OPPAU REPORT NO. 471

COMPARATIVE TESTS WITH AERO-ENGINE LUBRICANTS MIXTURES A.-F.

by Lauer.

SUMMARY.

A series of lubricant blends, made from synthetic components produced at Leuna and a mineral oil component of the Deutsche Vacuum Oil Gesellschaft were tested with and without additives in an engine. All the oils tested behaved better as regards ring-sticking than the reference lubricant, Rotring D. The addition of an inhibitor caused a further slight improvement in the new oils, whilst in regenerated oils of the same blends this produced no effect.

CONTENTS.

I. OBJECT OF THE TESTS.

Various blends, made in collaboration with the Ammoniakwerk, Merseburg G.m.b.H. and Intava Hamburg, of the synthetic lubricant SS.906 from Merseburg and a mineral oil component of Intava, were tested by both firms for performance in the engine, particularly deposit formation, and the opinions formed in the two cases were divergent. Considering the importance of a true assessment, in view of the possibility of production on a large scale, the test runs were made in the form of comparative tests at:-

Travemünde Testing Laboratories
The Intava Testing Laboratories
Technical Laboratories Oppau of I.G.

The effect of the inhibitor in SS.906 was specially observed, and comparison made with Rotring D.

To make the test as objective as possible, the 6 lubricants were delivered to the individual testing laboratories under the cover names A to F, all of them having been manufactured by the same process.

The key to the cover names, which was made known after the test, was as follows:-

A = SS.970 r = (SS.906 r from Leuna + component 7 of Intava) mechanically stirred.
E = SS.970 = (SS.906 from Leuna + component 7) mixed by air.
D = SS.970 r = (SS.906 r from Leuna + component 7) mixed by air.
C = SS.970 r = (SS.906 + r inhibitor + component 7 stored and regenerated at Neuburg) mechanically stirred.
F = SS.970 = (SS.906 + component 7 stored and regenerated at Neuburg) mixed by air.
B = SS.970 r = (SS.906 + r inhibitor + component 7 stored and regenerated at Neuburg) mixed by air.

II. TEST METHOD.

The lubricants were tested by the ring-sticking process under the usual conditions (cf. report No. 425 of Technical Laboratories Oppau) in a BMW.132N - single cylinder with petrol injection. The engine test conditions are shown in plates 2 to 15. The following conditions were also observed:-

Ignition advance = 34° crank angle before t.d.c.
The gas flow-by past the rings was determined by measuring the static pressure (without determining the absolute volume of gas).
The oil consumption was calculated hourly from the volume required to bring the level up to normal.

Since running time depends a great deal on the cylinders and pistons which are used, all the tests were made with the same cylinder and piston. When the runs were repeated, a new piston had to be fitted, with which the running times were considerably shorter. An indirect comparison between the running times in the two series is possible if they are reckoned as a percentage of the running times for Rotring, which are from 6 to 8 hours. The physico-chemical investigation of new and used oils, which was carried out in connection with the engine tests, was made with samples taken after 1, 3, 5 and 7 hours, and at the conclusion of the test.

The strip inspection included the determination of ring-wear and combustion deposits. The deposit on the piston top includes that on the piston top land.

The ring play given is the average of measurements made at 8 points.

III. TEST RESULTS.

The test results are given comprehensively at the end of the report, and cover the following:-

Running times - 1st series:			Plate	1.
Test conditions, observations on dismantling, and state of the rings,	Series	1	"	2 - 15
Oil consumptions	"	"	"	16 - 18
Variation of gas blow-by, and control temperature,	"	"	"	19 - 21
Deposit formation and wear on rings,	"	"	"	22 - 23
Analysis of and tests on new oils,	"	"	"	24 - 29
Properties of the used oils, and changes in properties,	"	"	"	30 - 43
Running times - 2nd series:			"	44
Test conditions, strip inspections, condition of rings,	"	2	"	45 - 58
Oil consumptions,	"	"	"	59 - 61
Deposit formation and wear on rings,	"	"	"	62 - 63.

a) Engine Test.

Plate 1 shows the running times of the first series of tests. Oils A, B, C and F have practically the same running time, averaging 13½ hours, compared with the 8 hours of Rotring D. Only E, and in a less degree D, vary, with 11¾ and 13 hours respectively. The observations on dismantling and the condition of the rings are the same for all the oils. The deposit measurements, whether considered as a total or in grammes per hour (plates 22 - 23) are practically the same for all the oils, and the oil consumptions (plates 16 - 18) do not reveal such

differences as would explain the shorter running times of E and D.

A series of check tests (plates 44 - 58) in which, as stated, Rotring D had a running time of only 6 hours - a result of the different behaviour of the individual pistons, which reveals itself in the higher oil consumption in these runs - gave similar results. If these running times are altered in the same ratio as that existing between the times for Rotring, so as to correspond to Series 1, then the running times are practically the same for oils A, D and E, while oils B, C and F are shorter by 1½ to 3 hours. Oil consumption and the strip inspection again do not provide any clues for the differences.

