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DEUTSCHE VERSUCHSANSTALT FÜR LUFTFAHRT (D.V.L.) INSTITUT FÜR BETRIEBSTOFF FORSCHUNG

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DEUTSCHE VERSUCHANSTALT FÜR LUFTFAHRT (D.V.L.)
INSTITUT FÜR BETRIEBSTOFF FORSCHUNG

Interrogation of Evacuated Personnel
at
Strass near Neuberg, Germany

August 4th and 8th
1945

Reported by

Captain C.C. Chaffee, U.S. Army Ordnance.
Dr. W.F. Faragher, US, Petroleum Administration for War.
Major W.H. Thomas, Br, Ministry of Fuel and Power

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Fuels and Lubricants

BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE
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CONTENTS

C O N T E N T S (Contd.)

PERSONNEL OF INTERROGATING TEAM.

Captain C.C.Chaffee, U.S.Army Ordnance.
Dr. W.F.Faragher, U.S., Petroleum Administration for War.
Major W.H.Thomas, British, Ministry of Fuel and Power.

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1. INTRODUCTION.

The evacuated staff from Deutsche Versuchsanstalt für Luftfahrt (D.V.L.) - Institut für Betriebstoff Forschung having been located at Strass, near Neuberg, a visit was made to Strass with the primary object of interrogating Dr. Philippovich and his staff on matters concerning German aviation fuels and lubricating oils. This was carried out on August 4th and 8th 1945. The evacuated D.V.L. Staff at this location are as follows:-

Von Philippovich,	Dr. Phil.	In charge of INSTITUT FÜR BETRIEBSTOFF FORSCHUNG, D.V.L.
Glaser,	Dipl. Ing.	Engine testing of lubricants.
Krienke,	Dr. Ing.	Laboratory testing of lubricants.
Meyer-Burstrom,	Dr. Ing.	Laboratory investigation of Fuels.
Morghen,	Dr. Tech. Dipl. Ing.	Fuel research.
Seeber,	Dr. Ing.	Engine testing of fuels.
Broicher,	Ing.	Engine investigations and exhaust gas testing.
Wenzel,	Ing.	Engine investigations.
Kasper,		Fitter.
Schmidt, Dagmar		Typist.
~~Seyfarth~~		~~Laboratory Assistant.~~

2. SUMMARY.

(a) This report details information obtained by interrogation of Dr. Philippovich and other members of the staff of Deutsche Versuchanstalt fur Luftfahrt (D.V.L.) - Institut für Betriebstoff Forschung evacuated from Adlershof, Berlin to Strass,

near Neuberg, Germany. The subjects discussed were limited to Fuel and Lubricant Utilisation and Performance.

(b) The Luftwaffe employed three main types of aviation fuel. A3 fuel of 80 C.F.R. Motor Octane Number and having an ethyl alcohol content of ca. 30% volume was used for training aircraft, B4 fuel of 89 Octane Number was the normal grade for operational aircraft and C3 fuel of 95 Octane Number was used in aircraft powered with high duty engines. In addition an easy starting fuel, comprising a blend of light gasoline and 5% lubricating oil and an unleaded "Running Out" fuel were also used. Recent specifications for these fuels are given. Safety fuels were not adopted by the Luftwaffe.

(c) All aviation fuels supplied to the Luftwaffe were required to pass specifications concerning general quality and in addition were required to give a minimum performance at both weak and rich mixture strengths in a supercharged single cylinder aero engine test involving the air cooled BMW 132 engine which was developed and standardised by D.V.L.

(d) An important factor in the utilisation of German aviation fuels was the use of 120° valve overlap in the aero engines. This enabled very good weak mixture performance to be obtained even with the highly aromatic C3 fuels.

(e) The non-aromatic German aviation fuels gave no stability or storage problems but trouble due to gum formation and lead precipitation was encountered when the highly aromatic fuels were introduced. These difficulties were however overcome by the addition of 0.01% vol. of a phenolic inhibitor extracted from Welheim synthetic gasoline.

~~(f) Galvanised filter corrosion with leaded fuels was~~ overcome by the adoption of cadmium plated filters but increase in the Octane Number of B4 fuels to 95 by the addition of methylaniline and by increasing the T.E.L. content to 7.3 ccs./Imp. gallon was not adopted because of increased valve corrosion and sparking plug failures and increased cold corrosion.

(g) Diesel fuels were but little used by the Luftwaffe because the take off power obtainable by the use of diesel engines was insufficient.

(h) Recent specifications for Jet Propulsion Fuels and Fuel for Flying Bombs are given. These reveal little of a novel character, the former being of the Kerosine - light gas oil type having good cold test properties and the latter being an inferior motor fuel.

(i) Two grades of aero engine lubricating oils were employed by the Luftwaffe. A blend of synthetic bright stock and light solvent refined petroleum oil was employed for the high duty engines and a compounded oil containing 3-4% of voltolised rape seed oil for the other engines and for the aero diesel engines. These oils were designated S3 and V2 respectively.

(j) All supplies of these oils were required to pass ring sticking and wear tests in the BMW 132 single cylinder aero engine and also to pass a 100 hour type test in a main engine. The BMW 132 tests are described and also ring sticking tests carried out on a DKW 2-stroke single cylinder liquid cooled engine using petroil lubrication.

(k) No ring sticking additives were used in Luftwaffe aero engine oils but the I.G. oxidation inhibitor R was employed and also dichloro diphenyl phosphorous acid as a wear reducing agent. Paraflow and Paratone additions were not required in the case of S3 oils containing synthetic bright stock.

(l) D.V.L. carried out laboratory work on lubricating oils and lubrication which covered such aspects as the chemical reactions occuring during lubricating oil oxidation, wear tests in conventional friction machines and wear testers and also fundamental studies on surface tension etc. This work is briefly described.

3. AVIATION FUELS

(a) Methods of Manufacture and Specifications.

At the outset, a gasoline synthesis based on coal was sought which would allow an adequate production of good quality aviation gasoline of 87 Octane Number containing paraffins, isoparaffins and naphthenes and only a small quantity of aromatics. At this time large scale production of alkylate or isooctane was not considered on account of lack of the raw materials although as the war proceeded an important production of these materials was achieved. At a later date however engine tests shewed that with aromatic fuels the take off power could be increased considerably by enriching the mixture strength and without experiencing detonation and for this reason, although aromatics are more sensitive to temperature conditions and mixture strength than other hydrocarbons, it was then decided to begin the large scale production of aromatic type fuels by dehydrogenation or aromatisation processes. These processes allowed the production of the so-called "100 Octane" class of German Aviation Fuels.

The various gasoline components available for blending in aviation fuel manufacture were as follows:-

Code Number	Description.	
VT100	Petroleum Gasoline.	
VT702	Leuna Hydro Gasoline.	
VT705	Scholwen do.	
VT707	Gelsenberg do.	
VT708	Politz paraffinic-naphthenic.	
VT810	Brabag Bohlen (5-15% aromatics)	
VT811	Zeitz.	
VT812	Brüx.	
VT813	Wesseling.	
VT330	Welheim.	
VT341	Ludwigshafen.	
VT342	Leuna.	
VT345	Scholwen Dehydrogenation Gasoline	
VT348	Pölitz do.	
VT350	Moos-Bierbaum.	
CV2b	Aromatised Aviation Gasoline.	
ET100	Iso-octane.	
ET110	Iso-octane or Iso-dodecane.	
ET120	Alkylate	Leuna
		Scholwen
		Pölitz
		Heydebreck
		Ploeschti
		Moos-Bierbaum.
VT302	Aviation Benzole.	
VT303	Diethylbenzene ex Huls.	

