German Aviation Research
Report No. 804

Tests on a synthetic oil of the Ruhrchemie A.G. in the liquid cooled (Reissgekühlt) single-cylinder test engine

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Synopsis:

An endurance test on the synthetic oil of the Ruhrchemie was carried out in the liquid-cooled single-cylinder test engine until the piston rings seized. The results are compared with those of other oils used with good results in aero-engine operations.

Contents:

I. Introduction:

On the basis of laboratory tests and of the test run in the Siemens oil test engine it must be assumed that the synthetic oil of the Ruhrchemie A.G., Holten, is an excellent oil for heavy duty aero engines. An endurance test was carried out in the single-cylinder test engine with the liquid cooled BMW VI cylinder in order to check this and particularly to obtain information on the behaviour of the oil in continuous operation.

II. Materials used:

The laboratory tests of fuels and lubricants used for this endurance test and for the test run with Stanavo 140 used as a basis of comparison are tabulated as follows :-

1. Fuels

	Endurance run 36_{II} with R.C. oil	Endurance run 9 with "Stanavo 140"
Fuel type	O.N. 87 aviation gasoline	Stanavo 87
Supplier	Olex (No. 258/36)	D.A.P.G.
Density @ 20°C (kg/l.)	0.731	0.728
Refractive Index	1.4096	1.4070
Gum test (glass dish) (mg.)	3.3	4.0
Sulphur content %	0.03	0.01
Iodine number	3.3	1.2
Octane number	87.3	87.6
T.E.L. (Vol. %)	0.083	

(continued on page 2)

Distillation on A.S.T.M. Method

	Endurance run 36II with R.C. oil	Endurance run 9 with Stanavo 140
I.B.P.°C	38	68
Distilled at 50°C (vol.%)	2.0	-
60 " "	5.5	-
70 " "	11.5	1.0
80 " "	21.0	11.4
90 " "	33.0	41.2
100 " "	49.5	69.0
110 " "	66.0	87.4
120 " "	80.0	94.4
130 " "	88.5	97.6
140 " "	94.0	-
150 " "	97.0	-
F.B.P.°C	152	134
Residue (vol. %)	1.4	1.5
Loss "	1.0	0.3

2. Oils

a) Test oil of Ruhrchemie A.G. Oberhausen/Holten
Type: SO 2001 (improved quality)
Rec. No. 41/36 (analysis) and 255/36 (endurance test)
The oils 41/36 and 255/36 supplied for the analysis and for the endurance test had to be delivered in the same quality. The figures for 255/36 are indicated in brackets in the following test results.

Colour: reddish-brown, slightly fluorescent
Smell: mild
Density @ 20°C (kg/l.): 0.863 (0.870)
Refractive Index : 1.4804 (1.4837)
Viscosity at 50°C (°E): 21.7 (22.5)
" " " (Cp): 139 (145)
Solid foreign matter : 0.0
Ash : 0.0
Asphalt : 0.0
Neutralisation No. : 0.0
Saponification No. : 0.0
Carbon Residue (Ramsbottom) : 0.30 (0.34)
DVL ageing:
Volatility (275°C) %: 79.0
Asphalt %: 8.8

Ageing Test (Air Ministry):

	Original oil	aged oil	increase
Specific gravity @ 20°C	0.863	0.893	0.030
Viscosity @ 37.8°C, °E (Cp)	44.5 (287)	150 (1002)	237 (249)
" " 50 " " "	21.7 (139)	64.7 (429)	198 (208)
Carbon residue (Ramsbottom)	0.30	0.82	0.52

(continued on page 3)

b) Reference oils

	Endurance run 9	Endurance runs 41, 44, 45
Type	Stanavo 140	Green Band
Supplier	D.A.P.G.	D.V.O.A.G.
Density @ 20°C (kg/l.)	0.892	0.883
Refractive Index	1.4964	1.4879
Viscosity @ 50°C (°E)	30.1	21.6
" " " (Cp)	199.4	141.4
Solid foreign matter (wt. %)	0.0	0.0
Ash	0.0	0.0
Asphalt	0.0	0.0
Neutralisation number	0.0	0.0
Saponification No.	0.0	0.0

III. Test procedure and results:

The test run was made on a DVL single-cylinder test engine, equipped with cylinder and piston of the BMW VI engine, series 7. The test was carried out as in the endurance runs described in the DVL report PB 172 Dehn/Glaser, "Use of motor-benzene in aero engines subject to high thermal load". One of these test runs carried out on O.N. 87 aviation gasoline and Stanavo 140 oil is used as a basis of reference for the following test run.

