

2006 MOV Users' Group Meeting

MOV LONG LIFE GREASE CONDITION MONITORING UPDATE

**Ken Brown*, Utility Service Associates
Ted Austin, Forsythe Lubrication Associates
Wayne Mackwood, Chemtura Co.**

***Toll Free 888 442-5008**

BACKGROUND

**AT THE 2003 AND 2004 MUG MEETINGS INFORMATION
HAD BEEN PRESENTED ON HOW MOV LONG LIFE CALCIUM
SULPHONATE GREASE COMPARED AGAINST THE NOW
OBSOLETE CALCIUM COMPLEX GREASE AND OTHER
GREASES BEING USED IN THE GEARBOXES, LIMIT
SWITCHES AND ON THE STEMS OF LIMITORQUE
ACTUATORS.**

**THIS AND TESTING BY EPRI AND COG WENT OUT TO FIVE
YEARS AND WHILE SOME OTHER GREASES CHANGED
SIGNIFICANTLY, MOV LONG LIFE SHOWED LITTLE
DEGRADATION.**

TEN YEAR AGING

THE LACK OF DEGRADATION WAS VERY GOOD BUT TO GET A BETTER UNDERSTANDING OF WHAT CAN HAPPEN THE EQUIVALENT TIME INTERVAL WAS INCREASED TO TEN YEARS.

THE AGED MOV LONG LIFE GREASE WAS THEN SUBJECTED TO A SERIES OF TESTS THAT MIGHT BE APPLICABLE TO THE SMALL SIZED SAMPLES TAKEN FROM IN-SERVICE GEARBOXES.

THE DATA WAS PRESENTATED AT THE 2005 MEETING SHOWED VERY LITTLE CHANGE (THIS IS GOOD). MORE TESTING WAS DONE AND THIS IS NOW AVAILABLE.

TESTING

THE FIRST TESTS INCLUDED FOURIER TRANSFORM INFRARED (FTIR), HIGH PRESSURE DIFFERENTIAL SCANNING CALORIMETRY (HPDSC), AND BLOTTER CHROMATOGRAPHY.

THE EPRI AND COG DATA WAS ALSO REVIEWED TO SHOW WHAT TESTING HAD AND BEEN DONE AND TO PRESENT THEIR 5 YEAR AGING RESULTS.

THIS TIME WE ADDED THE DROPPING POINT, 4-BALL WEAR, TOTAL BASE NUMBER (TBN), PENETRATION BY THREE METHODS, RULER TESTING, RHEOLOGICAL TESTING AND FTIR AT A 2ND LAB.

NLGI GREASE GRADES

| GRADE | PENETRATION |
|-------|-------------|
| 000 | 445-475 |
| 00 | 400-430 |
| 0 | 355-385 |
| 1 | 310-340 |
| 2 | 265-295 |
| 3 | 220-250 |
| 4 | 175-205 |
| 5 | 130-160 |
| 6 | 85-115 |

WHY MORE TESTING?

- SOME STATIONS USE GREASE HARDENING (TO SOME VALUE) AS THE MAIN CRITERIA FOR CHANGE. NLGI GRADE 3 FOR EXAMPLE.
- WHILE IT MIGHT HAVE BEEN SUITABLE FOR THE DISCONTINUED CALCIUM COMPLEX GREASE THAT WAS PRONE TO AGE HARDENING, IT MIGHT NOT BE SUITABLE FOR OTHER THICKENER SYSTEMS.