As regards ring wear which, experience shows, does not give a clear picture of the wear-inhibiting effects of a lubricant in runs which are continued up to ring-sticking, the differences in the oils are striking, but when they are compared with the values of Series II they prove, as expected, to be due to experimental variations.

b) Physico-chemical test.

A comparison of the properties of the new oils shows that A and D have low saponification numbers, and that all have low values for the carbon value compared with Rotring D. In the first case, no connection can be established between these values and the running time; but the carbon residue, which for Rotring is twice that for the test oils, agrees fairly well with the ratio of the running times with Rotring and the test oils.

In the Indiana Oxidation tests oil A is particularly noteworthy, although the high asphalt content - confirmed by a check test - needs explaining.

There are no great differences in the properties of the used oils. Where there are differences, as in the asphalt content of oils C and F, these bear no relationship to the running times. There are slight differences in the carbon contents of the oils. An examination of the curves shows that here again the differences are due to inaccuracies of analytical measurement, and there is again no connection with the running times.

IV. CONCLUSIONS.

Comparing all the results with the composition of the individual oils, in accordance with the key on page 1, the following facts emerge:-

The r-additive appears to be effective when mixed with Leuna SS.906, as judged from the running times in both series of tests. The manner of mixing, whether by air or mechanical stirring, makes no difference to the running time. There is no improvement when the r-additive is mixed with regenerated Neuburg SS.906. This result agrees with the results of earlier tests, in which the addition of the inhibitor to a regenerated lubricating oil containing SS.906 did not bring about any improvement (Report No.450 of the Technical Laboratories, page 6). In these mixtures also the manner of mixing has no effect. It is also remarkable that from the shorter running times and higher consumptions recorded in the second series of tests the regenerated oils show a falling off, whereas in the first series there was no difference in the running times. This is perhaps due to the fact that the regenerated

lubricant ages more rapidly under the more exacting conditions in the second series. With new oils, there is a lower saponification number when the r-additive is added to SS.906 (ex Leuna), so that the analytical values agree with the engine results, whereas the addition of r-additive to regenerated SS.906 does not affect the saponification number. Good agreement with engine test results is obtained in the low Conradson carbon values in comparison with Rotring D.

The used oil tests reveal no distinguishable differences, which is in agreement with the analyses of these oils.

Summing up, it may be said:-

The manner of mixing has no influence on the ring-sticking behaviour. The r-additive, when added to the SS.906 from Leuna in the mixture to hand, produced an improvement, however slight, whilst no effect was observed on regenerated SS.906 from Leuna. In general, the ring-sticking behaviour of all the oils was considerably better than that of Rotring D, running times being reached which were up to 75% above Rotring D.

PLATE I. RUNNING TIMES OF THE VARIOUS LUBRICATING OILS.

PLATE 2. OIL TEST RUN IN B.M.W. 132 N SINGLE CYLINDER ENGINE

Average Values

Object	Comparative tests	Lubricant	A.No. 692
Number of test	145	Fuel	B4
Date of test	5.7.41	Room Temperature	45°C
Atmospheric pressure	759 mm-Hg.	Intake air temperature	40°C
Humidity	72%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.	Temperature of cylinder flange	-°C
Power (N.)	63 H.P.	Temperature of thermal plug	-°C
Specific fuel consumption	209 gr./ H.P. hour.	Temperature of exhaust gases	750°C
Setting of gas throttle	74°	Temperature of plug ring - intake	222°C
Gas pressure	60 mm Water	Temperature of plug ring - exhaust	237°C
Oil inlet temperature	117°C	Running time, observed	13.15 hours
" outlet "	120°C	Running time, corrected	- hours
" pressure	3.8/3.0 atü	Carbon in first groove	2632 mg.
" circulation	10.5 kg.	Carbon on piston head and land	1596 mg.
" consumption	5.6g/H.P. hour		

Remarks:

STRIP INSPECTION

Piston Crown: Light greyish-brown deposit, somewhat heavier at the edges at E and A.

Rings: From W to E, moderate carbon, otherwise only light coating.

Interior of piston: Even, light, shiny deposit.

Note: E and A above refer to inlet and exhaust valves respectively.

PLATE 3.

Carbonaceous Matter

Groove 1.	2632 mg.
Groove 2.	-
Groove 3.	-
Groove 4.	-
Piston Crown	1596 mg

Piston Ring Wear

Ring No.		1.	2.	3.	4.
Weight before run	mg.	63499	62800	-	55791
Weight after run	mg.	61423	62332	-	55736
Wear in	mg.	2076	468		055
Condition of the ring (sharp, burred, broken)		normal	normal		-

PLATE 4.

