MUG

MOV Users' Group

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MOV Long Life Limit Switch Applications

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Abstract: At the 2003 meeting information had been presented on how MOV Long Life could be used in all three applications on Limitorque valve actuators. This included the main gearbox, the stems and the limit switch. The paper demonstrated that MOV Long Life offered improved performance over the now obsolete calcium complex grease and over other products. To get a better understanding of the relative strengths of the greases additional testing was done at independent laboratories and at Crompton. This included Navy Gear Wear Testing, anti-scuff, oil bleeding and salt fog corrosion. As well, MOV Extra for commercial actuators and in particular EP00 with much improved low temperature performance has been evaluated for the main gearbox applications. Compatibility testing of MOV Long Life with a lithium grease being used by one utility was also examined. In summary it was found that the calcium sulphonate greases did very well. This work also leads us to believe that the use of some of the greases suggested by others might require careful review for specific applications.

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Background

The now obsolete calcium complex grease had been used for years in the Limitorque main gearboxes and while it had some performance issues, it was generally believed that these were tolerable. In developing a replacement product, the first hurdle was determining which tests, of the multitude available, most closely represent the actual performance requirements for this application. The intent was to meet or exceed the performance of the previous grease in all the important parameters. Of the many grease thickeners available, calcium sulphonate technology[1-4] had many advantages and it had been suggested[5] in 1996 as being suitable for the three Limitorque actuator applications. In the case of nuclear plants, performance testing had to take into account both normal in-service and upset conditions. These conditions have been studied by COG[6] and EPRI[7] in which MOV Long Life grease based on this technology did better than the obsolete calcium complex grease and was recommended. The Limitorque approval for MOV Long Life, a calcium sulphonate grease, formulated for nuclear applications, is given in Reference 8.

With the work for nuclear applications near complete, the focus has shifted to the main gearbox used in commercial applications and for operating at low temperatures. Plus, while data was given at the 2003 MOV Users Group Meeting[9] there was a need to get more results for the limit switch application, for mixing in the main gearbox with greases other than the calcium complex grease and for other actuator types. Some of these use a stiffer NLGI Grade 2. For a Limitorque actuator see Figure 1.

As before the desired characteristics include; good wear or antiscuff performance, low oil bleed, good mechanical stability, good corrosion protection and good resistance to water. For commercial actuators add good low temperature properties. It would also be an advantage if the same grease could be used to lubricate the two gearboxes on Limitorque valve actuators and the stems. For the stems, testing by others at elevated temperatures and rate of loading effects were also given at the 2003 meeting[10,11] and a calcium sulphonate grease did very well in comparison.

The benefits of just one grease could include: simplified inventories, less chance of mixing incompatible greases, an improvement in performance, and possibly less maintenance. In addition, for nuclear plants if a qualified grease is used for all applications then there will be less chance of a non-qualified grease being used on safety related equipment.

In this paper the test comparisons for the main gearbox would be with the calcium complex grease and with replacement products recommended by others. For the limit switch application it would with a clay thickened polyalphaolefin based grease. An alternative lithium thickened synthetic base fluid grease is used to a lesser extent but there is already an NRC advisory[12] limiting its use to lower temperatures because of hardening.

Results

1. Navy Gear Wear Testing

This is Federal Standard 791, Method 335 called the FTM Gear Wear or Navy Gear Wear test. It uses a 1.1 cm brass gear meshing at right angles with a 1.2 cm steel gear. The reciprocal motion of the gears results in a measure as wear of a lubricants ability to protect the metals under dynamic load. This test was chosen because it is one of the few gear tests that has been standardized and which is suitable for greases. The current products were run as well as different NLGI grades of MOV Long Life. In addition, tests were done on MOV Extra. It was developed for commercial actuators and features a less viscous base oil for improved mobility at low temperatures.

