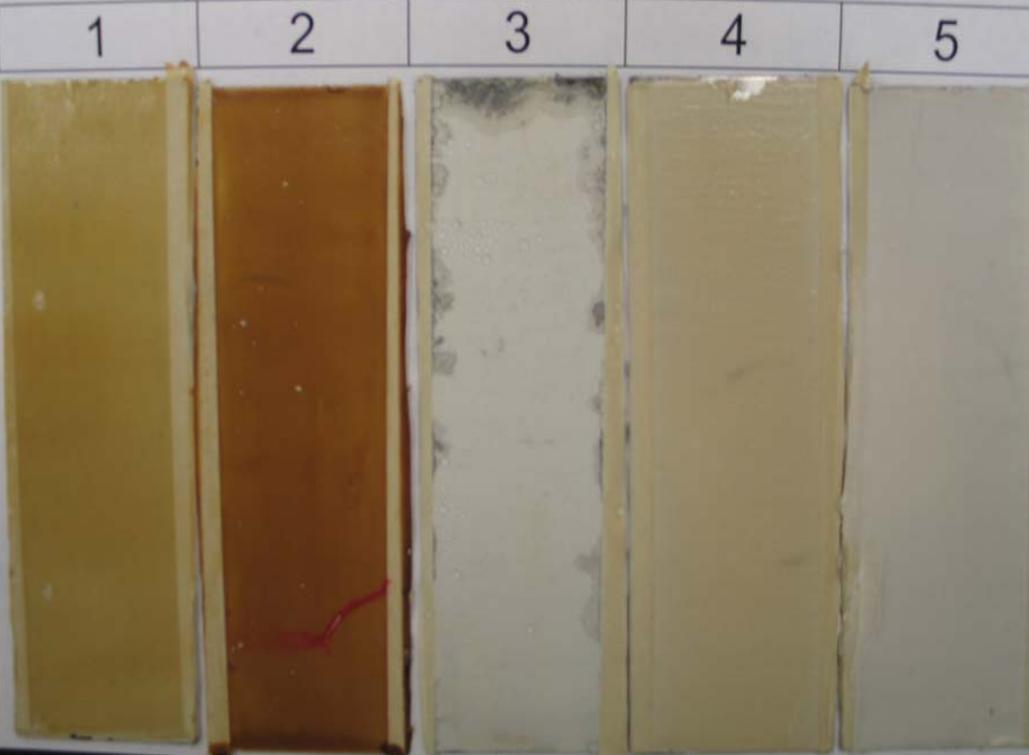
These products hardened

Castrol Braycote 194
Dinitrol AV30
Dow Corning High Vac Grease
Lear ACF-50
Lektro Super Corr A
Zip Cor Ban 35
Zip D5029NS

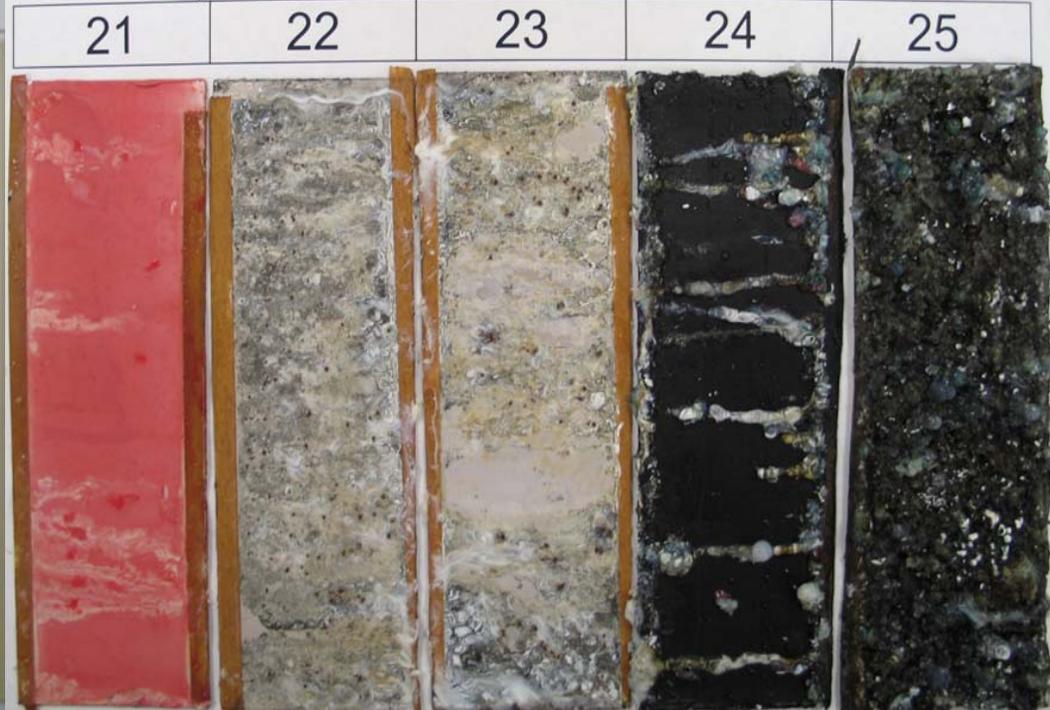
* Oil first observed after 20 hours at 400F