OIL TEST RUN IN B.M.W. 132 N SINGLE CYLINDER ENGINE

Average Values

Object	Comparative tests	Lubricant	B.693
		Fuel	
Number of test	152	Room Temperature	°C
Date of test	12.7.41	Intake air temperature	°C
Atmospheric pressure	748 mm Hg.		
Humidity	79%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.		
Power (N.)	63 H.P.	Temperature of cylinder flange	-°C
Specific fuel consumption	209 gr./H.P. hour	Temperature of thermal plug	-°C
Setting of gas throttle	74°	Temperature of exhaust gases	722oC
Gas pressure	66 mm Water	Temperature of plug ring - intake	226°C
		Temperature of plug ring - exhaust	239°C
Oil inlet temperature	116°C	Running time, observed	$13\frac{45}{}$ hours
" outlet "	120°C	Running time, corrected	- hours
" pressure	3.7/3.0 atü	Carbon in first groove	3152 mg.
" circulation	10.5 kg.	Carbon on piston head and land	2140 mg.
" consumption	8.0g/H.P.hour		

Remarks:

STRIP INSPECTION

Piston Crown: Light, dark coloured deposit, somewhat more pronounced at the edges of E and A.

Ring: Pronounced coking in neighbourhood of E, otherwise moderate carbon.

Interior of piston: Light asphaltic deposit in neighbourhood of E; thin, lacquered deposit in neighbourhood of A.

Note: E and A above refer to inlet and exhaust valves respectively.

PLATE 5.

Carbonaceous Matter

Groove 1.	3152 mg.
" 2.	-
" 3.	-
" 4.	-
Piston Crown	2140 mg.

Piston Ring Wear

Ring No.	1.	2.	3.	4.
Weight before run mg.	63364	62089		55983
Weight after run mg.	61421	61642		55838
Wear in mg.	1943	447		145
Condition of the ring (sharp,burred,broken)	normal	normal		

PLATE 6.

OIL TEST RUN IN B.M.W. 132 N SINGLE CYLINDER ENGINE

Average Values

Object	Comparative tests	Lubricant	C 694
		Fuel	B 4
Number of test	154	Room temperature	45°C
Date of test	14.7.41	Intake air temperature	40°C
Atmospheric pressure	751 mm Hg.		
Humidity	75%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.	" of cylinder flange	-
Power (N.)	63 H.P.	" " thermal plug	-
Specific fuel consumption	209 gr./H.P. hour	" " exhaust gases	730°C
Setting of gas throttle	74°	" " plug ring - intake	224°C
		" " " " - exhaust	238°C
Gas pressure	60 mm Water		
Oil inlet temperature	117°C	Running time, observed	14.00 hours
" outlet "	120°C	" " corrected	-
" pressure	3.7/3.0 atü	Carbon in first groove	3573 mg.
" circulation	10.5 kg.	Carbon on piston head and land	2411 mg.
" consumption	8.2g/H.P.hour		

Remarks:

STRIP INSPECTION

Piston crown: Light, dark coloured deposit somewhat more pronounced at the edges at E and A.

Rings: Pronounced coking in neighbourhood of E, otherwise moderate carbon.

Interior of piston: Light asphaltic deposit at E, thin lacquered deposit at A.

PLATE 7.

Carbonaceous Matter

Groove 1.	3753 mg.
" 2.	-
" 3.	-
" 4.	-
Piston Crown	2411 mg.

Piston Ring Wear

Ring No.	1.	2.	3.	4.
Weight before run mg.	62120	61830	-	55910
Weight after run mg.	60040	60960	-	55648
Wear in mg.	2080	870	-	262
Condition of the ring (sharp, burred, broken)	normal	normal		

PLATE 8.

OIL TEST RUN IN B.M.W.132 N SINGLE CYLINDER ENGINE

Average Values

Object	Comparative tests	Lubricant	D 695
Number of test	149	Fuel	B 4
Date of test	9.7.41	Room temperature	45°C
Atmospheric pressure	752 mm Hg.	Intake air temperature	40°C
Humidity	68%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.	" of cylinder flange	-
Power (N.)	63 H.P.	" " thermal plug	-
Specific fuel consumption	209 gr./H.P. hour	" " exhaust gases	725°C
Setting of gas throttle	74°	" " plug ring - intake	223°C
		" " " " - exhaust	241°C
Gas pressure	84 mm Water		
Oil inlet temperature	116°C	Running time, observed	13°° hours
" outlet "	120°C	" " corrected	-
" pressure	3.8/3.0 atü	Carbon in first groove	3159 mg.
" circulation	10.5 kg.	Carbon on piston head and land	2420 mg.
" consumption	9.4[x] g/H.P. hour		

Remarks:

STRIP INSPECTION

Piston crown: Thin black deposit, slightly more pronounced at the circumference in every case.

Rings: Pronounced coking in neighbourhood of E, elsewhere moderate carbon.

Interior of Piston: At E, more pronounced asphaltic deposit, at A thin, lacquered deposit.

Note[x]: Owing to an error in measurement, the consumption of 9.4g/H.P. measured at the beginning of the test is 10% high.

PLATE 9.

Carbonaceous Matter

Groove 1.	3159 mg.
" 2	-
" 3	-
" 4	-
Piston Crown	2420 mg.

Piston Ring Wear

Ring No.	1.	2.	3.	4.
Weight before run mg.	63594	62098		55920
Weight after run mg.	59495	59680		55257
Wear in mg.	4099	2418		663
Condition of the ring (sharp, burred, broken)	normal	normal		

PLATE 10.