Three main grades of aviation gasoline were produced, namely A3 for training purposes, B4 for normal use and C3 for aircraft powered with high duty engines requiring high performance fuels.

(i) A3 Fuel.

Specification TL 147 - 257/4 for this fuel, dated November 1944, is reproduced in Appendix 1. It requires a minimum Octane Number of 80 with the addition of not more than 0.045 vol. % T.E.L. (2.05 ml./Imp. Gallon) but calls for an ethyl alcohol content of 27-33% vol. and a maximum aromatic content of 35% vol. The use of ethyl alcohol in this fuel was first permitted on August 18th 1944, the reason being shortage of T.E.L. and benzole.

(ii) B4 Fuel.

This aviation fuel had a minimum C.F.R. Motor Method Octane Number of 89 and was, in addition, required to give a performance in the standard BMW-132 single cylinder aero engine test at least equal to B4 reference fuel ("Eich B4") over the range of fuel/air ratio 0.8 to 1.15. Specification TL 147/304/4 dated November 1944 is reproduced in Appendix 2. B4 aviation fuels normally comprised either hydro-gasolines from bituminous coal or mixtures of hydro-gasolines from brown coal and aromatic type gasoline, alkylate or benzole.

(iii) C3 Fuel.

The specification requirements for this fuel were relaxed in August 1944 although the official Specification TL 147 - 330/3 was not replaced by Specification TL 147 - 330/4 until November 1944. Relaxations covered the following points:-

Sp.Gr.at 15°C.	Changed from 0.76-0.795 to 0.74-0.795.
Boiling Range.	50% temperature increased from 100°C to 120°C max. 90% temperature increased from 160°C to 180°C max. FBP temperature increased from 180°C to 190°C max.

Storage Stability.

Increased from 3 months to 6 months, examination only being required after 3 months.

Single Cylinder BMW 132 Test.

This was retained but the fuel was required to give a performance at least as good as the reference fuel (Eich C3) over the restricted fuel/air ratio range 0.8 - 1.15 instead of over the range 0.75 - 1.3 previously insisted upon.

The amended Specification TL 147 - 330/4 is reproduced in Appendix 2.

C3 Fuels were manufactured by blending 80% vol. of aromatic type gasoline made by dehydrogenation with 20% vol. iso-octane or alkylate or alternatively by blending 45% B4 fuel with 25-30% diethyl benzene and 20-25% iso-octane or alkylate.

It should be noted that the Germans refer to C3 gasolines as 100 O.N. gasolines although the CFR Motor Method Octane Number requirements is only "about 95".

(iv) **Starting Fuel.** (Fl.-Anlasskraftstoff).

For easy starting a special fuel was used consisting of a blend of light gasoline and 5% lubricating oil. Specification TL 147 - 300/2 for this fuel, dated February 1944 is given in Appendix 3.

(v) **"Running Out" Fuel.**

To prevent corrosion of engines standing idle by the combustion products of leaded gasolines a so-called "Running Out" fuel was introduced which was lead free and of sufficiently high anti-knock value.

For high altitude flying a fuel was considered which would have the low vapour pressure of 0.2 atm. at 38°C. a density at 20°C of 0.800 and a Final Boiling Point of 185°C. which containing 20% iso-octane or alkylate would have a performance in the BMW 132 single cylinder aero engine at least equal to the reference fuel "Eich C3".

(vi) Safety Fuel.

The original idea in adopting the use of direct injection engines in the Luftwaffe was to use high boiling - i.e. "Safety" fuels. It is, however, necessary to define what safety really is because every fuel which is used to perform work by burning must be dangerous to a certain degree. For example, coal dust explodes under certain conditions. It was shewn in work carried out at D.V.L. Berlin that the idea of Safety embraces the properties of self-ignition (SZT) and inflammability (FLp) and the spreading of flames on fluid surfaces and safety fuels are of value if they are so viscous that they only give short flames in which case their lubricating value is an added advantage. Materials of this type were investigated experimentally but were not adopted. For their use the Ring method was proposed by the I.G. so that by the use of an "ignition oil" the sparking plug could be eliminated. Safety fuels were not used by the Luftwaffe because no need for such fuels arose and because their cold properties and storage characteristics had not been fully established.

(b) Engine Testing.

Engine tests on aviation fuels to determine the interrelation of engine constructional details, operating conditions, fuel type and knocking properties formed one of the main lines of work of the D.V.L. The facilities provided for this work were such that engine cylinders of widely different types could be studied, i.e. water cooled, air cooled, poppet valve, slide valve and sleeve valve, and gasolines of all chemical types could be examined.

One of the main results of this work was the development and standardisation of the BMW 132 single cylinder aero engine unit for the determination of aviation fuel performance and this unit was used widely in Germany in fuel development. The reproducibility of the performance curves was stated to be within 4-6% and although a liquid cooled engine such as the DB601 would have given better reproducibility the air cooled BMW engine was very much cheaper. The standard conditions used in the BMW test were as follows:-

RPM	1600
Intake air temp.	130°C - Supercharged.

Valve overlap.	40°
Cooling air pressure.	300 mm. Hg.
Oil Temperature.	90°C.
Cylinder Head Temperature	240-250°C. max.
Ignition	35°B.T.D.C.

and results were expressed in the form of a curve relating air-fuel ratio and mean effective pressure in the usual manner.

Philippovich stated that valve overlap had a profound effect on the shape of the performance curve obtained, the power drop at lean mixtures being markedly reduced with increased overlap, particularly at air intake temperatures below 100°C. At higher inlet air temperatures a reversed effect was sometimes observed. In general, however, with 120° overlap maximum power is obtained at about the theoretical air/fuel ratio and enrichment actually induces detonation. The effect is more marked in the liquid cooled D.B. engines than in the air cooled BMW engine and is brought about by the improved scavenging of exhaust products from the engine cylinder.

It is important to carry out single cylinder tests in engines of the same detailed construction and arrangement as the large scale engines otherwise the tests will be of little value in determining fuel behaviour in the main engine. This is illustrated in the graphs reproduced in Appendix 11.

Octane Number determinations were used for day to day control of fuel production and were carried out in CFR and later I.G. test engines. The supercharged I.G. engine (Oppau method) was also employed for determining performance curves as on the BMW 132 engine except that in this case the blower pressure was kept constant at 1000 mm. Hg. and the air/fuel ratio altered. This Oppau method agreed reasonably well with the larger engine and was widely used.

D.V.L. originally intended to develop a small fuel testing engine which would be suitable for testing lubricating oils as well as fuels but this idea was dropped at the outbreak of war and was not further pursued.

Philippovich stated that differences in the anti-knock properties of fuels gradually disappeared as the compression ratio was increased and that this tended to reduce the value of high performance fuels.

Pre-ignition was not a problem in German aero engines in spite of the wide use of aromatic type fuels but towards the end of the war BMW had reported its occurence and it was investigated in the single cylinder BMW unit.

(c) Gum Stability and Lead Stability.

