I.G. Oppau Report No. 455.

Testing the polyglycol ethers of multivalent alcohols as Lubricants.

by.

Dpl.Ing. Halder.

23rd April 1941.

Summary. The Lubricant L.K.2200, which is soluble in water, behaves like a good motor oil as regards resistance to cold, lubricating qualities and corrosion. The formation of residue is extremely low, both in the water-cooled engine for vehicles and in the air-cooled aeroengine, which runs under more stringent conditions. The running time until the ring sticks is 30 hours, which may be considered very good. The oil consumption remains within normal limits. A disadvantage, however, is the high content of dissolved ash. This is in all probability the cause of the formation of the granular sediment, which has been observed in experiments with engines. Lubricants of this nature do not dissolve in mineral oil and cannot therefore be used in I.C. engines where it is desired to go over at will to other lubricants.

Its solubility in water makes L.K. 2200 suitable for lubricating torpedo gear, as a visible oil track is avoided. Other applications are textile machinery and hydraulic gearing. When mixed with water, L.K.2200 may be used as a non-freezing cooling fluid.

Object of the experiment

Various polyglycol ethers of multivalent alcohols were to be tested as regards their suitability as lubricants. Among the five samples made available with the designations: L.K.1/Ja, L.K.3/Ja, L.K.5/Ja, L.K.11/Ja, L.K.14/10/Ja L.K.3/Ja seemed to be the most suitable as a lubricant as regards solidifying point and viscosity. Large quantities of this product were therefore prepared with the new designation L.K.2200 and tested in the manner described below.

A. Laboratory experiments.

Oil analyses. The most conspicuous property of this product is its behaviour with the normal solvents. In water and alcohol it is soluble in any proportions, but will not dissolve at all in benzol and petrol. From the physical and chemical data collated in Table.1, the following will moreover be noticed:

The specific gravity is higher than that of ordinary oils and of water. This circumstance may, among other things, bring about the fact that sludge and other impurities are not deposited on the bottom, but remain floating on the surface, and thus reach the engine. Whether in actual practice the higher specific weight has this unfavourable effect is a matter which must be demonstrated by experiment.

L.K.2200 has approximately the viscosity of a summergrade motor oil; with its viscosity index of 117 it shows very good viscosity-temperature behaviour (see Fig.8), while the solidifying, flash and spontaneous ignition points are likewise very favourable. L.K.2200, is somewhat hygroscopic. A water absorption experiment showed at 20°C and over a period of 24 hours, 0.40 gr. water. With concentrated sulphuric acid, under the same conditions, a water absorption figure of 4.5 gr. was ascertained.

With a water content of 4%, the viscosity at 38° C amounts to 105.cSt, as compared with the product free from water at 116.8 cSt. The viscosity change thus a amounts to approximately 10%.

Fig.1. shows the dependence of the solidifying point on the water content. Up to a water content of about 30%, the solidifying point falls and is here at about -47°. A further rise in the water content, even at relatively high temperatures, causes cloudiness, which is brought about by the formation of ice crystals. It will be seen from these experiments that an admixture of water up to 30% is without

significance as regards the position of the solidifying point. L.K.2200, is alkaline in nature, as will be seen from the negative acidity and saponification index. The asphalt content is 0, while the ash content, compared with Army unit oil (Wehrmachtseinheitsol) and Rotring attains a relatively high figure at 0.025. This is to be attributed to the experimental method of manufacture and could no doubt be greatly reduced. A less favourable feature would appear to be the high Conradson test, which, however, as experiments with engines have shown (cf.p.6) does not permit of deducing the formation of residue, which might be expected.

Artificial ageing by the Indiana method demonstrates the extremely favourable behaviour of L.K.2200 (see Fig.2). Particularly noticeable is the extraordinarily slow rise of the acidity index, which in the case of Rotring D very quickly attains high figures. The saponification indices are the other way round. From this it may be inferred that during the ageing of L.K.2200, it is mainly esters that are produced, which experience has shown to possess a good lubricating action, so that this phenomenon cannot be gegarded as unfavourable.

An examination of the oil aged in the BMW engine (cf.Fig.3) tallies with the results of artificial ageing. Here again we see a sharp rise in the saponification index, which points to the formation of a large amount of esters. The acidity index is a long way behind that of Rotring D. The thickening of the oil is scarcely noticeable in L.K.2200, whereas in Rotring D it reaches a considerable figure. With Rotring D the ash content is nil during the eight-hour experiment. With L.K.2200 even when the oil is fresh, the high ash content practically does not increase at all during the first stage; only during the last ten hours of the experiment could an increase in the ash content be observed. This concentration of dissolved ash towards the end of the experiment is probably to be attributed to the consumption of the oil and to the contamination of the oil with lead compounds, derived from the fuel. Since L.K.2200 showed almost four times the period of running compared with Rotring D, these influences have a particularly marked effect with L.K.2200..