OIL TEST RUN IN B.M.W.132 N SINGLE CYLINDER ENGINE

Average Values

Object	Comparative tests	Lubricant	E 696
Number of test	150	Fuel	B 4
Date of test	10.7.41	Room temperature	45°C.
Atmospheric pressure	749 mm Hg.	Intake air temperature	40°C.
Humidity	78%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.	" of cylinder flange	-
Power (N.)	63 H.P.	" " thermal plug	-
Specific fuel consumption	209 gr./ H.P.hour	" " exhaust gases	728°C
Setting of gas throttle	74°	" " plug ring - intake	227°C
Gas pressure	60 mm Water	" " " " - exhaust	238°C
Oil inlet temperature	116°C	Running time, observed	11^{45} hours
" outlet "	120°C	" " corrected	-
" pressure	3.8/3.0 atü	Carbon in first groove	2588 mg.
" circulation	10.5 kg.	Carbon on piston head and land	2173 mg.
" consumption	6.4g/H.P.hour		

Remarks:

STRIP INSPECTION

Piston crown: Very slight dark deposit.

Rings: Slight carbon at E, otherwise deposits insignificant.

Interior of piston: Light, asphaltic deposit.

PLATE 11.

Carbonaceous Matter

Groove 1.	2588 mg.
" 2.	-
" 3.	-
" 4.	-
Piston crown	2173 mg.

Piston Ring Wear

Ring No.	1.	2.	3.	4.
Weight before run mg.	62303	61807		55947
Weight after run mg.	61839	61647		55938
Wear in mg.	464	160		9
Condition of the ring (sharp. burred. broken)	normal	normal		

PLATE 12.

OIL TEST RUN IN B.M.W.132 N SINGLE CYLINDER ENGINE

Average Values

Object	Comparative tests	Lubricant	F 697
Number of test	151	Fuel	
Date of test	11.7.41	Room temperature	°C
Atmospheric pressure	747 mm Hg.	Intake air temperature	°C
Humidity	74%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.	" of cylinder flange	-
Power (N.)	63 H.P.	" " thermal plug	-
Specific fuel consumption	209 gr./ H.P.hour	" " exhaust gases	720°C
Setting of gas throttle	74°	" " plug ring - intake	225°C
Gas pressure	45 mm Water	" " " " - exhaust	239°C
Oil inlet temperature	116°C	Running time, observed	14.00 hours
" outlet "	120°C	" " corrected	-
" pressure	3.8/3.0 atü	Carbon in first groove	3019 mg.
" circulation	10.5 kg.	Carbon on piston head and land	2551 mg.
" consumption	6.1g/H.P.hour		

Remarks:

STRIP INSPECTION

Piston crown: Thin, greyish black deposit, slightly more pronounced at the edges at E and A.

Rings: Slight carbon at E, otherwise deposits insignificant.

Interior of piston: Thin, lacquered deposit.

PLATE 13.

Carbonaceous Matter

Groove 1.	3019 mg.
" 2.	-
" 3.	-
" 4.	-
Piston crown	2551 mg.

Piston Ring Wear

Ring No.		1.	2.	3.	4.
Weight before run	mg.	63150	62076		55892
Weight after run	mg.	62332	61817		55881
Wear in	mg.	818	259		11
Condition of the ring (sharp, burred, broken)		normal	normal		

PLATE 14.

OIL TEST RUN IN B.M.W.132 N SINGLE CYLINDER ENGINE

Average Values

Object	Comparative tests	Lubricant	Rotring D. 601
Number of test	142	Fuel	B 4
Date of test	2.7.41	Room temperature	45°C
Atmospheric pressure	757 mm Hg.	Intake air temperature	40°C
Humidity	83%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.	" of cylinder flange	-
Power (N.)	63 H.P.	" " thermal plug	-
Specific fuel consumption	209 gr./ H.P.hour	" " exhaust gases	740°C
Setting of gas throttle	74°	" " plug ring - intake	229°C
Gas pressure	40 mm.Water	" " " " - exhaust	238°C
Oil inlet temperature	117°C	Running time, observed	8.00 hours
" outlet "	120°C	" " corrected	-
" pressure	3.9/3.1 atü	Carbon in first groove	2114 mg.
" circulation	10.5 kg.	Carbon on piston head and land	1400 mg.
" consumption	6.7g/H.P. hour		

Remarks:

STRIP INSPECTION

Piston crown: Thin, greyish-brown to black deposit, slightly more pronounced at the edge at A.

Rings: Soot more pronounced at E, otherwise slight.

Interior of piston: Towards E, thin, dully shining deposit, at A, very thin lacquered deposit.

PLATE 15.

Carbonaceous Matter

Groove 1.	2114 mg.
" 2.	-
" 3.	-
" 4.	-
Piston crown	1400 mg.