The non-aromatic German Aviation Fuels gave no stability or storage problems but difficulty was experienced as soon as the aromatic fuels were employed. Investigations on this phenomenon shewed that the initial oxidation of the hydrocarbons in such fuels caused the decomposition of tetra ethyl lead and that the lead decomposition products accelerated the oxidation of the hydrocarbons. This process leads finally to lead sludge and also to a decrease in anti-knock value and is only prevented by the use of suitable inhibitors. Such an inhibitor is a phenolic type extract obtained from Welheim synthetic gasoline and was used in 0.01% vol. concentration.

It was also found that leaded fuels caused trouble with galvanised fuel filters, zinc salts being formed which plugged the filters. This was overcome by the adoption of cadmium plated filters.

(d) Analytical Estimation of T.E.L. and Ethylene Dibromide.

A quick and accurate semi-micro method was worked out by D.V.L. for the estimation of T.E.L. It involved the precipitation of T.E.L. as diethyl lead chloride and its titration with dithiozone solution and was stated to be capable of an accuracy of at least 0.001% vol. In the case of fuels containing amines the analysis was preceded by treatment with dilute sulphuric acid to remove the bases.

Ethylene dibromide contents were determined by ionisation with zinc in conjunction with alcohol, water, acetic acid and pyridine and then estimated by the Volhard method. This procedure uses only 25 cc. of fuel, takes 35 minutes to carry out and gives an accuracy of about ± 0.0005% vol.

(e) Anti-Knock Additives.

At one time the question of raising the anti-knock value of 87 O.N. gasoline to 100 O.N. by the addition of methylaniline and by increasing the T.E.L. content to 0.16% vol. (7.3 cc./Imp. gallon) was considered. This suggestion was, however, turned down because of increased valve corrosion, damage to sparking plugs and increased cold corrosion.

4. DIESEL FUELS

Diesel fuels were but little used by the Luftwaffe because take off power is insufficient with diesel engines. Both natural and synthetic oils were employed and the main requirements were good cold test properties and ease of ignition. As far as was known to Philippovich no ignition accelerators were employed. Specification TL 147 - 351/2 for Aero Diesel Fuel dated April 1944 is reproduced in Appendix 4. This specification demands a minimum Cetane Number of 50 and a Pour Point of -45°C max.

Diesel oil ignition value tests were carried out by the usual ignition delay or throttling methods but had little importance on account of the small demands on diesel fuel by the Luftwaffe.

5. JET PROPULSION FUELS.

As in the early days of the diesel engine it was originally considered that any type of liquid fuel could be burnt in jet units but experience shewed that it was necessary to establish somewhat stringent specifications if troubles in operation were to be avoided. Thus the fuels must have good cold test properties and allow easy starting, the sulphur content must be below 1.5% in order to avoid hot corrosion of the turbine blades, the coking properties must be good so as to avoid coke formation in the combustion chambers, on ignition plugs, in slit mixers and on turbine guide vanes. It was also necessary to restrict the aromatic and phenol contents in order to reduce corrosion and attack of pump packing materials etc. Based on these requirements Specification TL 147 - 286/2 was formulated for Jet Propulsion fuel which was known as J2 Fuel. A copy of the October 1944 issue of this specification is reproduced in Appendix 5.

Owing to supply difficulties a running in fuel of lower specific gravity, higher vapour pressure and inferior cold test properties was introduced known as Einlauf J2. The October 1944 issue of the specification for this material is also given in Appendix 5. Aviation fuel was used for starting Junkers jet units.

It was stated by Philippovich that as combustion chamber and turbine design is improved the fuel requirements should become less stringent and they were already considering the use of fuels of up to 15% phenol content, 3% sulphur content, 2.5% Conradson Carbon and of higher viscosity (8°E. at 20°C.)

6. FUEL FOR FLYING BOMBS (E1)

The important requirements were cold stability, high calorific value and freedom for corrosion. Anti-knock value, distillation properties and gum content were of no significance as shewn in the specification dated September 1943 reproduced in Appendix 6.

7. D.V.L. RESEARCH ON COMBUSTION.

Combustion was studied by D.V.L. in collaboration with Prof. Jost who investigated adiabatic spontaneous ignition by compression and also slow oxidation at low temperatures along the lines originally followed by Pope, Dykstra and Edgar (JACS., 1929, 51, 1875, 2203, 2213). The work on adiabatic spontaneous ignition served to characterise a fuel according to its ignition delay and when the log of the ignition delay was plotted against temperature a straight line relationship was obtained.

Later, however, F.A.F. Schmidt of D.V.L. shewed that this linear relation only applied for relatively long delays and at higher pressures and at short delay times the relationship was not linear. This work indicated that Jost's assumption that knock depended only upon temperature was incorrect and that it was also influenced by pressure. This work led D.V.L. to enlist the assistance of Dr. Tiechmann, an earlier cooperator of Jost and he extended the work, but complete agreement with engine results was not obtained and it appeared that knock was not only caused by a simple heat explosion but also by a cold reaction having a negative temperature coefficient.

For determining the onset of detonation in engines the D.V.L. Zeiss Ikon indicator was developed which permitted taking not only the simple pressure diagram but also its first and second differentials with respect to time. This indicator gave substantially the same results as were obtained with the A.W.Schmidt and Heitung indicators, both of which are of the quartz type, but these gave some trouble due to noise deflections.

For analysing exhaust gases the D.V.L. exhaust gas tester operating on a thermal conductivity principle was constructed in portable form capable of operating on 6, 12 or 24 volts and incorporating a flow controller for standardising the gas velocity and a fine ceramic filter for cleaning the exhaust gas passing to the instrument. The construction of an indicator for analysing the very weak mixtures used in jet units was begun but was interrupted by the end of the war. This was based on the paramagnetic properties of oxygen.

8. AERO LUBRICATING OILS.

The Luftwaffe used two grades of aero engine lubricating oils, namely S3 and V2, specifications for which, dated June 1944, are reproduced in Appendix 7.

(a) S3 Lubricating oil was a blend of petroleum base oil, solvent refiner, and having a viscosity of about 6°E. at 50°C. with synthetic bright stock of viscosity about 6°E. at 100°C. the latter being produced by the polymerisation of ethylene (I.G. - Leuna) and by the polymerisation of olefines obtained by cracking paraffin wax (Rhenania and Politz). Code numbers for these oils and for the petroleum oil components were as follows:-

Synthetic Bright Stocks.

906	I.G. Leuna ex Ethylene.
1006	Rhenania ex Paraffin Wax.
1106	Politz ex Paraffin Wax.

Petroleum Oils.

607	Rhenania - Edeleanu Process.
707	Deutsche-Vacuum - Duosol Process.
807	Deurag-Nerag - Furfural Process.

S3 lubricating oil was used in most operational aircraft, particularly high duty engines such as the BMW 801 series and the Daimler-Benz 603 and 605 series.

(b) V2 Lubricating Oil replaced the previously used Aero Shell Medium Oil (ASM) and comprised a petroleum oil compounded with 3-4% of voltolised rape seed oil. It was supplied exclusively by Rhenania Ossag and found its main use in the lower duty engines and also in the Junkers Jumo 205 and 207 aero diesel engines for which it was particularly specified despite the fact that its ring sticking propensities were greater than in the case of S3 oil. The detergency properties of V2 oil were considered to be very good indeed.

(c) Additives in Aero Engine Lubricating Oils.