MOV Long Life showed acceptable wear, see Table 1, and approached that of other premium products as well as meeting the requirements given in a MIL specification. For example, MIL-PRF-23827C, 'Grease, Aircraft and Instrument, Gear, and Actuator Screw' has wear limits of –2.5 g and –3.5 g after 1,000 cycles for 5 lb and 10 lb respectively. MOV Long Life and MOV Extra were well below these values and showed acceptable wear similar to the now obsolete calcium complex grease. It was also found that a stiffer grease, MOV Long Life NLGI Grade 2, also did just as well. MOV Extra and the clay grease are both formulated with a lower viscosity base oil, which can be a problem, but the wear results show that with the right formulation such greases can perform well. This data also correlates with field service reports that indicate that as long as the grease does not stiffen excessively, wear may not be an issue.

2. Wear and EP Testing

Two of the more common extreme pressure (EP) tests for greases are the Timken OK Load (ASTM D-2509) and the 4 Ball EP test (ASTM D-2596). A similar 4 Ball Wear test (ASTM D-2266) is used to measure wear. Timken OK Load and the 4 Ball EP tests were run with the results given in Table 2. For MOV Long Life, data for both a Grade 1 and a Grade 2 are given while the clay thickened grease is only available as Grade 1½. This is between the official NLGI grades.

The data shows that the clay grease is certainly not an EP grease because it has a very low Timken OK Load result of 12 lb versus 60 lb for the MOV Long Life greases. A grease can be considered an EP grease when the Timken OK Load is more than 25 lb. The 4 Ball Wear EP test data and the manufacturer's 4 Ball Wear for the clay grease were also not very good. These tie in with the poor ratings in the EPRI pin on disk testing for this grease. However, the intended application for this grease is in ball bearings seeing extreme temperatures, for which it is apparently well suited.

Table 3 provides explanations for the numbers in general and the comparative numbers for the clay grease and MOV Long Life Grade 2 are given in Table 4.

3. Mobility Testing

Good mobility is necessary because in gear cases grease must get into the gear meshing so that it can provide lubrication for the teeth. However, mobility can decrease with the age of a grease, with oil separation, with oxidation and with decreasing temperatures. One test for the last affect is the US Steel Mobility Test. For this a sample of grease is cooled down to the desired temperature and using 1035 kpa (150 psi) air pressure the amount of grease being forced out is measured. It is reported in either grams per minute or grams per second.

Table 5 gives the results for MOV Long Life and MOV Extra as well as for some products that had been reported by others as being suitable substitutes for the obsolete calcium complex grease. The Grade 00 was intended for cold temperature applications and this had a synthetic PAO (polyalphaolefin) fluid. The supplier suggested substitute has a lithium complex thickener and while also based on a PAO, this one has a much higher viscosity and hence has poorer mobility. This was confirmed in the testing where using the supplier's data, it barely matched the original Grade 0 in mobility. This might present problems in some applications. On the other hand, MOV Extra Grade 0 approached the performance of the original calcium complex Grade 00 with its PAO fluid. It did this without the higher cost PAO and while still providing the benefits of a calcium sulphonate thickener. While not shown, MOV Extra Grade 00 gave similar good results to the Grade 0. Both are much more mobile at low temperatures

4. Low Temperature Torque Characteristics

Another accepted method to determine the response of a grease to low temperatures is a torque test. In this test a bearing is packed with grease and they are cooled down to the desired temperature. The torque is measured on starting and after set periods of time such as 10 minutes and 1 hour. Depending on the test method either a roller bearing (ASTM D-4693) or a ball bearing (ASTM D-1478) can be used. A lower value means that the grease is more likely to provide lubrication at those temperatures and without over stressing the driver motor. No maximum value has been suggested for motor operated valves but for car wheel bearings the NLGI has set limits .