1. Reference run on "Stanavo 140" (endurance run 9)

Benzene-free "Stanavo 87" and "Stanavo 140" were used. The following operational conditions applied :

Power	4½ hours	45 H.P. at 1590 r.p.m.
	½ hour	50 H.P. at 1650 r.p.m.
Fuel consumption gr/HP/h	245	
kcal/HP/h	2560	
Coolant outlet temp.	140°C	
Oil outlet temp.	88°C	
Compression ratio	6.8	
Ignition timing (° b. T.D.C.)	20	
Temperature in the centre of the piston crown (determined by melting plugs)	between 290 and 305°C	

The test curves appear in Fig.1. The endurance test was discontinued after 63-3/4 hours because repeated power drops gave rise to the assumption that one or more piston rings were stuck. It was found that the top ring was stuck between 70° and 170°, the second between 70° and 175° . Rings 3 and 4 were free. The oil holes of the oil scraper ring were partly choked. Otherwise the engine condition was normal. During the test, oil samples were taken from the return pipe after 10, 25, 35, 50 and 60 hours, as well as shortly before stopping the engine.

2. Endurance run on R.C. oil (test No. 36II)

The O.N. 87 aviation gasoline used with Stanavo 140 later became no longer available without benzene; an O.N. 87 Olex aviation gasoline having the same density as the previously used Stanavo 87 was therefore used. The results of laboratory tests for this fuel and for lubricant SO 2001 (improved quality) are shown on pages 1 and 2. The operating conditions for this endurance test are the same as those of the

the reference test (see page 3). On the test run a new cylinder and piston with "Goetze-Full" rings were also used. After a 13 hours running-in period, cylinder and piston were taken down, cleaned and measured. The engine casing and the oil lines were also carefully cleaned before starting the endurance run.

The test curves are given in fig. 2. After 20, 35, 50 and 60 hours the cylinder was lifted and a check was made. The valves were always slightly slack and consequently were re-ground. This, however, occurred also in the earlier endurance tests with "Stanavo 140" and is caused by a failure of the valve seats. When examined after 60 hours, the piston rings were completely free. The result at this stage is therefore more favourable than after 63-3/4 hours in the reference test with "Stanavo 140", when two rings were partly stuck. The cylinder was not taken down between 60 and 90 hours. No power drop or increased blow-by into the crankcase was ascertained before this stage. After dismantling the cylinder, the following results were found :-

Piston rings: The top ring sticks somewhat at one point, though it still moves in its groove. The second ring is seized on a narrow sector between 120° and 165°. The fact that no irregularities occurred in the engine operation up to the 90th hour, leads us to infer that the two top rings moved quite freely in their grooves during operation. The 3rd and 4th rings are completely loose. The oil holes in the piston and scraper rings are unobstructed. The appearance of the gudgeon pin is normal. The piston crown shows little oil-carbon (about 0.1 mm.); on the piston rim a thin ridge of oil carbon can be seen on inlet and exhaust side. The rubbing faces on both piston and cylinder have worn well and present no scoring. Both valves are not quite gas-tight. Connecting rod and bush are faultless. The sparking plug has a good appearance. Fig. 3 shows the piston after 90 hours operation.

If the two tests are compared, it appears that the running time until the piston rings stick was considerably longer for the R.C. oil (90 hours) than for Stanavo 140 (63-3/4 hours). In the former no power drop or increased blow-by into the crankcase had occurred; the result was even better than with the reference oil.

3. Alteration of the oil

The test results of the oil samples taken during the endurance run 36_{II} are shown on fig. 4. It shows the increase of foreign matter, ash and asphalt content, as well as of density, viscosity and saponification number with the running time. The drop in values after the 70th hour is due to topping up with fresh oil (see fig. 2). No fresh oil was added between 35 and 70 or between 70 and 90 hours, because the oil consumption can better be determined if the oil circulation is disturbed as little as possible. If the oil consumed by the engine is made up at very large intervals, the quantity of oil in circulation decreases considerably (see fig. 2). (The "lubricant weight in the tank" includes the weight of the tank, ca 26 kg.). This must be taken into account when analysing the test results, because the oil ageing increases as the quantity of oil in circulation drops. In the R.C. oil the considerable rise in saponification number and in density is particularly surprising. The other properties of the oil change to the normal extent.

Fig. 5 shows the alteration of the oil in endurance run No. 9.