Detergency additives were not employed in Luftwaffe aero engine lubricants but many contained the I.G. additive known as "R inhibitor" the function of which was to improve oxidation stability. This inhibitor was, however, not always necessary as some of the synthetic oils were sufficiently stable without the inhibitor and in this respect were superior to petroleum oils. On the other hand the lubrication behaviour of the S3 oil blend was often insufficient and the use of a chlorine containing phosphorous acid ester as lubrication additive was introduced (This is probably the J7 compound manufactured by I.G. at Leverkusen, i.e. dichloro diphenyl phosphorous acid).

The synthetic oil blends did not need the addition of either Paraflow or Paratone but these dopes were used in some petroleum lubricants.

(d) Running Out Oil.

For use in engines being set aside idle for an extended period, Nachlaufschmierstoff T 42, a very thin compounded oil, was employed. The same oil was employed for starting in the Russian winter campaigns as it had a Pour Point of -45°C. max. Specification TL 147 - 700/1 for this material, dated October 1943, is given in Appendix 8.

(e) Cold Starting Oils.

For starting at low temperatures, as was required for example in the Russian Campaigns, the normal lubricating oil grades S3 and V2 were simply diluted with gasoline, the quantity of the latter being adjusted according to the prevailing temperature, as much as 25% being used in some cases. Little was known of the field experiences in the use of diluted lubricants but it was stated that wear was reduced because of the easy starting obtained and that crank case explosions rarely occurred.

(f) Engine Testing of Lubricating Oils.

During the first two years of the war lubricating oil quality was not a problem but when some trouble was encountered with the bearings of Daimler-Benz engines it was decided to inaugurate full-scale engine tests. The BMW 132 single cylinder aero engine unit was adopted as the acceptance test unit and all oils supplied to the Luftwaffe were also required to pass a 100 hour main Engine Test.

(i) Ring Sticking Tests.

The operating conditions used on the BMW 132 engine for this test were as follows:-

Compression Ratio	6:1
Supercharge	None
R.P.M.	2200
Approx. power	60 B.P.H.
Fuel Consumption	approx. 0.5 lb/BHP/H (B4 fuel used).
Ignition	30° BTDC.
Oil Inlet Temp.	110°C.
Oil Outlet Temp.	approx. 113°C.
Cylinder Temp. at Spark Plug.	256°C
Piston Temperature	310°C
Oil Consumption	about 0.04 lb./Hour.

Under these conditions oils were rated in terms of number of running hours possible before ring sticking occurred, the incidence of ring sticking being indicatod by decrease in power and increase of blow by of combustion gases into the crank case. Typical results were as follows:-

Aero Shell Medium	3½ - 4 hours.
S3 Oil	8 hours
Intava Rotring	9 "
Intava Green Band (Pre-war Supply)	12 "

Experimental work at D.V.L. has shewn that the ring sticking property of lubricating oils is primarily dependent on the temperature prevailing in the piston ring groove. This is illustrated by the graph given in Appendix 9, in which running time is plotted against temperature for five different oils in the BMW 132 test under conditions somewhat different from those given above and shews that with rise in temperature the running time decreases to a minimum value and increases again with further rise in temperature up to a point (not shewn in the figure) where still further rise in temperature again results in a decrease in running time due to rapid carbonisation. It is considered by Philippovich that the initial decrease in running time with rise in temperature is due to asphalt formation and that the subsequent increase in running time with rise in temperature is due to burning away of the asphaltic deposits.

Another ring sticking test developed by D.V.L. involved the use of a 2-stroke single cylinder liquid cooled D.K.W. unit fitted with a special piston having only one piston ring. Behind the ring in the groove are two small holes of 1.2 mm. diameter and blockage of these holes as indicated by an increase in power output is taken as a measure of ring sticking. Petroil lubrication is employed and the standard test conditions are as follows:-

Compression Ratio	5:1
R.P.M.	3000
Power Output	ca. 3.9 B.H.P.
Fuel	B4 plus 5% lube oil under test.
Air Intake Temp.	23 - 25°C.
Glycol coolant inlet Temp.	12 - 30°C.
Combustion Chamber Temp.	550 - 620°C.
Exhaust Temp.	470 - 480°C.
Ignition	30°BTDC.
Side clearance of piston.	0.15 mm.

In this test S3 oil and Intava Rotring give average ring sticking times of about 8 hours. It is essential in this test to control piston temperatures.

(ii) Wear Tests.

Various single cylinder test units (BMW 132, Siemens, NSU etc.) were employed for ~~determining the lubrication properties of oils~~ and extent of wear. Satisfactory results were obtained on these units after they had been adequately standardised and they were found capable of reproducible results and shewed up oil differences in such a manner as to allow good assessments of the effect of refining treatments, compounding, graphitisation, etc. The tests also shewed that for a series of oils all having the same viscosity at 50°C. the extent of wear could vary by as much as a factor of 4.

The engine most widely used for wear tests was the BMW 132 single cylinder aero engine as used for ring sticking tests but different operating conditions were employed, namely -

Oil inlet temperature	120°C.
Oil outlet temperature	122°C.
Cylinder temp. at Sparking plug.	260°C.
Quantity of oil in circulation	8 - 10 litres.
Duration of test	6 hours.

In other respects the test conditions were unaltered.

Wear was assessed by careful weighing of the piston rings before and after test.

Dr. Philippovich stated that in general oils found to have good wear properties were not very good from the ring sticking point of view and vice versa, a possible reason being that the active molecules responsible for good lubricity not being very stable. Furthermore, the mechanical condition of the engine, particularly ovality of the piston and cylinder, were often more important than differences in the properties of lubricating oils of similar viscosity. American test engine methods normally operate under less stringent conditions and hence give longer running times.

Investigations were also carried out at D.V.L. in which a single cylinder engine was operated without fuel but by air at 200°C blown in with a supercharger at 2.6 atm. pressure to give the requisite operating temperature and mean pressure. In this way the effects of fuel and lubricant could be separated and wear figures were obtained of the same order of magnitude as when operating the engine normally. The chief difficulty experienced was in obtaining a supply of oil free air, the blowers being oil lubricated and appreciable oil leakage occurred into the air stream.

(g) Laboratory Work on Lubricating Oils.

D.V.L. made attempts to determine the ring sticking properties of oils in simple laboratory type apparatus so as to avoid expensive and time consuming engine tests and in order to allow measurement of increased friction caused by asphalt formation. In this however they were not successful.

Laboratory tests on wear properties were made using standard Almen, Wieland, Thomas and Physikalisch Technischen Reichanstalt (Vieweg-Kluge) machines but these were not satisfactory as they gave variable results and a Four Ball apparatus was therefore constructed. This apparatus allowed the determination of friction coefficients with an accuracy of ± 0.001. It consisted of three balls touching each other on a plane representing the guide bearing and a fourth ball rotating in contact with the other three and operated by an air turbine filled with symmetrical tangentially arranged adjustable air jets. The test conditions were similar to those selected by Boerlage and the apparatus was so arranged that only very small lubricating oil samples were required and tests could be carried out over the temperature range -20°C. to +200°C. in various gas atmospheres and with a wide variety of bearing metals.

Investigations on the lubricity of engine oils revealed that differences in behaviour were due not so much to differences in chemical structure as to differences in sulphur content and reactivity of the sulphur compounds present towards the bearing metals. This conclusion was supported by general experience with Extreme Pressure lubricants and by the work of Professor Glocker at Stuttgart which resulted in the development of J7 chlorine-phosphorus dope.