Table 6 gives the ASTM D-1478 numbers for a range of MOV Long Life and MOV Extra grease grades. While the Grades 0 and 1 are generally used in Limitorque gearboxes a stiffer Grade 2 is used in some other gearboxes. The stiffer greases tend to have higher torques. Conversely, a softer grease would likely be more suitable at lower temperatures. A limiting number is not known for motor operated valves but US Navy specification MIL-G-18458 for wire rope and exposed gears uses 10,000 g·cm maximum. The data shows that both MOV Long Life and MOV Extra gave lower torques than the original calcium complex EP0 grease. Further, that MOV Extra EP00 gave results as good as the calcium complex EP00 grease having a PAO based oil. Unfortunately, data was not available for the suggested replacement.

5. Oil Bleeding Performance

This is a measure of the tendency of the oil used in grease to separate from the thickener. It can be important because excessive oil bleeding can lead to grease hardening as more of thickener is left behind, to increased leakage past seals and to house keeping problems with seepage from plugs and joints. Oil separation can also affect the shelf life and while this not expected to be a problem with the now obsolete calcium complex, it did had a stated shelf life of only 1 year. To be safe, greases older than this should be checked, at least visually, before use.

There are two common tests used to measure oil bleeding tendencies of grease; D1742-94 (2000)e1 Standard Test Method for Oil Separation from Lubricating Grease During Storage. This test method gives a measure of the tendency of a lubricating grease to separate oil during storage in normally filled and partially filled containers, and D6184-98 Standard Test Method for Oil Separation from Lubricating Grease (Conical Sieve Method). This test method is used to determine the tendency of lubricating grease to separate oil at an elevated temperature. This test is normally conducted at 100°C for 30 h unless other conditions are required by the grease specification. This test is very similar to FTM 321.

The second test is more severe but neither test method is said to be suitable for greases having a penetration greater than 340 (softer grade 1). No method has been suggested by ASTM as an alternate so they are used anyway.

Table 7 gives the D-1742 data. In these tests the Grade 0 calcium sulphonate thickened MOV Long Life and MOV Extra were similar to the original calcium complex EP0. This reportedly had been satisfactory in this regard. One grease, with a lithium thickener that had been recommended by a lubricant supplier as a replacement for the calcium complex, gave extremely high oil leakage. This had been confirmed by reports of excessive oil seepage at an actuator repair facility.

6. Salt Fog Corrosion Resistance

This is a test in which cold rolled steel panels are coated with a 1 mil thickness (typical) of grease and left in a closed chamber where they are exposed to a 5% sodium chloride (salt) fog. Failure occurs when a rust spot 1 mm in diameter perforates the grease film. Typical greases fail in less than 100 hours while a calcium sulphonate thickened grease can last many times this without the need for added rust inhibitors. Some common rust inhibitors, such as sodium nitrate, have been suspected of forming compounds that are of concern for health and safety reasons. Neither MOV Long Life nor MOV Extra requires added rust inhibitors.

As greases are left in service for longer and longer periods of time they have to provide extended corrosion protection to the parts that they are lubricating. Power stations tend to be wet places that can also see a lot of temperature variations so a grease having good corrosion resistance can be an advantage.

Salt fog results for several products are shown in Table 8. The original calcium complex gave average results of 110 hours while MOV Long Life and MOV Extra were still going at 2-3 times the exposure. The worst result was for the clay – PAO based grease. While it might be well protected in the limit switch gearbox it is sometimes used in the main gear case. Here it will not offer the same protection as the original grease and nowhere near as much as a calcium sulphonate grease. This is shown in Photo 1 which at 150 hours is past the failure point for both the clay – PAO grease and the original calcium complex EP0 grease. MOV Long Life at the same time had not failed.

7. Lithium Thickener Compatibility Test

Testing by the Candu Owners Group and EPRI had independently addressed the compatibility of the calcium sulphonate thickened MOV Long Life with the original calcium complex thickened grease and they were found to be compatible. However, some utilities have used other greases, one of which is a lithium thickened EP1 grease. It should be noted that while this grease did not suffer from the age hardening associated with the original calcium complex grease it did reportedly have “problems” at higher temperatures. Plus, while likely a good grease for many applications, the presence of about 5,000 ppm of a chlorinated paraffin EP additive might be cause for concern. Possibly there can be more expensive disposal requirements resulting from the chlorine and, although not proven, there could be stress corrosion cracking of stainless steels if chlorides form.