Salt Fog Test (Unscribed Panels)

Grease Exposed to Ambient Conditions
Then Exposed to Salt Fog for 336 Hours



Grease Exposed for 1 Hour at 400F
Then Exposed to Salt Fog for 336 Hours



Many Products Protected Unscribed Salt Fog Panels

- 10 of the candidates prevented corrosion as well or better than the Conoco HD-2 control
 - Conoco prevented all corrosion for 1000 hours
- 3 products were close to meeting the performance of the Conoco HD-2
 - Corrosion first appeared at 1000 hours
- The remaining products allowed corrosion before 1000 hours

**Products that were
As good or better than the
Conoco HD-2 control**

Castrol Braycote 194
Dinitrol AV30
Christo Lube MCG603
Christo Lube MCG 609AC
Dow Corning DC 112
DuPont Krytox LVP 228
DuPont Krytox KDP-4666
Exon Mobilith SHC220
PPG CA1000
Zip Cor Ban 35
Zip D5029NS

**Products that performed
Slightly worse than the
Conoco HD-2 control**

Castrol GXL682
DuPont Krytox 240AC
NYE Rheolube 2000

Salt Fog Test (Scribed Panels)



Fewer Products Protected The Scribed Salt Fog Panels

- 7 of the candidates prevented corrosion as well or better than the Conoco HD-2 control
 - Conoco protected 50% of the scribes
- 1 product was close to meeting the performance of the Conoco HD-2
 - NYE protected 25% of the scribes
- The remaining products allowed corrosion on all of the scribes (if not already dropped)

**Products that were
As good or better than the
Conoco HD-2 control**

Castrol Braycote 194
Castrol GXL682
Dinitrol AV30
Christo Lube MCG603
Christo Lube MCG 609AC
Exxon Mobilith SHC220
PPG CA1000

**Products that performed
Slightly worse than the
Conoco HD-2 control**

NYE Rheolube 2000

8 Products Have Potential for Use in Place of Braycote

Weight loss as good or better than the Braycote

Christo Lube MCG 108RP
Christo Lube MCG 136
Christo Lube MCG 155
DuPont Krytox LVP 228
DuPont Krytox KDP-4666
DuPont Krytox KDP-4668

Weight loss Slightly worse than the Braycote

Dow Corning DC 112
Dow Corning High Vac Grease
DuPont Krytox 240AC
DuPont Krytox KDP-4667
MG Chem 8463-7G

Good Separation & Wt. Loss Data

- Christo Lube MCG 108RP
- Krytox LVP228
- Christo Lube MCG 136
- Krytox KDP4666
- Krytox KDP4668
- Krytox KDP4667
- Krytox 240AC
- MG Chem 8463-7G

Separation better than Braycote

Castrol GXL682
Castrol GXL683
Castrol GXL684
Christo Lube MCG603
Christo Lube MCG 609AC
Christo Lube MCG 108RP
DuPont Krytox LVP 228
Exxon Mobilith SHC220
PPG CA1000

Separation same as The Braycote

Christo Lube MCG 136
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DuPont Krytox KDP-4666
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DuPont Krytox KDP-4667
DuPont Krytox KDP-4668
MG Chem 846-80G
MG Chem 8463-7G