This work led up to the estimation of the "reactive" sulphur contents of lubricating oils by heating in a current of hydrogen and determining the amount of hydrogen sulphide formed.

Work was also carried out at D.V.L. and also by Prof. Wolf at the University of Halle on surface tension studies of oils in contact with mercury. Prof. Erbacher of the K.W.I. für Chemie in Berlin was studying the surface characteristics of metals by means of radio active elements and Dr. Seolich of the K.W.I. für Physikalische Chemie in Berlin carried out research on the orientation of lubricating oil molecules at oil-water interfaces. Erbacher and Seolich were awarded contracts for these researches from D.V.L.

The deterioration of lubricating oils in use by oxidation and thermal breakdown reactions was also investigated at D.V.L. and the line of work undertaken was to develop analytical procedures for determining the various oxidation products formed so that the mechanism of the processes leading to asphalt formation could be better understood. The scheme of analysis followed is given in Appendix 10. The work was very tedious and the method was not fully developed. Similar work was also carried out on pure cetane and on the use of chromotographic methods for analysis of the oxidation products.

Work on the lubrication properties of oils in the hydrodynamic flow range was also carried out by D.V.L. but the end of the war brought it to a premature conclusion.

In their work on lubrication problems D.V.L. cooperated with Maschinenelemente Fachgruppe Schmiertechnik des D.V.I. In this work a series of lubricating oils of different chemical types and viscosities (the so-called H oils) distributed by I.G. were examined in various testing machines to determine their behaviour with the object of relating lubrication ability with chemical type and sulphur content.

(h) <u>Miscellaneous Information Concerning Aero Lubricating Oils.</u>

Philippovich stated that the normal life or aero lubricating oil was limited to 100 hours after which the used oil was returned to the manufacturer for re-refining. It was not reclaimed by conventional processes.

Oil centrifuges were developed for aircraft engines for the removal of sludge and materials which caused foaming. These were manufactured by Daimler-Benz and by Junkers and after their adoption no corrosion of bearings occurred which was traceable to the lubricating oil.

Jet propulsion units gave no special lubrication problems and as a result no investigations were carried out.

9. GREASES.

Calcium and aluminium soaps were found unsatisfactory as were the experimental batches of barium soaps. The change over to lithium base greases, however, brought about a considerable improvement particularly with regard to drop point and low temperature behaviour. Lithium greases were used for the lubrication of instruments. The lithium demand was only 1 ton/month and was easily met.

10. ANTI-CORROSION OILS.

The usual anti-corrosion oil contained originally 7-8% of naphthene sulphonate soap, which was difficult to procure. Thus as the war progressed the content of naphthene sulphonate soaps was lowered to 3-4% and in its place resin soaps from colophony were used. These soaps were very sensitive to oxidation and could therefore not be used for engine protection but only as additions to cooling water or glycol.

11. CODE NUMBERS FOR PETROLEUM AND SYNTHETIC OIL PRODUCTS

Dr. Philippovich was given a list of code numbers of various oils etc. taken from documents etc. obtained on previous trips and was asked to give their identity insofar as they were known to him.

He produced the following information:-

<u>H8-H140</u>	A series of hydrocarbons and synthetic lubricants of various viscosities prepared by I.G.Leuna for tests by Professor Heydebreck and other interested parties for lubrication tests.
<u>H426</u>	Ester (ex abietic acid?) also prepared by Leuna for Professor Heydebreck.
<u>R300</u>	Diesel ignition oil prepared by I.G.(Peroxide?)
<u>Autokollag</u>.	This is Oildag and contains whale oil.
<u>BH4</u>	Flying Pressure Oil (Fliegerdrucköl) Hydraulic Oil?
<u>K7</u>	Shell Transformer Oil.
<u>DA200</u>	Olex Machine Oil.
<u>NP2</u>	Naphthenic Lubricating Oil of Russian origin.
<u>ED24</u>	Olex spindle and flushing oil.

Dr. Philippovich disclaimed any knowledge of the following products:-

Calupsol K	M70
R200	M71
129	M8
E Mischung II	M9
RCH Diesel Oil D509.	M10
Sulphur Product B	Z111
SS902	Z111a
F25	21Vc
TP57	Dibutin
S Product J	

SS978
F250
T/Z 900/5
T/Z 900/2
Elaol 4
AEM3
S Ester
SS970R
H268
X7
SS1593
1568/80

12. **DOCUMENTS.**

Dr. Philippovich stated that a number of documents were removed from the D.V.L. laboratory at Strass near Neuberg on June 7th 1945 by 1st Lt. W.F.Hergrueter, C.O., 943 OQMG PPL and delivered to O.T. IT., 7 Augsberg. It was ascertained that these documents were shipped on June 13th to Chief Ordnance Officer, Hq., Com Z, A.P.O. 887, U.S. Army, Attn. EEIS, Technical Division (Major Heintz). It was also ascertained that the documents were received at this address and reshipped from there to an unknown address, probably to SHAEF forward documents section.

Philippovich gave the following list of these documents from memory:-

1. Meeting "Knock behaviour and storage of fuels" 16-17.6.41.

2. Lubricating oil meeting, 1st part: "Friction and wear, low temperature behaviour".

3. FB 690. Investigation of lead free gasoline/benzene/alcohol blends (80 O.N. class and above) by A.v.Philippovich and H.Berg.

4. FB 891. The heat conduction of exhaust gases from Otto engines as means for the evaluation of mixture formation by H.Berg.

5. FB 1034. Influence of engine design and operating conditions on the knock behaviour of fuels (Collective report) by H.Berg.

6. UM523/2. Influence of engine design and operating conditions on the knock behaviour of fuels. 2.Interim report. Tests on a FIAT single cylinder test stand (injection operation) by H.Berg.

7. UM523/3. Influence of engine design and operating conditions on the knock behaviour of fuels. 3.Interim report. Tests on a DB.600 two cylinder test set up with fuels of 80 and 87 O.N. (carburettor operation) by H.Berg.

8. UM523/6. Influence of engine design and operating conditions on the knock behaviour of fuels. 6.Interim report. Tests on a DVL one litre sleeve valve engine (carburettor operation) by H.Berg.

9. UM523/7. Influence of engine design and operating conditions on the knock behaviour of fuels. 7.Interim report. Tests on a BMW 132 N single cylinder engine on a DVL foundation with injection and carburettor operation by H.Berg.

10. UM688. Influence of the lead content of fuels on the constructional parts of aero engines. 1.Interim Report. Tests on a Jumo 211 by Denkmeier and H.Kervien.

11. UM688/2. Influence of the lead content of fuels on the constructional parts of aero engines. 2.Interim report. Tests on a DB 605A by Denkmeier and H.Kervien.

12. FB1469. Fuel consumption measurement according to weight (gravity) in a tapped test vessel by Muhlner.

13. UM1049. Sulphur content and lubrication ability by A.v.Philippovich.

14. UM1364. Contribution on non-hydrodynamic lubrication by I.Morghen.

15. UM520. Testing the lubrication ability of oils on the Almen, Wieland and Thomas oil test machines by K. Mayer-Bugstrom.

16. FB 976. Testing of glycerine substitute as to its usability as a coolant by K. Mayer-Bugstrom.

17. FB 912. The estimation of the thermal stability of various aero engine oils by M.Richter.

18. Deutsche Kraftfahrforsching, Interim report 31 (T.H.Dresden). The behaviour of fuel injection and supply pumps in operation with different diesel fuels by K.Richter.

