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BRANDSTOF-NAVORSINGS-INSTITUUT

VAN SUID-AFRIKA.

FUEL RESEARCH INSTITUTE

OF SOUTH AFRICA.

ONDERWERP:
SUBJECT: REPORT ON LUBRICATING OILS USED IN SUPERCHARGED ROLLS ROYCE KESTREL ENGINES.

AFDELING:
DIVISION: ENGINEERING.

NAAM VAN AMPTENAAR:
NAME OF OFFICER: J. J. COETZEE.

FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

REPORT NO. 19 OF 1939.

REPORT ON LUBRICATING OILS USED IN SUPERCHARGED ROLLS ROYCE KESTREL ENGINES.

1. GENERAL.

A number of samples of lubricating oils from Supercharged Rolls Royce Kestrel Engines were submitted to the Fuel Research Institute for test by the Officer Commanding, Aircraft and Artillery Depot, Voortrekkerhoogte. These oils were sent in because bearing troubles had been experienced when using them in these engines, which are fitted with copper lead bearings, although in other engines, similarly fitted, no such trouble had been met with.

From an examination of the used bearings by Dr. P. Groenewoud, of the Division of Chemical Services, it appeared that they had been, in some way, overheated during service. This might have been caused by:

1. Insufficient Cooling
2. Insufficient Lubrication
3. Breakdown of the Oil Film.

Three samples of new Aero Lubricating oils viz. Silvertown P 4, Intava Red Band - 100 M and Shell - 100 were tested as well as used samples of Silvertown P 4 and Shell - 100 from the engines which had shown abnormal bearing wear or from similar engines. The Silvertown P 4 used oil was the one which originally gave rise to the trouble which led to this investigation.

2 . TESTS.

(a) Specific Gravity at 20°C. I.P.T. Serial Design G. 1.

(b) Refractive Index at room temperature.

(c) Viscosity - Temperature Relation.

(d) Flash and Fire Points (Pensky-Martens).

(e) Conradson Carbon Residue. I.P.T. Serial Design. G.O. 9.

(f) Saponification Value. Mainly as tentative standard. (Volumetric) I.P.T. Serial Design L.O. 15 (T).

(g) Acidity. I.P.T. Serial Design L.O. 5.

(h) Ash Content. I.P.T. Serial Design G.O. 10.

(i) Sludge Content.

(j) Air Ministry Oxidation Test (on the new Silvertown P 4 oil).

Note I.

Viscosity determinations were done in an Ubbelohde Suspended Level Viscometer, the reading being direct in centi-stokes.

Note II. When determining Saponification Values, use was made of the indicator Alkali-blue 6 B as the oils were very dark in appearance. This necessitated the addition of another 50 m.l. Alcohol before titration in order to keep the water concentration in the alcohol down and obtain a good end-point.

Note III.

The sludge was determined by diluting the oil with two volumes of "Normal Benzin" and centrifuging. As a consequence of the method used in taking these samples the figures for sludge content indicate what percentage of sludge was kept in suspension in the oil rather than the total sludge content.

3. DISCUSSION.

(a) New Oils.

The Intava Red Band 100 M and the Shell - 100 give almost identical Viscosity and Flash Points. The Intava oil gave better results for Carbon Residue, Saponification Value and Refractive Index. The low figure for Refractive Index indicates a comparative high concentration of Saturated (paraffinic) compounds and therefore a stable oil with, generally, a good Viscosity Index. The Silvertown oil, on the other hand, gave a high value for Refractive Index and a very low Viscosity Index, lower indeed than that obtained for the usual type of motor car oil. This inferior position of the Silvertown oil in comparison with the other two oils is well illustrated by the Pole Height. A value below 2.0 indicates a good oil, whilst figures above 2.20 must be considered as high, especially for an aero oil.

It should be stated that all three oils comply with the British Air Ministry General Specification D.T.D 109 for lubricating oils with respect to those tests which were carried out. This, once more, shows that widely different oils can be manufactured to comply with this specification.

(b) Effect of Use On Oils.

The general effect of use is an increase in such values as Carbon Residue, Saponifiable Matter, Ash and Sludge Contents etc., the Viscosity-Temperature curve plotted on a log-log chart generally rotates in an anti-clockwise direction with increased use. This means that the viscosity of the oil decreases for low temperatures and increases for high temperatures and this, incidentally, improves the Viscosity Index of the oil.