In any case, an independent laboratory was chosen which was the same one used for the EPRI testing. Here various mixtures of MOV Long Life Grade 1 and the lithium grease were aged and the penetrations checked. The dropping point was also measured at the 100% ratios and at 50/50. The aging was done by heating the mixtures at 121°C (250°F) for 72 hours. A chart of the results is shown in Figure 2. This shows softening of the mixtures but the change was generally less than a NLGI Grade. Also there was not an obvious adverse impact on the dropping point of the mixture. In the NMAC Lubes Notes for November 2003[13] this was reported as being “borderline compatible”. In other testing it was also found that aging at 121°C (250 °F) might be too severe and that at 150°F there was little change. Additional testing at lower aging temperature but for a longer period of time might be required as well as oil bleed testing on aged mixtures. The EP characteristics should not be affected. In any case, it is generally recommended that when actuators are being overhauled that as much of the previous grease as possible be removed. This is not just for compatibility but because the old grease has already been degraded, just by time if nothing else.

One other test that was done on this grease was an ASTM D-1831 Shell Roll Stability Test. This has a metal roller in a cylinder and the test was modified to run at an elevated temperature and with 50% water. This is a form of EQ test and as with other lithium 12 hydroxystearate and lithium complex greases, this one also softened considerably. See Table 9. In this same table is data for the original calcium complex grease which stiffened on working a bit but also softened with heat and water. MOV Long Life did not.

Table 10 shows a test-by-test comparison of these two greases with MOV Long Life better in most if not all categories.

Discussion

For the limit switch application MOV Long Life has the better oxidation resistance reported last year and this year it was shown to have better wear resistance and better salt fog corrosion resistance. Given these benefits it should be very well suited to this application as well as for use in the main gearbox.

For commercial actuators, MOV Extra has the benefits of the calcium sulphonate thickener and a lower viscosity base oil for improved low temperature performance. In fact at lower temperatures it far exceeds the performance of a currently product recommended by a lube supplier. Even with the lower base oil viscosity, MOV Extra had good numbers in EP and wear testing.

For users of the lithium EP1 grease it was determined that mixing with MOV Long Life might lead to some softening, that MOV Long Life has better 'EQ' stability, better salt fog corrosion resistance and similar good EP performance without the possible disadvantage of the chlorinated paraffins. However, given that extensive testing was not done on the mixtures, that for safety related equipments it might be prudent not to mix them. For non safety related equipment, the risk is likely only some softening plus since new grease being added sits on top of the old grease it is not considered likely to get to the lower seals where it might led to increased leakage.

Conclusions

1. Compared to the clay thickened grease grease, MOV Long Life offers better wear and corrosion protection for the limit switch gearbox.

2. For commercial actuators both MOV Long Life and MOV Extra can provide more than adequate performance without the high oil bleed associated with a suggested substitution.

3. For low temperature applications, the mobility of MOV Extra Grade 0 and Grade 00 is much better than a suggested substitution.

4. For stations using the lithium thickened EP1 grease, MOV Long Life Grade 1 offers many advantages. While 'compatible', follow the general recommendations for safety related equipment that mixing should be minimized as much as possible. This is also to get the full benefits of MOV Long Life.