19. UM 518. On the constitution and properties of lubricating oils and their alteration by oxidation by O.Selter.

20. FB 875. Investigation of oils of German origin in the Siemens oil test engine by H.Wenzel.

21. FB 893/1. Special investigation with aero engine fuels by O.Widmaier.

22. FB 893/2. The boiling behaviour of aero engine fuels by O.Widmaier.

23. FB 893/3. Deposit formation of lead containing fuels by O.Widmaier.

24. FB 1107. The influence of aromatic compounds on the knock resistance of fuels.

25. FB.1186. Influence of fuels on deposit formation in lubricating oils by O. Widmaier.

26. FB 1325. Artificial and engine aging of lubricating oils by O.Widmaier.

27. 1252. O.Widmaier.

28. 1048. by O.Widmaier and L.Nenninger.

29. FB 1090. Influence of operating temperature on piston rings of various cast alloyed materials by M.Kahm and H.Platz.

30. 1081. by G.Fischer.

31. 690. Gross.

32. 1748 Jung.

33. 998 W.Linke.

34. 1108 "

35. 1164 "

36. 1207 "

37. T 172 Theiner.

38. T 254 Sabath

39. G 172 Bech/Kunselmann.

40. 213 15 W. Siedenburg.

41. 35 Nagel.

42. I.G. Report 298c.

43. Broschur Braicher.

44. Page Summary.

45. Page acknowledgement.

APPENDIX I

SPECIFICATION FOR AVIATION FUEL A3.

Oberkommando der Luftwaffe.
TLR/M 2 III(A)

Sheet 21, issued November, 1944.
For Service use only.

Method of Test as in BVM 40/42 Edn. and alterations as in technical information service of RLM-GL-A-M since Oct. '43. No.	Specification	TL $\frac{147-257}{4}$
	Appearance	Clear, free from undissolved water and acids, must contain no solid impurities
	Colour	Blueish, corresponding to 1.6 - 2.6 mg. of Sudan Blue GN per litre of colourless fuel.
7070 - 7094	Octane number	at least 80 with 0.045 Vol. % T.E.L.
7055	Density at 15°C.	0.700 - 0.770
7100 - 7113	Boiling Range	I.B.P. - not below 40°C. 50% Vol. point - about 100°C. F.B.P. - below 180°C. Distillation loss - 2% Vol. max. Reaction of residue - Trace of acidity only
7130 - 7138	Vapour Pressure	0.5 Kg./cm.² max.
7150	Freezing Point	As determined by initial crystallisation point, must not be above -50°C.
7160	Evaporation Residue	10 mg./100 ml. max.
7200	Corrosion Test	No grey or black spots or pitting in the copper strip test. (3 Hours at 50°C.)
7200 - 7211	Ethanol content	30 Vol. % (± 3 Vol. %)
7270 - 7271	T.E.L. Content	0.045 Vol. % min. (up to 0.120 permitted for use at the Front)
7280 - 7282	Aromatic Content	35 Vol. % max.
Storage and Storage Stability	Containers of black plate or burnt lacquer treated. No zinc treatment. Since the alcohol content is accompanied by a certain danger of separation of the fuel, it is essential to keep out water. The specified "water safety value" (see Tagtt-Kz: I C qc, No. 4 Lfd. No. 342/44) is at least 0.7 Vol. %. Admixture of B 4 and C 3 with A 3 in storage tanks is in all cases prohibited. A monthly examination of A 3 is necessary.	

NOTE: Earlier delivery specifications for A 3 are hereby superseded.

APPENDIX 2

SPECIFICATION FOR AVIATION FUELS B4 AND C3.

Oberkommando der Luftwaffe.
TLR/M 2 III(A)

Sheet 22, issued November, 1944[1]
For Service use only.

Method of Test as in BVM 40/42 Edn. Alterations as in technical information service of RLM-GL/A-M since Oct. '43. No.	Description of Test	B 4	C 3
	Technical Specification	TL $\frac{147 - 304}{4}$	TL $\frac{147 - 330}{4}$
	Appearance	Clear, free from undissolved water and acids. Must not contain solid impurities.	
	Colour	Bluish [2] corresponding to an 4.0-4.3 mg. Sudan Blue GN per litre of colourless fuel	Greenish addition of 0.5 mg. Sudan Blue GN and 0.5 mg. fluorol per litre of colourless fuel
7070 - 7095	Octane Number	89 min. with 0.115 Vol.% T.E.L.	about 95
7230 - 7239	Single Cylinder Performance	In the region = 0.8-1.15 the curve must be above that of the comparison fuel.	
7055	Density at 15°C.	0.700 - 0.760	0.740 - 0.795
7106 - 7113	Boiling Range I.B.P. 10 Vol. % min. 35 " " 50 " " 90 " " 95 " " F.B.P.	 not below 40°C. 75°C. 110°C. - - 180°C. below 190°C.	 not below 40°C. 80°C. - 120°C. 180°C. - below 190°C.
7130 - 7138	Vapour Pressure	0.5 kg./cm.² max.	0.45 kg./cm.² max.
7150	Melting Point	- 60°C. max.	- 60°C. max.
7160	Evaporation Residue	10 mg./100 ml. max.	
7200	Corrosion Test	No grey or black spots or pitting in the copper strip test.	
7280 - 7282	Aromatic Content	35 Vol. % max.	45 Vol. % max.
7270 - 7271	T.E.L. Content	0.115 - 0.120 Vol. % (3)	
7274	Ethylene Dibromide Content	0.050 - 0.053 Vol. % (4)	
7214	Inhibitor Content	-	0.01% by wt. (5)
	Storage Stability	After 6 months' storage, examination should be carried out every 3 months.	

NOTES: (1) Sheet 22 renders invalid :
(a) Specifications for fuels B4 and C3 in sheet 1, issued May, '44, and sheet 2, issued April '44.
(b) Technical Regulations 8/44, 11/44 and 12/44. These should be destroyed.
(2) When a mixed colour results on the addition of C3 to B4 a corresponding quantity of Sudan Blue GN (max. 2 mg./lt.) should be added.
(4) See also Techn. Regulation 3/44.
(5) " " " " 6/43.
(6) In special cases aviation fuel C3 delivered without inhibitor must not be held. However OKL Chef TLR/M 2 III should be informed.

APPENDIX 3

SPECIFICATIONS FOR AVIATION STARTING FUELS FOR OTTO ENGINES.

RLM-GL/A-M II

For Service Use Only.
Sheet 15, Issued March 1944.

Method of Test BVM 1940 Edn. and Technical Information Service. No.	Techn. Delivery Specification	TL $\frac{147 - 300}{2}$ Feb. '44
	Composition	95-96 Vol. % light gasoline 4-5 Vol. % aero engine lub. oil. As oil additive, only aero-oil S3 or V2 permissible. For estimation of lubricating oil content see overleaf.
	Purity	The fuel must be water-white, free from undissolved water, acids and solid material.
7055	Density at 15°C.	0.640 - 0.675 kg./ltr.
7070 - 7095	Knocking Behaviour	Octane No. at least 70
7100 - 7115	Boiling Range	I.B.P. not above 30°C. to 35°C. at least 10 Vol. % " 100°C. at least 85 Vol. % F.B.P. not above 165°C. Residue not above 6 Vol. % Loss in distillation not above 6 Vol. %
7160	Residue on Evaporation	Not above 6% by wt.
7130 - 7138	Vapour Pressure at 37.8°C.	0.9 - 1.5 at.
7190 - 7191	Sulphur Content	Not above 0.1% by wt.
7200 Reflux Condenser 3 Hrs. at 50°C.	Corrosion	No grey or black spots or pitting in the copper strip test
	Storage	To be protected from direct sunlight and kept as cool as possible
	Stability on Storage	After storing for a year, examination of boiling ranges and octane number is necessary. The containers must be carefully re-sealed as soon as the samples have been taken. Containers which have been opened must be used up as soon as possible. In disputed cases a full analysis must be made. In the report, the filling date and filling sign of the party concerned must be given.