(c) Comparison of used Silvertown P 4 with Used Shell - 100 Oil.

The effects of service on these oils are given in Tables 1 and 2 and in figures 1 to 4.

The general tendency for Silvertown P 4 oil to deteriorate more rapidly than Shell - 100 is obvious. It must be remembered that the oils in these engines are continually being topped up so that the bulk of an oil sample marked 40 hours may actually have been in use for only a few hours. But the products of deterioration for 40 hours service have accumulated in this sample. A case in point is sample X Table II., which consisted mostly of comparatively fresh oil as can be seen from its analysis.

From figures 3 and 4, we see that although the Shell oil gave higher values for Carbon Residue and Saponification Value for the first ten hours of service, the position was thereafter reversed.

Although both oils improved their Viscosity characteristics during use, the Silvertown oil never reached the level of Shell. In addition the whole Viscosity-Temperature curve of Silvertown oil showed an upward movement after about ten hours of service. This, together with the increase in specific gravity would increase the pressure loss in the oil feed lines to some extent.

The Shell oil did not show such a marked variation from its original characteristics and its operation is thus more uniform. The Shell oil also gave the better values for Flash and Fire Points, but very little value is nowadays attached to small differences in these figures.

None of the figures for Saponification Value or Acidity for these oils were dangerously high and these oils should not normally cause any difficulties in service on that account. However, Larson states (S.A.E. Journal 34-35, 1934, p. 444) that there is a decided advantage in using high-viscosity-index oils with copper-lead bearings and other investigators have produced evidence to the same effect.

A low Viscosity-Index may not, primarily, be responsible for the formation of sludge, but this may be caused by the generally more rapid deterioration of such oils as compared with high-viscosity-index oils.

In spite of the unsatisfactory way in which the oil samples were taken, the figures found for sludge in the various samples indicated that Silvertown P 4 had a greater tendency towards sludge formation than the Shell - 100 oil. Roughly twice as much sludge was found in the Silvertown oil as in the Shell oil for the same service time.

4. POSSIBLE CAUSES OF BEARING FAILURE.

It appears that both oils are satisfactory in so far as they fulfil the Air Ministry Specification and exhibit fair to good lubricating properties on the used oil samples. There are however, some possible causes of bearing failure, particularly in the case of Silvertown P4 oil, when used in a high-duty aero engine under severe conditions.

(i) Excess Sludge Formation.

It has already been stated that the bearings seemed to have been over-heated. This may have been caused by sludge deposits which choke the oil passages and thus starve the bearings of oil. If this is the case, we must assume the formation of sludge as a primary effect of service on the oil. This does not appear to be justified by the results of the Air Ministry Oxidation test. Excessive sludge may be formed as a secondary effect due to oxidation catalysed by lead boiled out of the bearings because of overheating.

The fact that No. 4 Main bearing suffered most in these failures suggests that other primary causes of failure, not related specifically to the oil may exist.

(ii) Overloading of Bearing.

During the sudden speed-up of an engine, there is some time-lag before the oil-pressure builds up and reaches the bearings. The maintenance of an oil film in the bearings during this period depends largely on the viscosity of the oil at the working temperature of the bearing, otherwise the bearing may temporarily run under boundary lubrication conditions with the possibility of failure very much increased. It is clear that an oil with a low viscosity-index is a positive danger under such conditions unless adequate oil pressure is provided before accelerating the engine or the oil is doped to give a high film strength. This danger of momentarily overloading the bearings is possible to a greater extent in engines fitted with a supercharger.

Unfortunately, we are handicapped by a lack of data on the engine conditions after failure in our attempt to further correlate the oil analyses results. Such factors as number and degree of rings stuck, service time since last overhaul, oil consumption, bearing wear and cleanliness of inside of the engine, the oil feed lines and filters etc., would make the correlation of the oil-test results much easier and more definite.

Too much stress cannot be put on the necessity for draining the engine, whilst hot, in order to get a representative oil sample.

Oil sample S Table II was so badly contaminated by glycol, sand and metal chips (even small nuts) that this sample was not suitable for a complete analysis. Further work on this sample was abandoned after the earlier tests had revealed its unsuitability.

One may say in conclusion that although it is not possible to come to a definite conclusion as to the cause of these bearing failures, an investigation into the possibility of temporary overloading is indicated and could best be undertaken in bench tests. Here such overload conditions are easily reproduced and a careful check is kept of all test data.