177°C (350°F) FOR 66 HOURS

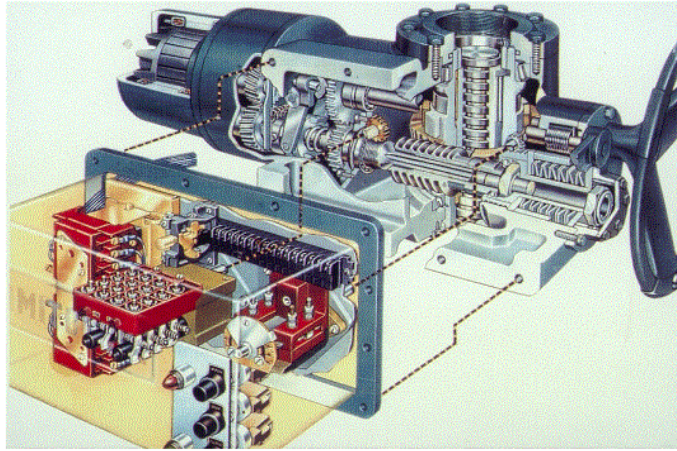


**Previous Calcium Complex
HARD**

177°C (350°F) FOR 66 HOURS



**MOV Long Life Grade 0
STILL GREASE-LIKE**



EPRI TEST CONDITIONS

'COMPARATIVE ANALYSIS OF NEBULA AND MOV LONG LIFE FOR LIMITORQUE MAIN GEARBOX APPLICATIONS', REPORT #1003483, DECEMBER 2002

AGING:

BULK -300 HOURS AT 150°C (300°F)

THIN FILM – 100 HOURS AT 150°C (300°F)

BULK AGING SAID TO BE EQUIVALENT TO 27 YEARS AT 54°C (130°F) OR 84 YEARS AT 38°C (100°F). APRIL 19/05

THIN FILM STEAM FOR 24 HOURS AT 150°C (300°F)

PLUS 220 MRAD AND EQ (MODIFIED RBOT)

EPRI GREASE TESTS

- **WORKED PENETRATION: 1/4 AND 1/2 SCALE**
- **WEIGHT LOSS AFTER AGING**
- **DROPPING POINT (ASTM D2265)**
- **INFRARED (FTIR) TRACES**
- **DIFFERENTIAL SCANNING CALORIMETRY (HPDSC)**
- **RHEOMETER STUDIES – YIELD STRESS**
- **PIN-ON-DISC (POD), FRICTION & WEAR STUDIES**

COG (CANDU OWNERS GROUP) TESTING

SAMPLES OF MOV LONG LIFE AND THE DISCONTUNUED CALCIUM COMPLEX GREASE* WERE TO BE AGED FOR 660 HOURS AT 130°C (266°F) PLUS 70 MRAD AND LOCA CONDITIONS OF 6 HOURS IN 171°C (340°F) AND 105-KPA (15-PSI) STEAM.

THE AGING WAS TO SIMULATE 5 YEARS OF SERVICE AT TEMPERATURES UP TO 80°C (176°F) FOLLOWED BY A LOSS OF COOLANT ACCIDENT.

*** FAILED IN 3½ YEARS.**

COG TESTS

- PENETRATION (ASTM D-1403)
- RHEOMETRY (BROOKFIELD R/S CONE/PLATE)
- BASE NUMBER
- FOUR BALL WEAR TEST (ASTM D-2266)
- APPEARANCE
- EVAPORATION LOSS (ASTM D-972)
- DROPPING POINT (ASTM D-2265)
- INFRARED
- ROLL COMPATIBILITY (ASTM D-1831)

TEST SAMPLE SIZES

| | |
|--------------------------------|---------|
| ■ APPEARANCE | SMALL |
| ■ FTIR | TRACE |
| ■ RULER | 0.2 ML |
| ■ HPDSC | 1 or 2G |
| ■ TACTILE STIFFNESS | SMALL |
| ■ BLOTTER TEST | SMALL |
| ■ RHEOMETRY | SMALL |
| ■ DROPPING POINT | 5G |
| ■ BASE NUMBER | 20G |
| ■ EVAPORATION LOSS | 25ML |
| ■ OIL SEPARATION | 100G |
| ■ PENETRATION: 1/4 & 1/2 SCALE | 100G |
| ■ FOUR BALL WEAR | 200G |
| ■ DELETERIOUS PARTICLES | 200ML |
| ■ PENETRATION: FULL SCALE | 1LB |
| ■ PIN-ON-DISC (POD) | 1OZ |

WHAT WAS DONE

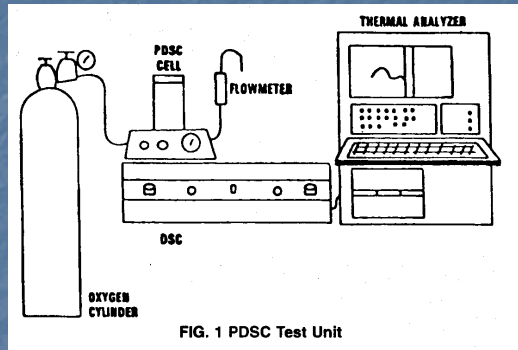
THE EQUIVALENT IN-SERVICE TIME INTERVAL WAS INCREASED BY 50% AND THEN 100% MORE THAN THAT USED BY EPRI.