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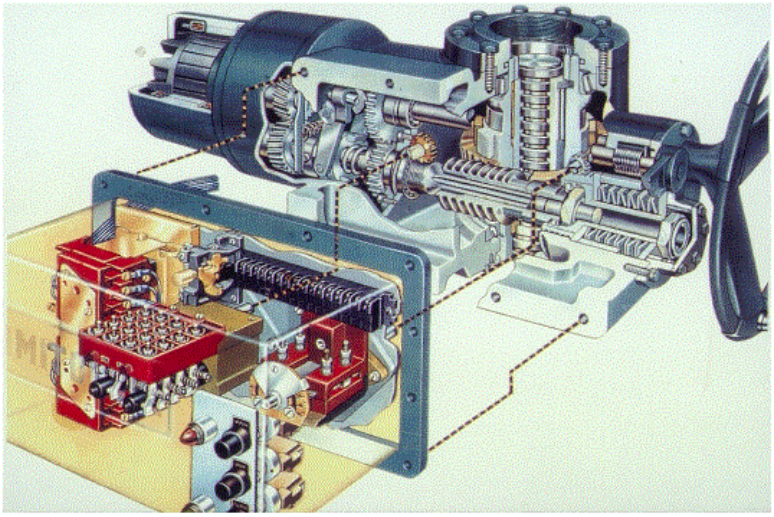


Figure 1: Limitorque Actuator

TABLE 1

NAVY GEAR WEAR
(mg per 1000 cycles)

	NLGI Grade 0	NLGI Grade 1	NLGI Grade 2
MOV LONG LIFE			
5 lb load	-0.13	-0.22	-0.25
10 lb load	-0.93	-0.80	-0.93
MOV EXTRA			
5 lb load	-0.55		
10 lb load	-1.27		
Calcium Complex EP1			
5 lb load		-0.07	
10 lb load		-0.37	
Clay Thickened PAO Grease			
5 lb load			-0.15*
10 lb load			-0.47*

* Grade 1½.

TABLE 2
WEAR PROTECTION

CHARACTERISTIC	Clay - PAO Grade 1½*	MOV Long Life Grade 1	MOV Long Life Grade 2
Color	Dark Red	Tan	Tan
Thickener	Organo-clay "Nonsoap"	Calcium Sulphonate	Calcium Sulphonate
Timken OK Load: kg (lb) ASTM D-2509, *higher is better*	5.4 (12 lbs)	27.2 (60 lbs)	27.2 (60 lbs)
4 Ball EP: load wear index, kgf weld point, kgf, ASTM D-2596 *higher is better*	31.03 200	62.5 500	63.4 500
4 Ball Wear: scar dia., mm, ASTM D-2266, *smaller is better*	1.30	0.49	0.49

* Not an official NLGI Grade but commonly used.

TABLE 3
EXPLANATION OF COMPARISON DATA

CHARACTERISTIC	SIGNIFICANCE
Color	A natural color can be better because dyes can have lower stability.
Thickener	Better if compatible with existing product.
NLGI Grade	Typically Grade 0 or a 1, which only indicates consistency.
Penetration: worked @25°C, ASTM D-217	Must be in grade.
Stability: % change, ASTM D-217	Less of a change is better.
Dropping Point: (°C), ASTM D-2265	Higher can be better.
Base Oil Viscosity: (cSt), ASTM D-445 @40°C @100°C	Should not be too low or too high. Too low can affect low speed performance.
Shell Roll Stability: % change, 2 hours ASTM D-1831 @ 20°C	Less of a change is better.
Bearing Life: hours, ASTM D-3527	Longer is better.
Bomb Oxidation: kPa drop, ASTM D-942 (500hr)	Less of a pressure drop is better.
Oven Panel: 96 hours @ 150°C, 30 mils Per a modified GM 9075-P.	The longer with less of a change or oil bleed the better.
Timken OK Load: (kg), ASTM D-2509	Higher should be better.
4 Ball EP: ASTM D-2596 load wear index (kg) weld point (kg)	Higher is better for both.
4 Ball Wear: scar dia. (mm), ASTM D-2266	Lower is better.
Copper Strip Corrosion:(rating), ASTM D-4048	The lower the better.
Salt Fog: hours to failure, ASTM B-117	The longer the better.
Hazardous Materials or Heavy Metals	The fewer ‘problem’ compounds the better