4 Products Have Potential for Use in Place of Conoco

Good Heat & Salt Fog Performance*

- **Castrol GXL682**
- **Christo Lube MCG 603**
- **Christo Lube MCG 609AC**
- **Krytox KDP4666**

* Best salt fog performance from Exxon Mobilith SHC220

Unscribed salt fog equal or better than Conoco HD-2

Castrol Braycote 194
Dinitrol AV30
Christo Lube MCG603
Christo Lube MCG 609AC
Dow Corning DC 112
DuPont Krytox LVP 228
DuPont Krytox KDP4666
Exon Mobilith SHC220
PPG CA1000
Zip Cor Ban 35
Zip D5029NS

Heat performance equal or better than Conoco HD-2

Castrol GXL682
Castrol GXL683
Castrol GXL684
Christo Lube MCG603
Christo Lube MCG 609AC
DuPont Krytox KDP-4668
MG Chem 8463-7G
MG Chem 846-80G

Scribed salt fog equal or better than Conoco HD-2

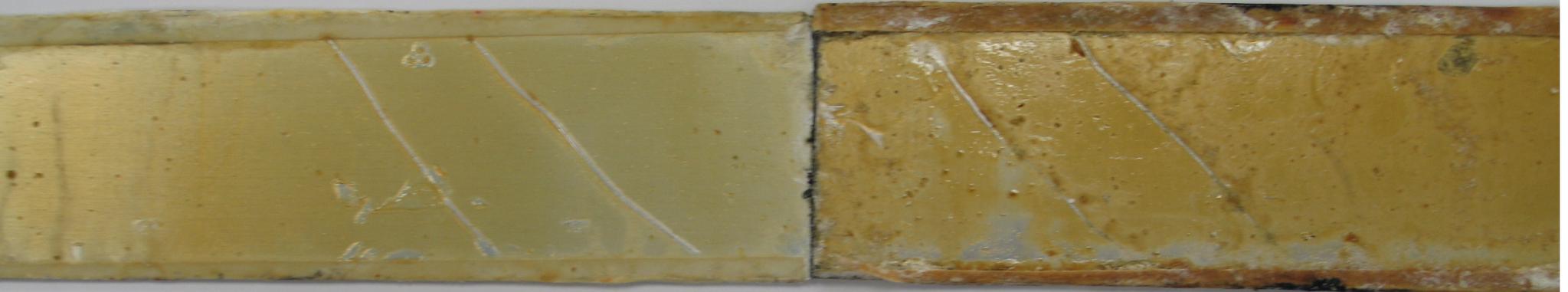
Castrol Braycote 194
Castrol GXL682
Dinitrol AV30
Christo Lube MCG603
Christo Lube MCG 609AC
Exxon Mobilith SHC220
PPG CA1000

1 Product May Fill Both Braycote & Conoco Applications

- **Krytox KD-4666 performed well in all but scribed salt fog**
 - Prevented corrosion for 1000 hours on unscribed panels
 - Same as Conoco
 - Braycote fails before 336 hours
 - Oil separation at 10 cycles = to Braycote (Conoco 6 cycles)
 - Heated weight loss 3 times better than Braycote (100 times better than Conoco)
 - Did not oil or harden after 14 hours at 400F (it oiled at 20 hours)
 - Conoco hardened at 20 hours
 - Braycote separated out oil after 90 minutes
 - Did allow corrosion in scribed panels
 - Conoco prevented corrosion in most scribes
- **Recommend the Krytox KDP-4666 be moved into Phase 2 for further evaluation**
 - Vacuum stability testing
 - Remaining MB0 specification testing