THIS WAS TEN YEARS EQUIVALENT AND WAS PERFORMED AT HERGUTH LABORATORIES IN CALIFORNIA.

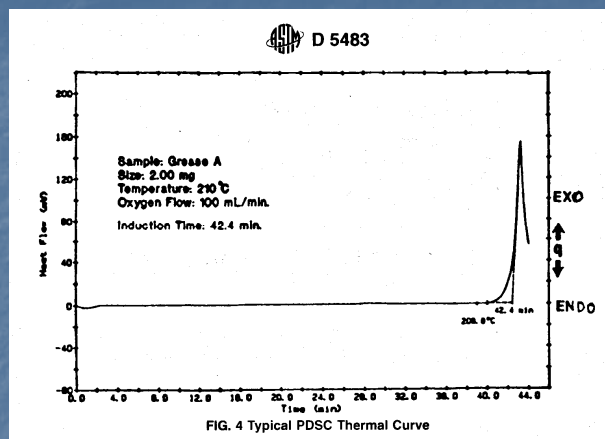
SAMPLES WERE HEATED AT 150°C (300°F) FOR 300, 450 AND 600 HOURS.

TESTS - HIGH PRESSURE DIFFERENTIAL SCANNING CALORIMETRY (HPDSC)

THIS DETERMINES THE OXIDATION INDUCTION TIME (OIT) OF LUBRICATING GREASES SUBJECTED TO OXYGEN AT TEST CONDITIONS OF 3.5 MPA (500 PSIG) AND TEMPERATURES BETWEEN 155 AND 210°C.



HPDSC



OXIDATION INDUCTION TIME

HPDSC

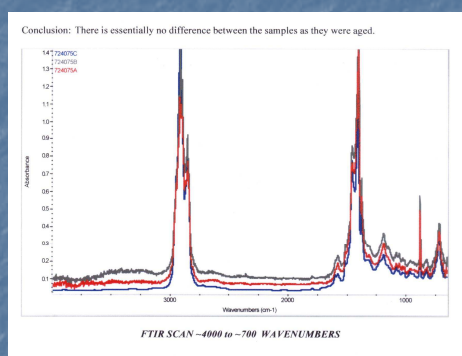
| HPDSC TEST TEMPERATURE | AGING* | OIT (MINUTES)** |
|------------------------|--------|-----------------|
| 200°C (392°F) | NONE | 24 |
| 210°C (410°F) | 300 | 28.82 |
| 210°C (410°F) | 450 | 28.78 |
| 210°C (410°F) | 600 | 28.77 |

HERGUTH - NOVEMBER 04 (batch K-7-23)

* TIME AT 150°C (300°F)