Piston Ring Wear

Ring No.		1.	2.	3.	4.
Weight before run	mg.	62169	61680	-	56090
Weight after run	mg.	61395	61193	-	55996
Wear in	mg.	0,774	0,487	-	0,094
Condition of the ring (sharp, burred, broken)		sharp	normal		

PLATE 24

COMPLETE ANALYSIS OF AERO-ENGINE LUBRICANTS

Sample Ref. and Origin.	A.No. 692		B.No. 693		C.No. 694.	
Colour according to Rob/Lov. (^{X}8055)	6/6		6/6		> 6 < 7/7	
Smell	cracked		cracked		cracked	
Refractive Index n_D^{20} (^{X}8060)	1,4825				1,4835	
Density at 20°C (^{X}8065)	0,869		0,872		0,875	
Viscosity in Engler° and CS. at: (^{X}8070)	E°	CS	E°	CS	E°	CS
-10°C						
+ 0°C						
+10°C						
+20°C	122,0	927,0	122,8	934,2	117,0	888,8
+50°C	18,7	142,1	18,7	142,3	18,8	142,9
+100°C	3,06	21,68	3,03	21,37	3,01	21,23
+150°C	1,59	7,25	1,57	7,13	1,59	7,25
Pole height (^{X}8071)	1,77		1,81		1,81	
Directional factor m: (^{X}8071)	3,24		3,28		3,28	
Viscosity ASTM at 100°F						
Viscosity ASTM at 210°F						
Viscosity index: (^{X}8072)	107		104		102	
Setting point: (^{X}8075)°C	-28		-29		-28	
Flow point: (^{X}8076)°C	-22		-22		-21	
Flash point: (^{X}8080)°C	247		231		232	
Fire point: (^{X}8081)°C	279		289		287	
Neutralisation number (^{X}8085)	0,04		0,04		0,05	
Saponification number (^{X}8090)	0,19		0,23		0,27	
Fatty oil content (^{X}8090)						
Vaporisation test by Dr. Noack's method:						
at 225° %	3,4		3,8		4,5	
at 250° %	7,8		7,5		6,4	
at 275° %	10,3		9,4		9,5	

PLATE 24 (contd.)

Sample Ref. and Origin.	A.No. 692	B.No. 693	C.No. 694
Analine point °C (X7290 fuels)			
Iodine value (X7220 fuels)			
Mean molecular weight			
Conradson Carbon: (X8110)	0,10	0,17	0,12
Water content (X8105) weight %			
Solid foreign matter (X8101)			
Hard asphalt (X8100)	0,0%	0,0%	0,0%
Ash content (X8095)	< 0,01%	< 0,01%	< 0,01%
Oxidation test by Dr. Noack's method	before oxidation / after oxidation / Δ %	before oxidation / after oxidation / Δ %	before oxidation / after oxidation / Δ %
Viscosity at 50°C in CS			
Resin Content %			

X The figures refer to the B.V.M. test regulations.

PLATE 25

COMPLETE ANALYSIS OF AERO-ENGINE LUBRICANTS. SUPPLEMENT.

INDIANA TEST

mg. of Asphalt in 10 gm. oil.				Viscosity at 100°C in °E	Viscosity at 100°C in CS		
Oil	A No.692	B No.693	C No.694		A	B	C
Duration of test in hours	200	200	200				
0	0	0	0		21.88	21.37	21.23
25	2.0	2.3	1.6		23.79	23.53	22.62
50	2.8	2.1	2.6		25.72	25.28	25.58
75	2.6	2.3	2.2		27.87	28.31	26.86
100	2.6	2.2	2.2		31.11	31.66	31.64
125	2.9	2.3	2.3		37.07	36.67	36.63
150	2.8	2.7	2.2		48.21	45.50	45.13
175	3.2	2.5	2.6		65.71	59.81	58.43
200	10.0	3.3	3.2		109.4	100.3	84.02

PLATE 26

COMPLETE ANALYSIS OF AERO-ENGINE LUBRICANTS

Sample Ref. and Origin.	D.No. 695		E.No. 696		F.No. 697	
Colour according to Rob./Lov. (^{X}8055)	6/6		6/ 6 7		6 7/7	
Smell	cracked		cracked		cracked	
Refractive Index n_D^{20} (^{X}8060)	1,4825		1,4825		1,4835	
Density at 20°C (^{X}8065)	0,869		0,869		0,872	
Viscosity in Engler° and CS. at: (^{X}8070)	E°	CS	E°	CS	E°	CS
-10°C						
+ 0°C						
+10°C						
+20°C	120,2	913,7	118,3	899,0	117,1	890,8
+50°C	19,0	144,5	19,1	145,3	18,7	142,0
+100°C	3,03	21,37	3,02	21,30	2,99	21,04
+150°C	1,58	7,23	1,59	7,25	1,57	7,06
Pole height (^{X}8071)	1,78		1,79		1,74	
Directional factor m: (^{X}8071)	3,27		3,26		3,22	
Viscosity ASTM at 100°F						
Viscosity ASTM at 210°F						
Viscosity index: (^{X}8072)	102		104		101	
Setting point: (^{X}8075)°C	-28		-28		-30	
Flow point: (^{X}8076)°C	-21		-21		-22	
Flash point: (^{X}8080)°C	233		231		234	
Fire point: (^{X}8081)°C	287		278		279	
Neutralisation number (^{X}8085)						
Saponification number (^{X}8090)						
Fatty oil content (^{X}8090)						
Vaporisation test by Dr. Noack's method:						
at 225° %	3,9		3,9		3,6	
at 250° %	6,9		7,1		5,8	
at 275° %	9,1		9,5		9,7	

PLATE 26 (contd.)