TABLE 4
COMPARISON TO CURRENT LIMIT SWITCH GREASE

CHARACTERISTIC	Clay - PAO	MOV Long Life NLGI 1
Color	Dark Red	Tan
Thickener	Organo-clay "Nonsoap"	Calcium Sulphonate
Penetration: worked, ASTM D-217	305	325
Stability: 100,000 strokes, ASTM D-217	2% change	3% change
Dropping Point: (°C), ASTM D-2265	232	>318
Base Oil Viscosity: (cSt), ASTM D-445 @40°C @100°C	 30 5.8	 95 10.8
Shell Roll Stability: %change, ASTM D-1831	?	3.7
Bearing Life: hours, ASTM D-3527	?	220
Bomb Oxidation: kPa drop, ASTM D-942	?	5.5 (500hr)
Oven Panel: 96 hours @ 150°C, 30 mils Per a modified GM 9075-P.	?	Pass
Timken OK Load: (kg), ASTM D-2509	5.4	27.2
4 Ball EP: load wear index (kgf) weld point (kgf), ASTM D-2596	31 200	62.5 500
4 Ball Wear: scar dia. (mm), ASTM D-2266	1.30	0.49
Oil Separation: (mass%), ASTM D-1742	2-6	0
Copper Strip Corrosion: (rating) ASTM D-4048	?	1b
Salt Fog: (hours to failure) ASTM B-117	48	>300
Hazardous Materials or Heavy Metals	1-5% Pentaerythritol & possibly NDMA	None added

TABLE 5
LOW TEMPERATURE MOBILITY

	MOV EXTRA EP0	MOV LONG LIFE EP0	Obsolete Calcium Complex EP0	Other Lithium Complex - PAO
Thickener	Calcium Sulfonate Complex	Calcium Sulfonate Complex	Calcium Complex	Lithium Complex
Base Oil	Group 1	Group II	Group I	Group IV
Penetration, worked	370	370	370	415
Base oil viscosity, cSt @ 40°C	23.4	95	96.3	460
Mobility @150 psi, g/min				
0° F (-18°C)	287	39.8	21	27
-10° F (-23°C)	139	19.1	5.6	-
-20° F (-29°C)	68.5	8.6	2.4	-
-30° F (-34°C)	16.5	2.2	1.3	-
Rating	best	good	poor	poor

TABLE 6
ASTM D-1478 LOW-TEMPERATURE TORQUE

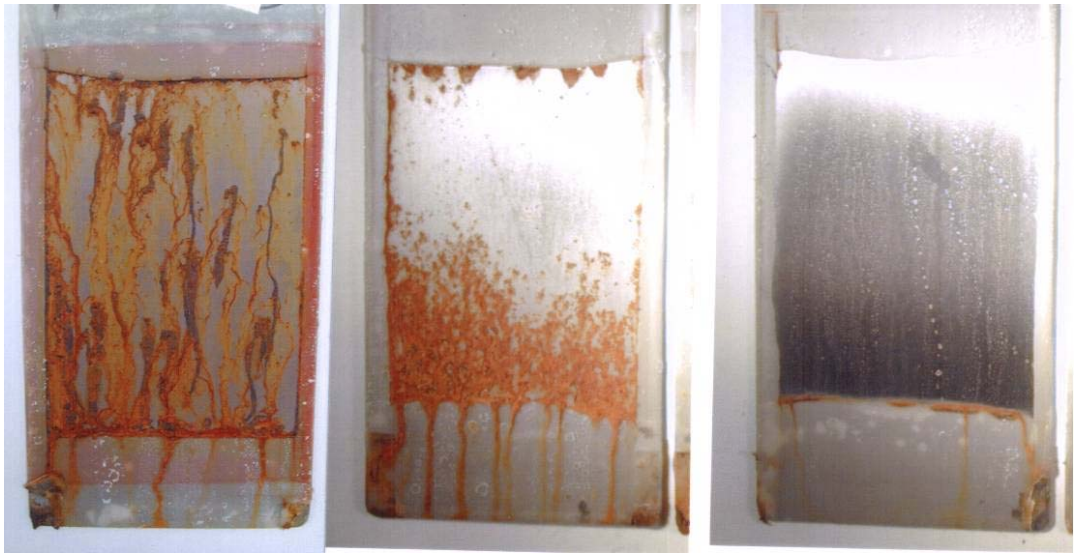
GREASE	TORQUE START / 1 HOUR (g·cm)	
	–40°C (-40°F)	**-29°C (-20°F)**
MOV Long Life EP00	13,572 / 2,347	2,607 / 319
MOV Long Life EP0	-	2,000 / 1,000
MOV Long Life EP1	-	2,500 / 1,500
MOV Long Life EP2	-	2,979 / 1,652
MOV Extra EP00	728 / 280	442 / 130
MOV Extra EP0	2,425 / 351	533 / 130
MOV Extra EP2	14,000 / 1,900	-
Calcium Complex EP0	26,891 / 5,057	2,483 / 559
Calcium Complex EP00	878 / 358	299 / 150
Clay - PAO	10,000 / 1,000 @-54°C	-