** OXIDATION INDUCTION TIME (LONGER IS BETTER)

TESTS - FTIR

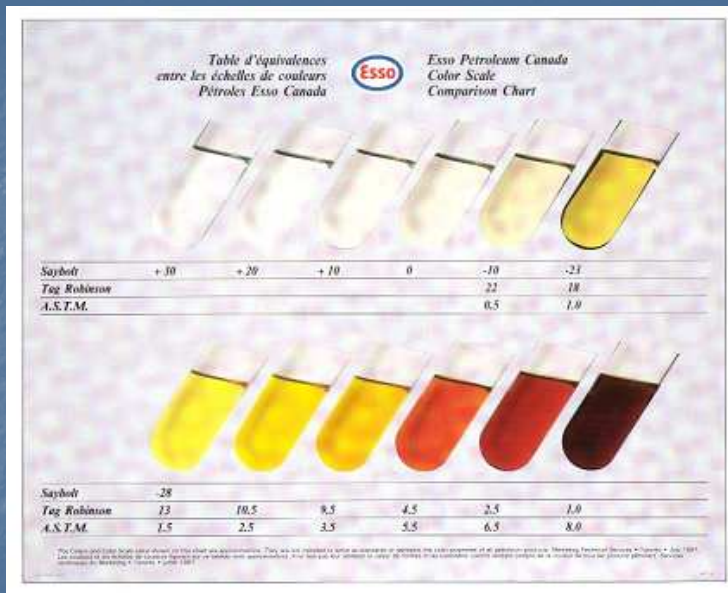


SHOWING NO OBVIOUS
DEGRADATION AFTER AGING

TESTS- BLOTTER



FRESH AND THREE AGED SAMPLES
(LEFT FOR 5 HOURS AT ROOM TEMPERATURE)



10 YEAR AGING RESULTS

BASED ON HPDSC, FTIR AND APPEARANCE, BLOTTER AND TACTILE TESTING EVEN AFTER 10 YEARS EQUIVALENT AGING, MOV LONG LIFE DID NOT SHOW SIGNIFICANT DEGRADATION.

THIS IS EXCELLENT AND FURTHER TESTING WAS PERFORMED TO HELP IDENTIFY A GOOD MOV LONG LIFE IN-SERVICE TEST.

TESTS - DROPPING POINT

| SAMPLE | DROPPING POINT (ASTM D-2265) °C (°F) |
|----------------|--|
| NEW | 318° (605°) |
| 300 HOURS AGED | 318° (605°) |
| 450 HOURS AGED | 318° (605°) |
| 600 HOURS AGED | 318° (605°) |

AGING WAS DONE AT 150°C (300°F)

TESTS - 4-BALL WEAR

| SAMPLE | 4-BALL WEAR (ASTM D-2266) Scar (mm) |
|----------------|---|
| NEW | 0.45 |
| 300 HOURS AGED | 0.43 |
| 450 HOURS AGED | 0.45 |
| 600 HOURS AGED | 0.44 |

AGING WAS DONE AT 150°C (300°F)

TESTS - FTIR (SUPPLIER)

| SAMPLE | FTIR |
|----------------|-----------|
| NEW | NORMAL |
| 300 HOURS AGED | NO CHANGE |
| 450 HOURS AGED | NO CHANGE |
| 600 HOURS AGED | NO CHANGE |

AGING WAS DONE AT 150°C (300°F)

TESTS - TOTAL BASE NUMBER

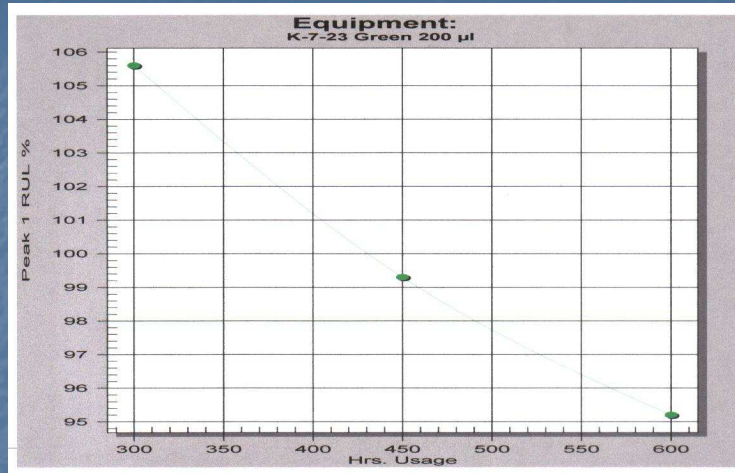
| SAMPLE | TBN (ASTM D-974) | |
|----------------|---------------------|--------|
| | 7 pH | 9.4 pH |
| NEW J-5-3 | 37.35 | 10.72 |
| NEW K-11-4 | 37.63 | 7.08 |
| NEW K-7-23 | 35.96 | 7.25 |
| 300 HOURS AGED | 36.29 | 7.87 |
| 450 HOURS AGED | 35.92 | 7.78 |
| 600 HOURS AGED | 36.96 | 6.92 |