NOTE: The previous specification TL $\frac{147 - 300}{1}$ of Sept. 1939 is hereby superseded and should be destroyed.

METHOD FOR THE ESTIMATION OF THE OIL CONTENT OF AVIATION STARTING FUELS.

(a) The starting fuel (100 ml.) is heated in an evaporation dish of the usual type on a vigorously boiling water-bath, with air-blast, until the gasoline has evaporated. The dish containing the oil is then dried in an oven at 110°C. for half an hour and weighed. The oil content is then calculated.

(b) Most of the gasoline is distilled off from 1500 ml. of starting fuel using an electric hot-plate and a distilling flask of the normal type. It is essential to avoid overheating of the oil. The residue from the distillation is transferred to a 250 ml. round-bottomed flask and saturated steam blown through it until the steam distillate contains no more gasoline.

The residual oil is separated using a separating funnel and freed from water. The analytical data of the oil obtained in this way must correspond to the specification for the oil used in the starting fuel.

APPENDIX 4

SPECIFICATION FOR AERO DIESEL FUEL K1.

RLM
GL/A - M II

For Service Use Only.
Sheet 2 issued April 1944 (1)

Method of Test DVM 1940/42 Edn. No.	Description of Test	K1
	Technical Specification	TL $\frac{147 - 351}{2}$
	Appearance	Clear, free from undissolved water and acids. Must not contain solid impurities.
	Cetane Number	50 min.
7055	Density at 20°C.	0.810 min.
7100 - 7113 Water Cooling	Boiling Range	I.B.P. about 160°C. 96 Vol. % min. at 350°C.
8075	Pour Point	-45°C. max.
8070	Viscosity at 20°C.	1.1°E. min.
Pensky-Martens	Flash Point	above 50°C.
8085	Acid Value	0.7 mg. KOH/g. max.
7190 - 7191	Sulphur Content	1% by wt. max.
8095	Ash Content	Traces only.
DIN 2 DVM 3763	Corrosion Test	4 mg. max.
8110	Conradson Test	0.1% by wt. max.
8105	Water Content	Traces only.
	Storage Stability	After storage for 1 year six-monthly tests are necessary.

NOTES: (1) Sheet 2, April 1944 supersedes Sheet 2 May 1942.
Copies still in existence should be destroyed.

APPENDIX 5

PROVISIONAL SPECIFICATION FOR JET FUEL J2 AND RUNNING-IN FUEL EINLAUF J2

Oberkommando der Luftwaffe
Chef der Technischen Luftrustung
Az. : 85 g. TLR/M 2 III (A)

For Service Use Only
Sheet 14, issued Oct. 1944 (1)

Method of Test BVM 1940/42 Edn. of Technical Information Service No.	Technical Specification	J 2 VTL 147 - 286 / 2	Einlauf - J 2
	Appearance and Colour	Clear, free from undissolved water and acids, must not contain solid impurities.	
7055	Density at 15°C. kg./lt.	0.800 min.	0.760 min.
7130 - 7138	Vapour Pressure at 37.8°C.	0.2 kg./cm.² max.	0.5 kg./cm.² max.
8070 - 8072	Viscosity at +20°C. " 0°C. " -20°C.	1°E min. - - - - 3°E max.	1°E min. 3°E max. - - - -
8075	Pour Point (3)	below -25°C.	below 0°C.
7190 - 7191	Sulphur Content % wt.	1.5 max.	
7214	Phenol Content Vol. %	1.0 max.	
7230 - 7231	Aromatic Content Vol. %	45 max.	
8110	Conradson Test % wt.	1.5 max.	
8095	Ash Content % wt.	0.5 max.	
7225 - 7228	Lower Cal. Value (2)	9000 K.Cal./Kg. min.	
7200 DIN 2 DVM 3763	Corrosion Test. Copper Strip Zinc Strip	negative 4 mg. max.	
(3)	Filtrability (2) (Hammerich) at 400 mm. Vacuum	120 secs. max. at -25°C.	120 sec. max. at 0°C.
	Re-examination	After a year	
	Storage	The fuels must be kept apart from one another and from other fuels (A3, B4, C3, E1) during storage. Admixture with the remains of other fuels and admixture of the latter with J2 in pipe-lines, barrels etc. is strictly to be avoided.	

NOTES: (1) This sheet renders Sheet 14, March 1944 obsolete and the latter should be destroyed.
(2) This is only to be carried out during acceptance tests.
(3) See "Techn. Anord." 1/45 and 8.T.45.

APPENDIX 6

PROVISIONAL SPECIFICATION FOR FLYING BOMB FUEL E 1.

Planungsamt (Planning Dept.)
GL/A-M II B

Berlin 21/9/43
App. 4302.

(1) Appearance	clear, free from undissolved water and acids. Solid impurities must be absent.	
(2) Density at 15°C.	0.740 - 0.760.	
(3) Boiling Range.	I.B.P.	30.50°C.
	10 Vol. % min.	75°C.
	30 Vol. % min.	100°C.
	95 Vol. %	not above 220°C.
(4) Residue on Evaporation	50 mg./100 ml. max.	
(5) Corrosion Test	no grey or black spots or pitting in the copper strip test.	
(6) Separation	must not occur above -60°C.	
(7) Cloud Point	the M. Pt. of the fuel, cooled until crystallisation commences, must not be above -60°C.	
(8) Lower Cal. Value	9600 Kg. Cal./Kg. min.	

APPENDIX 7

SPECIFICATIONS FOR AERO-ENGINE OILS S3 AND V2

RLM
GL A-M II

Appendon to DVL Nr. 1477/430
40/1510/43 g.
For Service Use Only.
Sheet 7, June 1944.