Sample Ref. and Origin.	D.No. 695	E.No. 696	F.No. 697
Analine point °C (X7290 fuels)			
Iodine value (X7220 fuels)			
Mean molecular weight			
Conradson Carbon: (X8110)	0,14	0,14	0,14
Water content (X8105) weight %			
Solid foreign matter (X8101)			
Hard asphalt (X8100)	0,0%	0,0%	0,0%
Ash content (X8095)	0,01%	0,01%	0,01%
Oxidation test by Dr. Noack's method	before after oxidation Δ %	before after oxidation Δ %	before after oxidation Δ %
Viscosity at 50°C in CS			
Resin Content %			

PLATE 27

COMPLETE ANALYSIS OF AERO-ENGINE LUBRICANTS

SUPPLEMENT

INDIANA TEST

mg. of Asphalt in 10 gm. oil.				Viscosity at 100°C in °E	Viscosity at 100°C in CS		
Oil	D No.695	E No.696	F No.697		D	E	F
Duration of test in hours	200	200	200				
0	0	0	0		21,37	21,30	21,04
25	2,0	1,7	2,3		23,79	23,23	22,83
50	2,2	2,4	2,6		25,72	25,30	25,58
75	2,8	2,2	2,6		27,91	26,91	28,57
100	3,0	2,2	2,7		31,27	29,24	32,81
125	3,0	2,4	2,8		36,40	34,41	39,89
150	2,8	2,7	2,8		45,32	43,78	50,00
175	2,8	3,1	3,4		61,26	61,99	70,96
200	5,2	4,2	4,1		86,51	94,07	136,2

PLATE 28

COMPLETE ANALYSIS OF AERO-ENGINE LUBRICANTS

Sample Ref. and Origin.	Rotring D.	
Colour according to Rob./Lov. (^{X}8055)	6/6	
Smell	normal	
Refractive Index n_D^{20}	1,4925	
Density at 20°C (^{X}8065)	0,890	
Viscosity in Engler° and CS. at: (^{X}8070)	E°	CS
-10°C		
+ 0°C		
+10°C		
+20°C	119,8	911,0
+50°C	17,7	134,8
+100°C	2,73	18,85
+150°C	1,50	6,31
Pole height (^{X}8071)	2,01	
Directional factor m: (^{X}8071)	3,43	
Viscosity ASTM at 100°F		
Viscosity ASTM at 210°F		
Viscosity index: (^{X}8072)	90	
Setting point: (^{X}8075)°C	-23	
Flow point: (^{X}8076)°C	-17	
Flash point: (^{X}8080)°C	275	
Fire point: (^{X}8081)°C	322	
Neutralisation number (^{X}8085)	0,02	
Saponification number (^{X}8090)	0,14	
Fatty oil content (^{X}8090)		
Vaporisation test by Dr. Noack's method.		
at 225° %	0,6	
at 250° %	1,3	
at 275° %	2,9	

PLATE 28 (contd.)

Sample Ref. and Origin.	Rotring D
Analine point °C (X7290 fuels)	
Iodine value (X7220 fuels)	
Mean molecular weight	
Conradson Carbon: (X8110)	0,28
Water content (X8105) weight %	
Solid foreign matter (X8101)	
Hard asphalt (X8100)	0,0%
Ash content (X8095)	0,01%
Oxidation test by Dr. Noack's	before oxidation after oxidation Δ %
Viscosity at 50°C in CS	
Resin content %	

PLATE 29

COMPLETE ANALYSIS OF AERO-ENGINE LUBRICANTS

SUPPLEMENT

INDIANA TEST

mg. of Asphalt in 10 gm. oil		Viscosity at 100°C in °E	Viscosity at 100°C in CS
Oil	Rotring 601		
Duration of test in hours	200		
0	0		18,85
25	1,4		19,46
50	2,3		19,50
75	1,8		22,41
100	1,8		24,49
125	2,0		27,31
150	2,3		31,71
175	2,4		41,01
200	4.2		61,19

PLATE 45

OIL TEST RUN IN B.M.S. 132 N SINGLE CYLINDER ENGINE

Average Values

Object	Comparative tests	Lubricant	A Nr.692
Number of test	164	Fuel	B 4
Date of test	28.7.41	Room temperature	42°C
Atmospheric pressure	752,9 mm Hg	Intake air temperature	40°C
Humidity	23,8%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.	" of cylinder flange	-
Power (N.)	63 H.P.	" " thermal plug	-
Specific fuel consumption	209 gr./ H.P. hour	" " exhaust gases	730°C
Setting of gas throttle	74°	" " plug ring - intake	218°C
Gas pressure	30 mm Water	" " " " - exhaust	241°C
Oil inlet temperature	118°C	Running time, observed	9^{25} hours
" outlet "	120°C	" " corrected	-
" pressure	3,8/3,0 atü	Carbon in first groove	2580 mg.
" circulation	10.5 kg.	Carbon on piston head and land	1673 mg.
" consumption	11,6g/H.P.hour		

Remarks:

STRIP INSPECTION

Piston crown: Thin, dark deposit, slightly more pronounced at the edge at E and A.