AGING WAS DONE AT 150°C (300°F)

TESTS - RULER



600 HOURS AGING RESULT

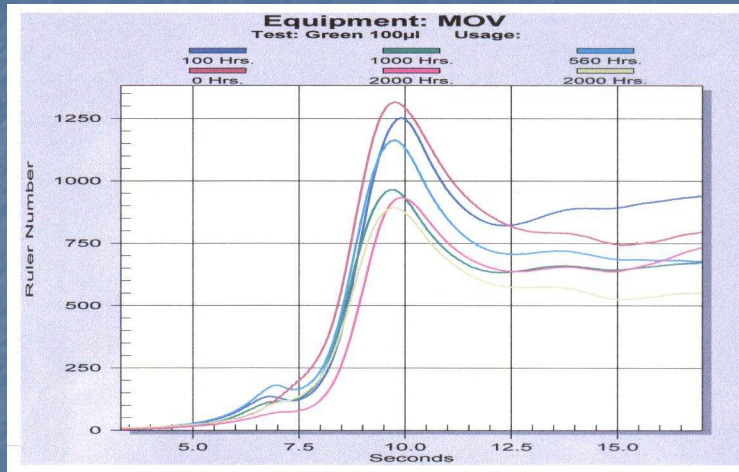


AGED GREASE RULER RESULTS

RULER TESTING (GREEN SOLVENT)

| SAMPLE | ADDITIVE RUL#1% |
|----------------|--------------------|
| NEW K-7-23 | 100 |
| 300 HOURS AGED | 95.2 |
| 450 HOURS AGED | 93.7 |
| 600 HOURS AGED | 82.7 |

AGING WAS DONE AT 150°C (300°F)



OTHER MOV LONG LIFE RULER RESULTS



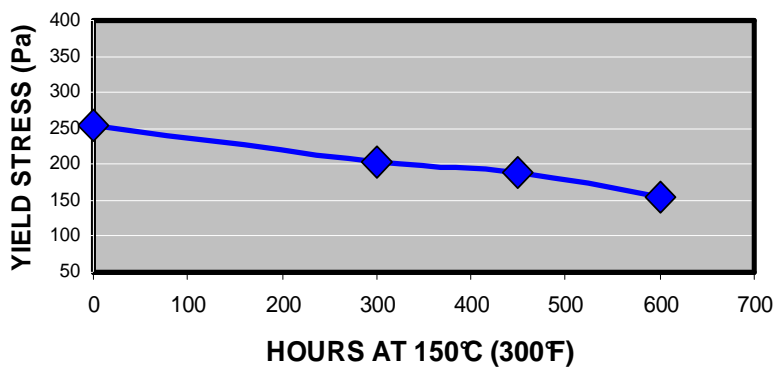
R/S RHEOMETER

RHEOMETER TESTING

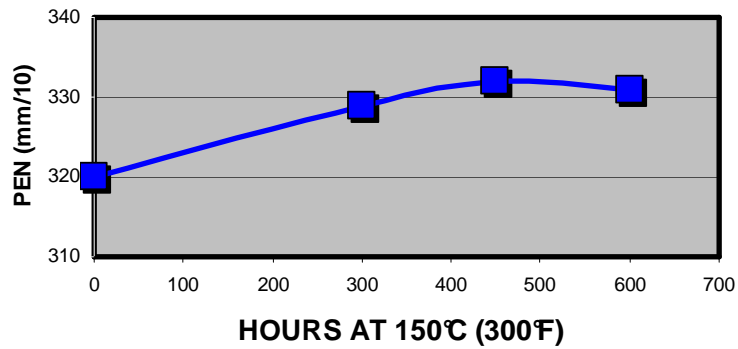
| SAMPLE | YIELD POINT (Pa) | Plastic Viscosity (Pa·s) | Est'd Pen | Grease Pen 1/4 scale | Grease Pen Full Scale |
|----------------|------------------|--------------------------|-----------|----------------------|-----------------------|
| NEW J-5-3 | 256 | 37.7 | 320 | 328 | - |
| NEW K-11-4 | 254 | 43.3 | 320 | 320 | - |
| NEW K-7-23 | 253 | 44.9 | 321 | 305 | 320 |
| 300 HOURS AGED | 202 | 42 | 335 | 332 | 329 |
| 450 HOURS AGED | 188 | 40.3 | 339 | 335 | 332 |
| 600 HOURS AGED | 155 | 38.3 | 352 | 339 | 331 |