Krytox KDP-4666 Allowed Some Corrosion In Scribe

Conoco HD-2 Grease After 1000 Hrs Salt Fog



Ambient Exposure

1 Hr at 400F Exposure



Dupont Krytox KDP-4666 After 1000 Hrs Salt Fog

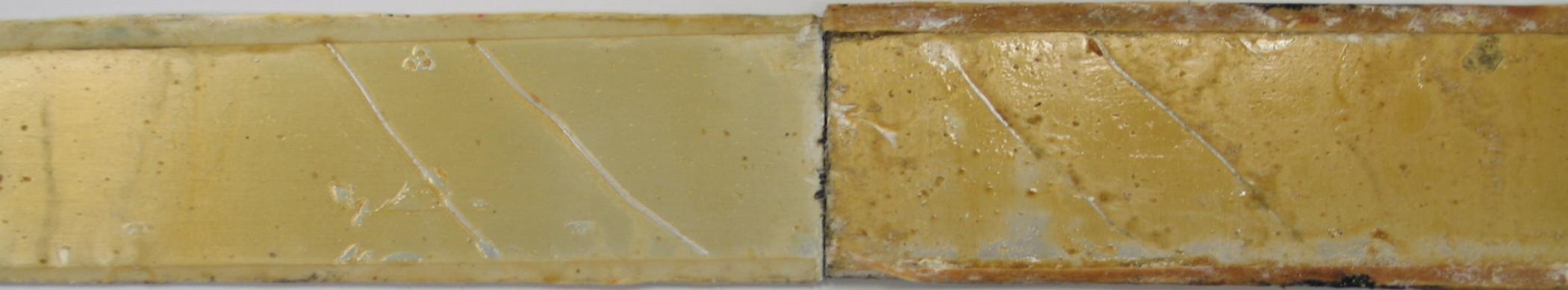
Recommend That Testing Continue On 5 Other Products

- **Consider 4 other Conoco substitutes (none expected to be vacuum stable)**
 - Christo Lube 603 & Castrol GXL 682
 - Good resistance to heat & separation
 - Good scribed & unscribed corrosion protection
 - Christo Lube 609AC
 - Performance almost equal to the 603, but may be more electrically conductive
 - Exxon Mobilith SHC 220
 - Best overall corrosion protection
 - Good separation resistance at 250F, but oils in 90 min at 400F
- **Consider 1 other Braycote substitute**
 - DuPont Krytox LVP 228*
 - Provided good salt fog performance on unscribed samples
 - Good weight loss data, but quick to separate out oil at temperature

* Replace with DC 112 if Krytox LVP 228 does not meet vacuum stability requirements, & the DC 112 does

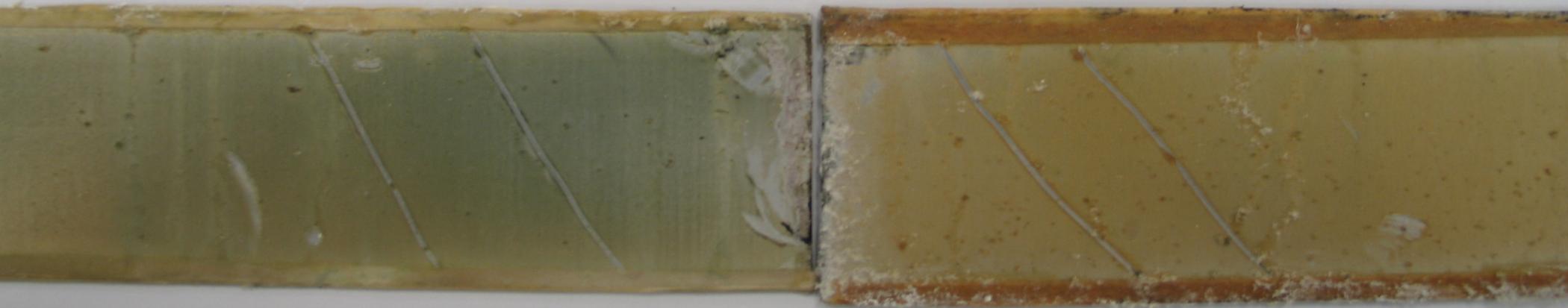
Christo Lube MCG 603 Performed as Well as Conoco