4. Piston ring wear

The weight-loss of the piston rings at 1 hourly intervals in test No. 36_{II} is shown in fig. 6. The wear per hour of the piston rings in 3 runs which extended for 15 hours and in which "Gargoyle Aero Mobiloil

Green Band" was used, is also given for comparison. These short endurance tests were carried out within the frame-work of other tests, though on the same engine and under nearly equal test conditions as test 36II. In particular the "Goetze F.11" piston rings used for all tests illustrated in fig. 6 came from the same delivery. In the tests carried out with "Green Band" however "special aviation gasoline" was used. The piston ring wear can be influenced by a whole series of factors. All the same, the results illustrated in fig. 6 lead to the conclusion that the R.C. oil has exceptionally good lubricating properties, because the piston ring wear in this oil is lower than in the well-known Green Band oil.

It can be assumed that the high saponification number and the low piston ring wear are interconnected. The high saponification numbers show that beside organic acids, large quantities of saponifiable products have been formed during the run. Among these are esters and lactones, which presumebly have a positive effect on the lubricating ability similarly to the acids; metal soaps are also formed. From the ash content in the filtered oil it is possible to draw a certain conclusion regarding the amount of metal soaps, e.g. in the filtered used oil after 90 hours running time, 0.11% ash was found which means that at the most 40% of the saponifiable components are present as metal soaps, whereas the greater proportion are esters and lactones.

5. Oil consumption

Both for R.C. oil and Stanavo 140 the specific consumption varied between 4 and 6 g/HP/h., which corresponded to the normal consumption for the BMW-VI engine. On the basis of our tests it is impossible to decide whether the consumption was lower with one oil than with the other, because the variations lay within limits of errors in measurement. When "Green Band" was used the oil consumption lay within the indicated limits.

6. Behaviour of the oil in other endurance tests

After this test 36II with the Ruhrchemie oil and Aviation Gasoline O.N. 87, three other runs were carried out with the same oil, but with other fuels. A detailed report on these tests with the 3 test fuels: R.C. alkyl benzene (No.38) and I.G. isopropylbenzene (No. 39II) was already published (DVL report UM 428 Glaser/Dehn - "Testing of different alkyl benzenes in the liquid-cooled aero engine single-cylinder engine". The tests were carried out in the same conditions as No. 36II. The running times were however shorter, which is due to the fuels employed. Test No.38 was discontinued after 57 hours. At that time no power drop or increased blow-by into the crankcase had occurred, just as in Test 36II. Also the piston condition corresponds roughly to that of test 36II because in both cases the time of onset of ring sticking was determined, but during the run the rings still moved freely in their grooves. Consequently a comparison of the piston ring wear in the two tests seems possible. The ring wear, especially the top ring, depends on whether a ring sticks. In this case the hot combustion gases can flow around the ring, thus considerably accelerating its wear. Beside test 36II the weight-loss at hourly intervals, of the piston rings in test 38II is also plotted in fig. 6. It appears that here too the piston ring wear is very low. For the first ring the wear is rather higher than in the previous test. This is due perhaps to the fact that in the operation with alkyl benzene mixture the mean temperatures in the combustion chamber are rather higher than when O.N. 87 aviation gasoline is used. This is most apparent in the case of the top ring which is most exposed to the combustion gases.

In tests 37 and 38 oil samples were also taken during operation. The test results are shown in figs. 7 and 8. Here too a comparatively

steep rise of the saponification number appears although not to the same degree as in test 36_{II}.

In both cases, however, a saponification number of over 3.0 is reached after 40 hours.

VI. Summary

In the comparison of the synthetic oil of Ruhrchemie "SO 2001, improved quality" in the liquid-cooled BMW VI single cylinder test engine with "Stanavo 140", a considerably longer running time before the piston rings stuck was found in the former than in the latter. Particularly surprising is also the low wear of the piston rings in the test on the synthetic oil. The investigation of the oil samples taken after 10, 25, 35, 50, 70, 80 and 90 hours showed generally the normal ageing tendencies. The saponification number, however, increases exceptionally rapidly. It is possible that the high saponification number and the good lubricating ability are interdependent. Later tests with the synthetic oil and different fuels mainly confirmed the previous results.

Fig.1 - Curves for endurance test No. 9.
" 2 - Curves for endurance test No. 36II.
" 3 - Piston after 90 hours run with Ruhrchemie oil.
" 4 - Alteration of the oil after endurance test 36II.
" 5 - Alteration of the oil after endurance test 9.
" 6 - Comparison of the wear of piston rings in the various endurance tests.
" 7 - Alteration of the oil after endurance test 37.
" 8 - Alteration of the oil after endurance test 38.