AGING WAS DONE AT 150°C (300°F)

AGED MOV LONG LIFE YIELD STRESS



AGED MOV LONG LIFE - PENETRATION



ESTIMATED SERVICE LIVES

| TEMPERATURE | | LIFE | |
|-------------|-----|---------|-------|
| °F | °C | HOURS | YEARS |
| 302 | 150 | 600* | 0.07 |
| 284 | 140 | 1200 | 0.14 |
| 266 | 130 | 2400 | 0.27 |
| 248 | 120 | 4800 | 0.55 |
| 230 | 110 | 9600 | 1.1 |
| 212 | 100 | 19200 | 2.2 |
| 194 | 90 | 38400 | 4.4 |
| 176 | 80 | 76800 | 8.8 |
| 158 | 70 | 153600 | 17.5 |
| 140 | 60 | 307200 | 35 |
| 122 | 50 | 614400 | 70 |
| 104 | 40 | 1228800 | 140 |

* PREVIOUS GREASE WAS DEAD AT <300 HOURS

CONCLUSIONS

1. EVEN WHEN AGED AT TWICE AS LONG AS THE EPRI CRITERIA, MOV LONG LIFE DID NOT SHOW SIGNIFICANT DETERIATION IN PERFORMANCE BASED LAB TESTS.

2. WHEN AGED, MOV LONG LIFE TENDS TO SOFTEN SLIGHTLY RATHER THEN HARDEN CONSIDERABLY AS DID THE NOW OBSOLETE CALCIUM COMPLEX GREASE.

3. THE TESTS THAT SHOW SOME DIFFERENCES AFTER SEVERE AGING ARE COLOR, BLOTTER CHROMOTOGRAPHY, RULER AND YIELD STRESS. THE TBN DID AS WELL DEPENDING ON THE END POINT USED.

4. THE TESTS THAT DID DETECT CHANGE REQUIRE VERY LITTLE GREASE AND CAN BE SUITABLE FOR IN-SERVICE CONDITION MONITORING.

CANDIDATE IN-SERVICE TESTS ON SMALL SAMPLES

- **COLOR**
- **BLOTTER CHROMATOGRAPHY**
- **RULER**
- **YIELD STRESS**

- **TOTAL BASE NUMBER**
- **WEAR METALS**

HELPFUL DOCUMENTATION

EQ – 'EPRI 'COMPARATIVE ANALYSIS OF NEBULA AND MOV LONG LIFE FOR LIMITORQUE MAIN GEARBOX APPLICATIONS', REPORT #1003483, DECEMBER 2002

USE – MOV USERS' GROUP POSITION PAPER 'EQUIVALENT REPLACEMENT EVALUATION FOR MOV GEARBOX LUBRICANT', E. CAVEY, MUG FILE 02G-J01, MAY 2002

STEMS – INEEL 'MOV STEM LUBRICANT AGING RESEARCH', K. DEWALL & J. WATKINS, INEEL/EXT – 02-00975, SEP 02. SEE ALSO MUG FILE 03J-P21, HANDOUTS JAN 2003

ROL – 'RATE OF LOADING', F. BENSINGER (FLOWSERVE), MUG FILE 03J-P07, HANDOUTS JAN 2003

GEN – 'ALL-IN-ONE, AN UPDATE ON MOV LONG LIFE', K. BROWN ET AL, MUG FILE 03J-P04, HANDOUTS JAN 2003

'MOV LONG LIFE LIMITSWITCH APPLICATIONS, K. BROWN ET AL, MUG FILE 04J-P07 & P11, JAN 2004

MOV LONG LIFE CONDITION MONIITORING, K, BROWN ET AL, JAN 2005