Rings: Moderate coking at E, otherwise only slight deposit.

Interior of piston: Thin lacquered deposit.

PLATE 46

Carbonaceous Matter

Groove 1.	2580 mg.
" 2.	-
" 3.	-
" 4.	-
Piston crown	1673 mg.

Piston Ring Wear

Ring No.	1.	2.	3.	4.
Weight before run mg.	63018	62087		55727
Weight after run mg.	62192	61797		55698
Wear in mg.	826	290		29
Condition of the ring (sharp, burred, broken)	normal	normal		

PLATE 47

OIL TEST RUN IN B.M.W. 132 N SINGLE CYLINDER ENGINE

Average Values

Object	Comparative tests	Lubricant	B.No.693
		Fuel	B 4
Number of test	168	Room temperature	42°C
Date of test	6.8.41	Intake air temperature	40°C
Atmospheric pressure	748,4 mm Hg.		
Humidity	21,3%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.	" of cylinder flange	-
Power (N.)	63 H.P.	" " thermal plug	-
Specific fuel consumption	209 gr./ H.P. hour	" " exhaust gases	730°C
Setting of gas throttle	74°	" " plug ring - intake	222°C
Gas pressure	50 mm Water	" " " " - exhaust	242°C
Oil inlet temperature	117°C	Running time, observed	800 hours
" outlet "	120°C	" " corrected	-
" pressure	4,1/3,2 atü	Carbon in first groove	2525 mg.
" circulation	10.5 kg.	Carbon on piston head and land	1343 mg.
" consumption	11,4g/H.P.hour		

Remarks:

STRIP INSPECTION

Piston crown: Slight greyish black deposit, slightly more pronounced at the edges at E and A.

Rings: Moderate coking at E, otherwise slight.

Interior of piston: Thin, lacquered deposit.

PLATE 48

Carbonaceous Matter

Groove 1.	2525 mg.
" 2.	-
" 3.	-
" 4.	-
Piston crown	1343 mg.

Piston Ring Wear

Ring No.		1.	2.	3.	4.
Weight before run	mg.	63047	62612		55702
Weight after run	mg.	61615	62303		55411
Wear in	mg.	1432	309		291
Condition of the ring (sharp, burred, broken)		normal	normal		

PLATE 49

OIL TEST RUN IN B.M.W.132 N SINGLE CYLINDER ENGINE

Average Values

Object	Comparative tests	Lubricant	C.No.694
Number of test	167	Fuel	B 4
Date of test	5.8.41	Room temperature	42°C
Atmospheric pressure	746,2 mm Hg.	Intake air temperature	40°C
Humidity	22,3%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.	" of cylinder flange	-
Power (N.)	63 H.P.	" " thermal plug	-
Specific fuel consumption	209 gr./ H.P.hour	" " exhaust gases	730°C
Setting of gas throttle	74°	" " plug ring - intake	218°C
Gas pressure	50 mm Water	" " " " - exhaust	244°C
Oil inlet temperature	118°C	Running time, observed	8^{30} hours
" outlet "	120°C	" " corrected	-
" pressure	4.1/3.2 atü	Carbon in first groove	2666 mg.
" circulation	10.5 kg.	Carbon on piston head and land	1396 mg.
" consumption	9,65g/H.P.hour		

Remarks:

STRIP INSPECTION

Piston crown: Thin, dark brown deposit, slightly more pronounced at the edge.

Rings: Moderate coking at E, otherwise slight.

Interior of Piston: Thin, lacquered deposit.

PLATE 50

Carbonaceous Matter

Groove 1.	2666 mg.
Groove 2.	-
Groove 3.	-
Groove 4.	-
Piston crown.	1396 mg.

Piston Ring Wear

Ring No.	1.	2.	3.	4.
Weight before run mg.	62820	63516		56088
Weight after run mg.	61077	62690		55354
Wear in mg.	1743	826		734
Condition of the ring (sharp, burred, broken)	normal	normal		

PLATE 52

Carbonaceous Matter

Groove 1.	2550 mg.
" 2.	-
" 3.	-
" 4.	-
Piston crown	2162 mg.

Piston Ring Wear

Ring No.		1.	2.	3.	4.
Weight before run	mg.	62552	62596		55449
Weight after run	mg.	62158	62471		55356
Wear in	mg.	394	125		93
Condition of the ring (sharp, burred, broken)		normal	normal		

PLATE 53

OIL TEST RUN IN B.M.W. 132 N SINGLE CYLINDER ENGINE

Average Values.