Similar conditions are obtained by investigations with oil aged for 50 hours in the Opel engine (see Table 1.) By way of comparison Wahrmachtseinheitsol was used. Here, L.K.2200 showed a rather higher saponification index and a greater ash content than Wehrmachtseinheitsol; on the other hand, there was no formation of asphalt. The thickening of the oil was slight and about the same for both types.

Testing the lubricating properties:

a. Four ball machine.

L.K.3, which is the equivalent of L.K.2200, attains in the four ball machine, i.e. at very high surface pressures, about the same figures as Rotring D and is superior to Aeroshell. In this respect, therefore, it is the equivalent of a good engine oil (see Fig.4).

b. Wear machine.

In the wear machine, L.K.2200 shows very slight wear. It behaves somewhat like T standard, while the more fluid Shell AB 11 and the two engine oils Aeroshell medium and Rotring D quadruple these wear figures (see Fig.5). In this apparatus, therefore, L.K.2200 is far superior to mineral oils.

Heat test.

The bearing of the Wieland bearing machine was subjected to the constant load of 210 kg/sq cm and treated with 12 ccm oil. After the machine had been started up, the oil temperature was measured at determined intervals. With Wehrmachtseinheitsöl, resistance occurred at 43°C, while with L.K.2200 it was noted as low as 39° (cf. Fig. 9). A repitition of this experiment confirmed this result. With Wehrmacht-seinheitsöl, therefore, the difference between oil temperature and room temperature is 23° C, while with L.K.2200 it is 19° C. This represents a difference of 20%. This phenomenon is to be attributed to the superior heat conductivity and to the higher specific heat exhibited by materials of this type. Such behaviour is undoubtedly highly desirable in many cases occurring in practice. In the case of varying operation with greatly fluctuating temperatures, L.K.2200 is not liable to such great temperature changes as ordinary oil. The viscosity will therefore only vary within narrow limits. As a result of this behaviour, the effect of the viscosity index, which is very high with L.K.2200, is still further enhanced.

Corrosion test.

In addition to L.K.2200, this test embraced several analogous products, viz. L.K.2324, L.K.2325 and L.K.2326. The test was carried out at 100° C in a test tube without air passage and lasted 96 hours. Every 24 hours the oil was renewed.

When fresh, the oils L.K.2200, 2324 and 2325 cause appreciable corrosion with zinc, which exhibits a well-defined loss of weight (Fig.7). With other metals, all the products behave quite normally. The lowest degree of corrosion was observed in the case of L.K.2326. In this respect it is superior to RotringD.

In the used oil from the Opel engine (L.K.2200), the very appreciable increase in weight of electron is apparent, but in order to give an opinion on this phenomenon, a comparative experiment with used Rotring D is necessary.

Resistance to cold.

An investigation of viscosity in the cold state in Schwaiger's apparatus down to -30o C yielded no significant result. As will be seen from Fig 8, throughout the whole temperature range L.K.2200 occupies a position between Wehrmachseinheitsol and Rotring D. The poor agreement between extrapolated viscosity and the results in Schwaiger's apparatus has been observed in all the oils, and is therefore by no means a special feature.

On a par with the experiments in the Schwaiger apparatus the breakaway experiments in the I.G. cold chamber also show a good behaviour in the cold, compared with Rotring D (see Fig.9).

B. Experiments with engines.

50 hour's running in an automobile, Otto engine.

L.K.2200 was tested for engine behaviour and lubricating properties in a 1.3 litre Opel engine. The test lasted 50 hours with varying loads.

The engine behaved quite normally (cf. Table 2). An oil temperature between 65° and 95° was attained. The oil pressure was 15-20% higher than in the case of the Wehrmachtseinheitsol used for comparative purposes. This phenomenon may be attributed to the higher viscosity of the L.K.2200 and is without significance for forming a judgement.

After running for 50 hours, the machine was dismantled. The findings in all parts were very satisfactory. The running surfaces of the piston rings and pistons, as well as the working parts of the cylinders, were completely smooth; the connecting rod bearings also presented a polished appearance without grooves. The wear in the rings corresponded to the normal extent of wear with normal auto oils.

The residues on the top of the piston and combustion chamber, as well as on the valves, were extremely slight and could easily be removed. The high Conradson test does not, therefore, have a prejudicial effect in practice.

Oil consumption, at 25.5 gr/hour, is more than that of Wehrmachtseinheitsol. The additional consumption in these experiments is no doubt due to the lack of accuracy in measuring the oil. As experiments with the BMW aero-engine show, where a more exact measurement of oil consumption is possible, the consumption of L.K.2200 is on a par with good engine oil.

Ring breakdown test in a BMW aero-engine.

During these tests the BMW-132 aero-engine ran under intensified conditions, so that after running for 8 hours, the calibration oil, Rotring D, brought about a failure of the rings. L.K.2200 was tested under the same conditions and the following results were secured: (cf.table3.)