Method of Test B V M[1] 1938 Edn. No.				
	Military Name	S 3		V 2
	Filling Station Mark	VK, VB, NM, WD, WH, WN, WL, WR, WM, WY, WV, WF, WB, WG.	RG, HL, WD, WH, WN, WL, WR, WM, WG, WV, WF, WB, WG.	R G
	Technical Specification for Delivery	TL 147-502 TL 147-503 TL 147-506	TL 147-(561-563) TL 147-(571-573) TL 147-(581-583)	TL 147-500
	Appearance	The lubricating oil must be clear, free from undissolved water and mineral acids and must contain no solid impurities.		
8060	Refractive Index Max.	1.4995	1.4990	1.5070
8065	Density at 20°C. kg./ltr. Max.	0.897	0.895	0.920
8070	Viscosity at 50°C. at 100°C. Min.	cs. °E. 125-137 (16.5-18.0) 18.5 (2.70)	cs. °E. 125-143 (16.5-18.8) 19.0 (2.75)	cs. °E. 133-144 (17.5-19.0) 19.4 (2.80)
	Pole Height Max.	2.04	1.95	1.9
	Slope Max.	3.45	3.35	3.4
8072	Viscosity Index Min.	92	98	95
8075	Pour Point °C. Max.	-17[2]	-20	-25
8080	Flash Point °C. Min.	260	225	235
8081	Ignition Point °C. Min.	300	255	270
8085	Acid Value mg. KOH/g. Max.	0.06	0.06	0.1
8090	Saponification Value mg. KOH/g. Max.	0.2	0.2	8.0
See note (3)	Evaporation Test (Dr. Noack) 250°C. % wt. Max.	3.0[4]	11.0	5.0
8110	Conradson % wt. Max.	0.35	0.25	0.5
8095	Ash Content % wt. Max.	0.01	0.01	0.02
8100	Hard Asphalt % wt.	0	0	0
8105	Water Content % wt.	0	0	0

NOTES: 1. Constructional specifications for BVM Aero-Engines "Test Regulation for Aero-Engine lub. oils for use in Otto engines". Can be obtained from the Scientific Reports section (ZWB) of the DVL, Berlin-Aldershof, Rudower Chaussee 16/25.
2. For S3, the filling station mark VK allows a max. setting point of -10°C.
3. "Angewandte Chemie" 1936. Vol. 49, page 385.
4. For S3 — VK the max. Noack Test value is 5.0.
5. The present sheet 7 supersedes the "Technical Acceptance Conditions for Aero-Engine Lub. Oils" issued by the R.L.M. L.C. II 2e on 15.3.36. Copies still in existence should be destroyed.

ABBREVIATIONS:- V = Vakuum K = Koln B = Bremen W = Wifo.

PREPARED BY :- Mineral Oil Section. Group GL/A-M II. This sheet is primarily intended for the suppliers. Thus there are two columns for S3 (to differentiate finished products from blended stocks) - see the other sheet 7 for military applications.

APPENDIX 8

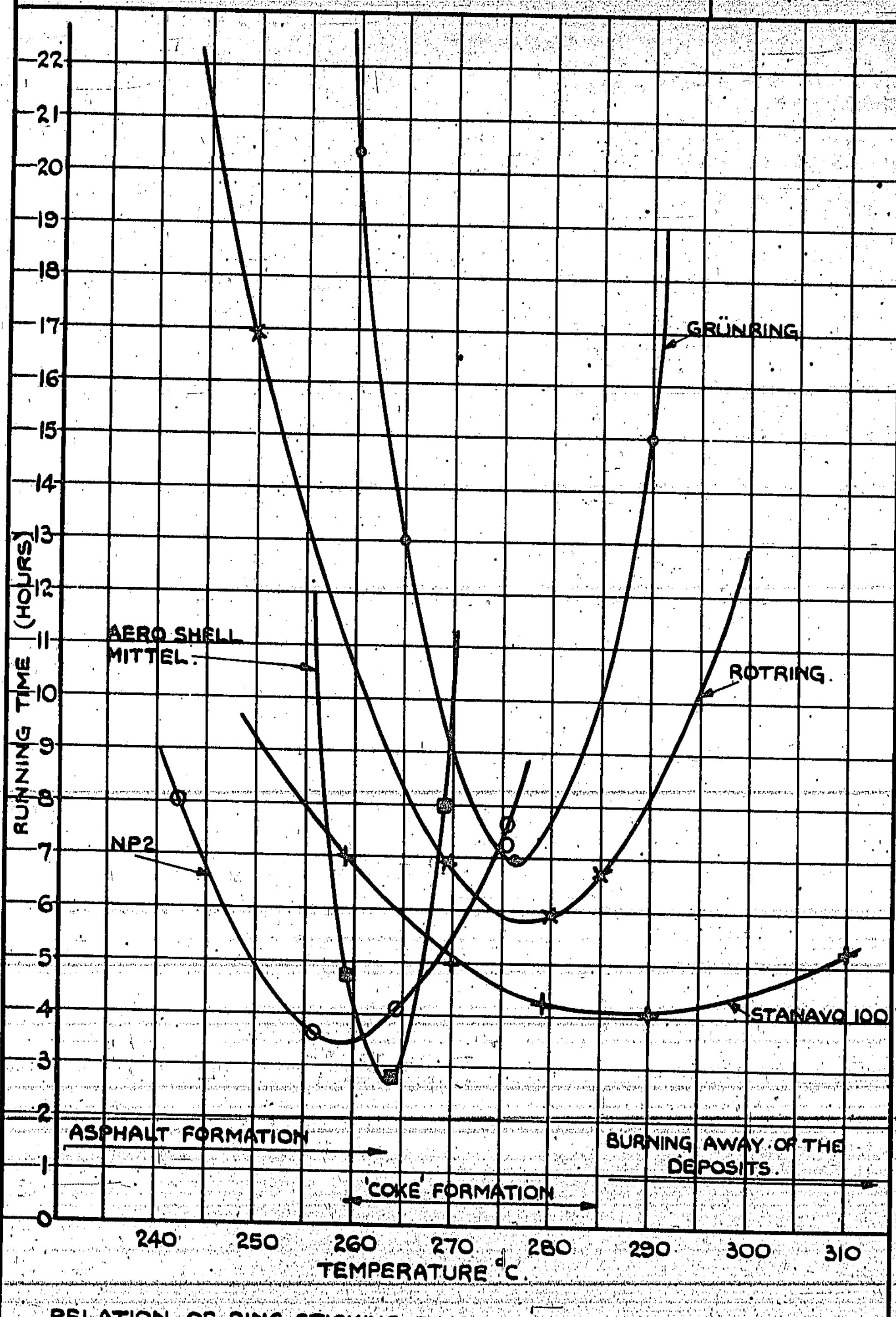
SPECIFICATION FOR RUNNING IN AERO LUBRICATING OIL T.42.
(NACHLAUFSCHMIERSTOFF)

RLM-GL/A - M II Oct. 43 Sheet 13.

Method of Test B V M 1938 Edn. *	Technical Specification	TL 147 - 700 / 1
	Composition	Selective Raffinate and Voltol
8055	Purity	The oil must be clear, water and mineral acid free and must contain no solid impurities.
8065	Density at 20°C. Kg/lt.	0.875 - 0.895
8070 - 8072	Viscosity	at 20°C. 8 - 9.5°E at 50°C. 2.5 - 2.9°E at -30°C. 800°E max.
8075	Pour Point	-45°C. max.
8080	Flash Point	155°C. min.
8085	Acid Value	0.15 mg. KOH/g. max.
8090	Saponification Value	5 - 6 mg. KOH/g.
8095	Ash Content	0.01 % wt. max.
8100	Hard Asphalt	0
8105	Water Content	0
	Miscibility	With Rotring (S 3) and Aero Shell medium (V 2) miscible in all proportions
	Storage Stability	After a storage period of 2 years, re-examination every 6 months is necessary.

* Instructions for B V M aero-engines "Testing Regulators for Aero-engine lub. oils for use in Otto engines" can be obtained from the D V L Berlin-Adlershof, Rudower-Chaussee 16/25.

DVL | ENGINE TESTS OF LUBRICATING OILS. | B M V 132 OIL-TESTING ENGINE.



RELATION OF RING STICKING-TIME TO TEMPERATURE FOR VARIOUS OILS.

DVL.

AN EXAMPLE OF THE TWO DIFFERENT FORMS OF THE KNOCKING BOUNDARY CURVE.