Object	Comparative tests	Lubricant	E.No.696
Number of test	166	Fuel	B 4
Date of test	1. 8.41	Room temperature	42°C
Atmospheric pressure	751,2 mm Hg.	Intake air temperature	40°C
Humidity	19%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.	" of cylinder flange	-
Power (N.)	63 H.P.	" " thermal plug	-
Specific fuel consumption	209 gr./ H.P.hour	" " exhaust gases	730°C
Setting of gas throttle	74°	" " plug ring - intake	220°C
Gas pressure	40 mm Water	" " " " - exhaust	243°C
Oil inlet temperature	119°C	Running time, observed	8[45] hours
" outlet "	120°C	" " corrected	-
" pressure	4,1/3,2 atü	Carbon in first groove	2967 mg.
" circulation	10.5 kg.	Carbon on piston head and land	1712 mg.
" consumption	10.3g/H.P.hour		

Remarks:

STRIP INSPECTION

Piston crown: Thin, dark deposit, slightly more pronounced at the edge at E and A.

Rings: Slight soot, somewhat more pronounced towards E.

Interior of piston: Thin, lacquered, deposit.

PLATE 54

Carbonaceous Matter

Groove 1.	2967 mg.
" 2.	-
" 3.	-
" 4.	-
Piston crown	1712 mg.

Piston Ring Wear

Ring No.	1.	2.	3.	4.
Weight before run mg.	62634	63051		56024
Weight after run mg.	61238	62740		55745
Wear in mg.	1396	311		279
Condition of the ring (sharp, burred. broken)	normal	normal		

PLATE 55.

OIL TEST RUN IN B.M.W.132 N SINGLE CYLINDER ENGINE

Average Values

Object	Comparative tests	Lubricant	F.No.697
Number of test	161	Fuel	B 4
Date of test	26.7.41	Room temperature	44°C
Atmospheric pressure	751 mm Hg.	Intake air temperature	40°C
Humidity	24.8%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.	" of cylinder flange	-
Power (N.)	63 H.P.	" " thermal plug	-
Specific fuel consumption	209 gr./ H.P.hour	" " exhaust gases	730°C
Setting of gas throttle	74°	" " plug ring - intake	222°C
Gas pressure	30 mm Water	" " " " - exhaust	242°C
Oil inlet temperature	118°C	Running time, observed	9.30 hours
" outlet "	120°C	" " corrected	-
" pressure	3.8/3.0 atü	Carbon in first groove	2586 mg.
" circulation	10.5 kg.	Carbon on piston head and land	1342 mg.
" consumption	11.1g/H.P.hour		

Remarks:

STRIP INSPECTION

Piston crown: Slight dark deposit.

Rings: Moderate soot at E, otherwise slight.

Interior of piston: Thin, lacquered deposit.

PLATE 56

Carbonaceous Matter

Groove 1.	2586 mg.
" 2.	-
" 3.	-
" 4.	-
Piston crown	1342 mg.

Piston Ring Wear

Ring No.		1.	2.	3.	4.
Weight before run	mg.	62273	62638		55752
Weight after run	mg.	61899	62516		55750
Wear in	mg.	374	122		2
Condition of the ring (sharp, burred, broken)					

PLATE 57

OIL TEST RUN IN B.M.W. 132 N SINGLE CYLINDER ENGINE

Average Values

Object	Comparative tests	Lubricant	Rotring D No. 601
Number of test	162	Fuel	B. 4.
Date of test	26.7.41	Room temperature	44°C
Atmospheric pressure	751 mm Hg.	Intake air temperature	40°C
Humidity	24.8%		
Engine speed	1900 r.p.m.	Temperature of cylinder head couple	250°C
Power (measured)	57 H.P.	" of cylinder flange	-
Power (N.)	63 H.P.	" " thermal plug	-
Specific fuel consumption	209 gr./ H.P. hour	" " exhaust gases	730°C
Setting of gas throttle	74°	" " plug ring - intake	219°C
Gas pressure	60 mm Water	" " " " - exhaust	242°C
Oil inlet temperature	117°C	Running time, observed	6°° hours
" outlet "	120°C	" " corrected	-
" pressure	3.8/3.0 atü	Carbon in first groove	2391 mg.
" circulation	10.5 kg.	Carbon on piston head and land	2012 mg.
" consumption	10.5g/H.P.hour		

Remarks:

STRIP INSPECTION

Piston crown: Thin, dark-brown deposit, somewhat more pronounced at the edge at E and A.

Rings: From E to WS moderate carbon, otherwise normal.

Interior of piston: Thin, lacquered deposit.

PLATE 58

Carbonaceous Matter

Groove 1.	2391 mg.
" 2.	-
" 3.	-
" 4.	-
Piston crown	2012 mg.

Piston Ring Wear

Ring No.		1.	2.	3.	4.
Weight before run	mg.	62734	62126		55499
Weight after run	mg.	61238	61527		55176
Wear in	mg.	1496	599		323
Condition of the ring (sharp, burred, broken)		normal	normal		