The running time of 30½ hours may be regarded as very good and corresponds to the best aero-engine oils. Oil consumption is normal. Wear on the piston rings is favourable, and despite the long running time, it is less than that of the Rotring test.

Dismantling yielded the following noticeable findings:

The piston was in a somewhat dry state, but otherwise presented the normal appearance. A conspicuous feature was a somewhat granular deposit, which was observed both on the piston and on the shafting. The rough running of the connecting rod ascertained after the test is probably also to be attributed to this residue. The cause of this formation of residue is no doubt to be found in the high content of dissolved ash.

<u>Possibility of application</u>

L.K.2200 can be used by itself as an engine oil. Difficulties, however, attend the transition from normal oil to this product and vice versa. Since no solvent is known which dissolves both lubricants, a thorough cleaning of the machinery followed by a change to the other lubricant is both troublesome and takes time. For this reason L.K.2200 can scarcely be considered for automobile or aircraft work. The ability of an oil to dissolve in water is in certain cases and advantage, e.g. for torpedo machinery, in order to avoid a visible oil track; furthermore, in lubricating textile machinery, in order to remove any stains in the spools due to the lubricant. Moreover, it might be possible to use this product as a filling for turbo-gear. In the case of vehicles, a mixture of water and oil would be advantageous, not only as gear fluid but also as a cooling fluid for the engine.

TABLE.1. ANALYTICAL RESULTS.

Values		Unused Oil			Trial run 50 hrs in Opelengine		Trial run in BMW Aero-engine.		
		L.K.2200	Army Standard Oil	Rotring.D.	L.K.2200	Army Standard Oil	L.K. 2200 8.hrs	L.K. 2200 30 hrs	Rotring D. After 8 hrs.
Density	Kg/lt	1.119	0.897	0.890	1.122	0.902	-	-	=
Viscosity -10°	c.St	6330	-	-	-	-	-	-	=
+20°	c.St	332	-	-	-	-	-	-	-
+38°	c.St	116.8	101.9	262.3	122.6	108.6	122.9	126.2	316.4
+50°	c.St	64.4	-	-	-	-	-	-	-
+99°	c.St	13.91	10.42	19.78	14.32	10.62	13.93	14.24	22.11
Pole-Height		1.55	2.15	2.05	1.63	-	-	-	-
Constant of Slope		3.23	3.9	3.48	3.275	-	-	-	-
Viscosity Index		117	90	94	113	84	117	117	93
Pour Point	°C	-38	-25	-13					
Flash Point	°C	307	229	268	286	226	274	247	269
Ignition Point	°C	345	274	322	328	278	326	311	329
Acid Value	MgKOH/g	-0.51	0.03	0.03	+0.59	+0.39	0.31	0.67	0.93
Saponification Value	MgKOH/g	-0.51	0.22	0.25	+3.49	+1.6	6.5	30.3	3.4
Asphalt Content	%	0	0	0	0	0.03	0	0	0.05
"Dissolved" Ash Content	%	0.025	0.01	-	0.14	0.08	0.06	0.10	0
Conradson Test	%	1.171	0.27	0.23	1.Y18	0.61	-	-	0.87
Oil Dilution	%						0.44	0.51	-

TABLE 2. RESULTS OF TRIALS IN THE OPEL ENGINE.

		L.K.2200. 50 Hour run	Army Standard Oil 100 Hour run.
Oil consumption	g/h	25.5	15.4
Piston ring wear			
absolute:	mg	522.2	641
hourly:	mg/h	10.5	6.4
Deposit on the four piston heads	g	1.220	2.9603

Table 3. - RESULTS OF ENGINE TRIALS IN THE BMW AERO ENGINE.

	L.K.2200 m	Rotring D.
Running time to ring failure h	30½	8
Oil consumption g/h	395	380
Piston ring wear absolute: g	2.899	3.712
per hour: g/h	0.095	0.464
Results on dismantling: Piston head	Thin, black coating at edge, granular residue esp. on exposed side	Thin, grey-brown coating at edge moderate formation of oil carbon.
Ring unit	Slightly soiled. esp. on exposed side.	Moderate coking
Shaft	On inlet side, fine, light brown coating. on outlet side, normal pressure points.	Burnt black.
Bolt eye	Thin, dark brown coating on exposed side somewhat more strongly.	Burnt black.
Oil holes	Free	Free
Inner side	Moderate, black matt coating, on inlet side rather thicker, foliated partly blistered residue	Black coating, thin, like lacquer.
Inlet valve	Compared with normal oil rather heavier, black, foliated residue	No findings.
Connecting rod:	Rather rough connecting rod running. Piston bolt bush slight pressure points, easily soiled by granular impurities.	No findings.
Connecting rod head:	Dark matt black, cracked coating, like piston head inside, rather dry and brittle.	No findings.
Crank web:	Blackish-grey, oily sediment, rather like asphalt.	No findings.

Figures.