Conoco HD-2 Grease After 1000 Hrs Salt Fog



Ambient Exposure

1 Hr at 400F Exposure



Christo-Lube MCG 603 After 1000 Hrs Salt Fog

Christo Lube MCG 609AC Also Performed as Well as Conoco

Conoco HD-2 Grease After 1000 Hrs Salt Fog



Ambient Exposure

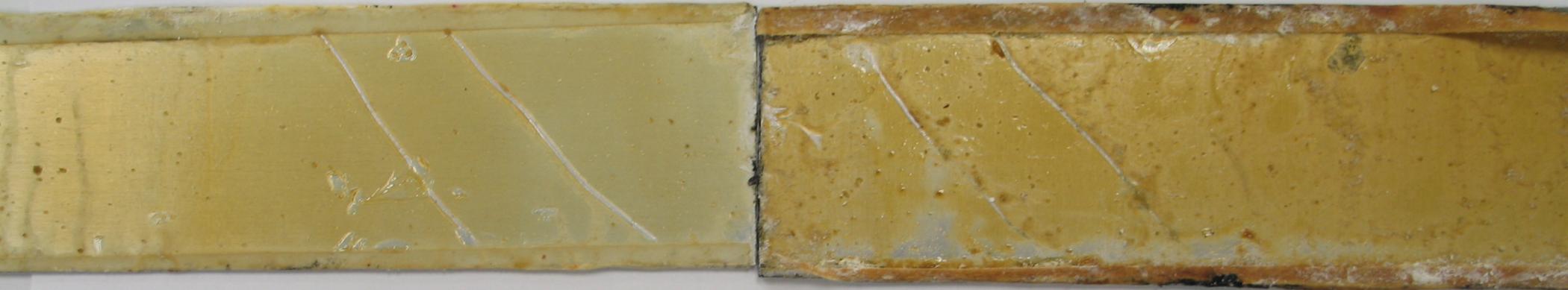
1 Hr at 400F Exposure

Christo-Lube MCG 609AC After 1000 Hrs Salt Fog



Exxon Mobilith Did Well In Salt Fog Testing

Conoco HD-2 Grease After 1000 Hrs Salt Fog



Ambient Exposure

1 Hr at 400F Exposure



Exxon Mobil Mobilith SHC 220 After 1000 Hrs Salt Fog

Krytox LVP 228 Allowed Some Corrosion In Scribe

Conoco HD-2 Grease After 1000 Hrs Salt Fog



Ambient Exposure

1 Hr at 400F Exposure



Dupont Krytox LVP 228 After 1000 Hrs Salt Fog

Summary

- **Phase 1 has been completed – 5 tests performed**
 - Weight loss at ambient & 400F
 - Thermal exposure at 400F up to 44 hours
 - Unscribed salt fog corrosion testing
 - Scribed salt fog corrosion testing
 - Oil separation with thermal cycle -40F to 250F

- **Six Products recommended for Phase 2 testing**
 - DuPont Krytox KD-4666
 - Appears to prevent corrosion & likely to be vacuum stable
 - Christo Lube 603 & Castrol GXL 682
 - Good alternatives to Conoco HD-2
 - Christo Lube 609AC
 - Conoco alternative that may be conductive
 - Exxon Mobilith SHC 220
 - Conoco alternative with excellent corrosion protection
 - DuPont Krytox LVP 228*
 - Potentail Braycote alternative

Back-Up

- MB0 Requirements
- Products & Services

Requirements In MB0140-011 Currently Control Orbiter Grease

- **Composition:** Grease shall contain no silicones, MoS₂, undesirable fillers or abrasive particles.
- **Corrosion Resistance:** ASTM B117 - 4 Panels - 2024 Non-clad Aluminum, Etched per MA0110-305, Coated with Continuous Film (10 Mils Max), Exposed for 1000 Hours in 5% Salt Spray – No Corrosion.
- **Heat Resistance:** Fed-Std-141 Test 6051: No Blistering, Cracking, Loss of Adhesion, or Other Film Failures.
- **Penetration:** ASTM D217 - 265 to 295 units of 0.1 mm
- **Dropping Point:** ASTM D2265 – Not less than 490F.
- **Contamination:** ASTM F312 - See MB0-Spec for Requirements with Nothing Above 125 Micron.
- **Shelf Life:** 36 Months after DOM, with Recert Option up to 24 Additional Months.

The Following Products & Services Will Be Provided In This Effort

- **Phase 1 Screening Tests**
 - **Product Review**
 - **Physical characterization & separation**
 - **Salt fog corrosion**
 - **Outgassing**

- **Phase 2 Qualification Tests**
 - **MB0140-011 Testing**
 - **Dissimilar metal corrosion testing**
 - **Electrical & water resistance testing**
 - **Outgassing in triplicate**

- **Report on Results**
 - **Final report**
 - **Final briefing to Program**