TABLE 7
ASTM D-6184 OIL SEPARATION TEST
Cone Method, 100°C for 30 Hours

GREASE	(% mass)
MOV LONG LIFE EP0	8.3
MOV LONG LIFE EP1	9.4/5.4
MOV LONG LIFE EP2	3.0
MOV EXTRA EP0	8.1
Calcium Complex EP0	4.6
Clay – PAO 1½	0.8
Microgel EP0	2.3
Lithium EP0	42.7

TABLE 8 ASTM B-117 SALT FOG TEST	
GREASE	**HOURS TO FAILURE** @ 1MIL D.F.T. (Based on 2 of 3 Panels)
Clay – PAO 1½	48
Microgel EP0	76
Calcium Complex 'clone' 0	94
Lithium EP0	100
Calcium Complex EP0	110
MOV Extra 0	>300
MOV Long Life 0	>300

D.F.T. = Dry Film Thickness



Clay – PAO 1½ **Calcium Complex EP0** **MOV Long Life EP0**

Photo 1: Salt Fog ASTM B-117 after 150 hours

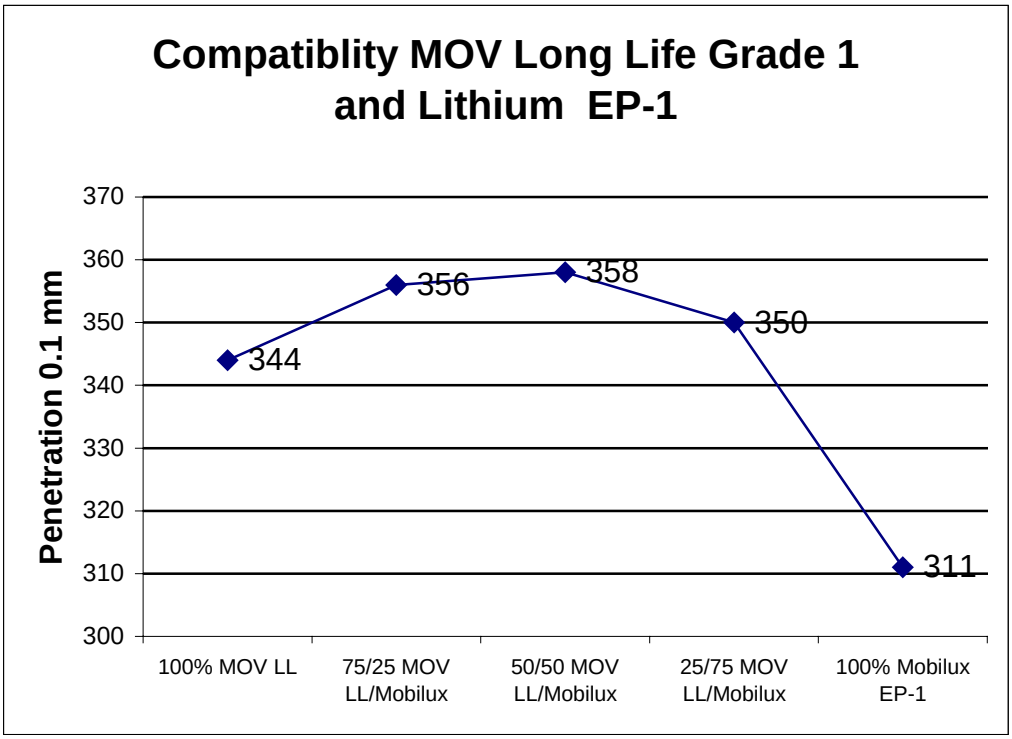

Compatiblity MOV Long Life Grade 1 and Lithium EP-1
Penetration 0.1 mm
370
360
350
340
330
320
310
300
344
356
358
350
311
100% MOV LL
75/25 MOV LL/Mobilux
50/50 MOV LL/Mobilux
25/75 MOV LL/Mobilux
100% Mobilux EP-1

TABLE 9
'ENVIRONMENTAL QUALIFICATIONS'
SHELL ROLL STABILITY ASTM D-1831 WITH HEAT AND WATER

PRODUCT	LONG LIFE Grade 1	Calcium Complex EP1	Lithium EP1
THICKENER CONDITIONS	Calcium Sulphonate	Calcium Complex	Lithium 12 Hydroxy-stearate
Initial Worked Penetration	321	317	324
25°C (77°F)	327 (+1.9%)	287 (-9.5%)	350 (+16%)
25°C (77°F) and 50% water	311 (-3.1%)	309 (-2.5%)	347 (+7.1%)
One hour preheat at 77°C (170°F)	324 (+0.9%)	322 (+4.8%)	347 (+7.1%)
One hour preheat at 77°C (170°F) and 50% water.	313 (-2.5%)	407 (+28.4%)	399 (+23.2%)
SUMMARY	**Very slight changes**	**Considerable softening with heat and water**	**Considerable softening with heat and water**

TABLE 10
COMPARISON WITH ALTENATIVE GREASE

CHARACTERISTIC	MOV LONG LIFE Grade 1	Lithium EP1
Color	Tan	Medium Brown
Thickener	Calcium Sulphonate	Lithium 12 hydroxystearate
Penetration: worked @25°C, ASTM D-217	325	310-340
Stability: pen change after 100,000 strokes	2.3%	?
Dropping Point: (°C), ASTM D-2265	318	171
Base Oil Viscosity: (cSt), ASTM D-445 @40°C @100°C	 95 10.8	 170 13-16
Shell Roll Stability: % change, ASTM D-1831 @ 77°C @ 77°C and 50% water	 +0.9 -2.5	 +7 +23
Bearing Life: hours, ASTM D-3527	280	?
Bomb Oxidation: kPa drop, ASTM D-942	38 after 500 hrs	10 after ?
Oven Panel: 96 hours @ 150°C, 30 mils Per a modified GM 9075-P.	Pass, stayed grease-like, no bleed	Fail, severe oil bleed
Timken OK Load: (kg), ASTM D-2509	27.5	18
4 Ball EP: weld point (kg), ASTM D-2596	500	?
4 Ball Wear: scar dia. (mm), ASTM D-2266	0.49	?
Copper Strip Corrosion: 24h @100°C, ASTM D-4048	1a	?
Salt Fog: hours to failure, ASTM B-117	>300	<95
Heavy Metals/Additives of concern	None added	Zinc plus chlorinated agents