A memorandum by Dr. Wasserstein of the Geological Survey on the nature of the sludge recovered from the engine sump is included as an addendum.

J. J. Coetzee

ASSISTANT

18/12/39

TABLE I.

OIL SAMPLE	Silvertown P 4 New	Intava Red Band 100 M New	Shell 100 New	Shell 100 Used	Shell 100 Used	Shell 100 Used
Laboratory Identification Symbol	R	1	V	Z	Y	3
Date of Sample	7/10/39	30/10/39	12/8/39	23/10/39	23/10/39	24/11/39
Sample obtained from	A.& A.Depot	Vacuum Oil Co. Pretoria	Shell Oil Co. Laboratory J/Burg	A.& A.Depot	A.& A.Depot	A.& A.Depot
Used in R.R. Kestrel						
Engine No.	-	-	-	9369	9367	-
Hartbees No.	-	-	-	823	810	-
Hours since last oil change	0	0	0	5	11	40
Specific Gravity at 20°C	0.902	0.883	0.890	0.893	0.892	0.894
Refractive Index	1.496	1.483	1.490	-	-	-
S. A. E. No.	50	50	50	50	50	50
Viscosity Index	75	95	96	96	96	99
Pole Height	2.29	1.94	1.95	1.94	1.94	1.84
Angular Index "M"	3.62	3.38	3.38	3.40	3.40	3.32
Viscosity at 20°C.C.ST.	950	950	918	795	795	850
50°C.C.ST.	124	138	138	120	120	131
Flash Points (P.M.)						
Closed °F	415	480	480	170	155	217
Open °F	443	516	517	366	401	498
Fire Point °F	493	570	568	545	546	560
Conradson Carbon Residue % Weight	0.27	0.20	0.66	0.94	1.18	1.64
Saponification Value mg KOH/gr.Oil	1.4	0.8	1.3	2.5	2.5	2.7
Acidity mgKOH/gr.Oil	0.02	0	0	0.14	0.12	0.09
Ash % Weight	0.002	0.003	0.001	0.09	0.12	0.14
Sludge % Weight	-	-	-	0.18	0.37	0.63
Air Ministry Oxidation Test						
Viscosity Ratio	1.71	-	-	-	-	-
Conradson Carbon Residue on Oxidised Oil % Weight	1.48	-	-	-	-	-

TABLE II.

OIL SAMPLE	Silvertown P 4 Used	Silvertown P 4 Used	Silvertown P 4 Used	Silvertown P 4 Used	Silvertown P 4 Used	Silvertown P 4 Used
Laboratory Identification Symbol	W	2	U	X	T	S
Date of Sample	18/10/39	1/11/39	13/10/39	18/10/39	13/10/39	6/10/39
Sample obtained from	A.& A. Depot	A. & A. Depot	A.&A.Depot	A.& A.Depot	A.& A.Depot	A.& A. Depot
Used in R.R. Kestrel						
Engine No.	9293	5013	9323	9279	9299	R.R. Merlin Engine
Hartbees No.	841	-	804	838	813	-
Hours since last oil change	3/4	8	9½	23½	40	21
Specific Gravity at 20°C	0.902	0.903	0.905	0.904	0.909	-
S. A. E. No.	50	50	50	50	50	-
Viscosity Index	84	84	86	77	86	-
Pole Height	2.20	2.14	2.11	2.20	2.07	-
Angular Index "M"	3.57	3.54	3.50	3.56	3.46	-
Viscosity at 20°C.C St.	900	890	1020	1000	1100	-
Viscosity at 50°C.C.St.	120	121	135	131	150	-
Flash Points (P.M.)						
Closed °F	199	178	209	210	220	-
Open °F	373	283	415	399	390	-
Fire Point °F	488	475	484	495	477	-
Conradson Carbon						After passing through filter press.
Residue % Wt.	0.56	0.79	1.19	1.04	2.06	1.43
Saponification Value mg.KOH/gr.Oil.	1.8	2.1	2.7	3.0	3.2	-
Acidity mgKOH/gr. Oil.	0.10	0.10	0.11	0.10	0.10	0.18
Ash % Wt.	0.08	0.11	0.14	0.09	0.16	-
Sludge % Wt.	0.25	0.70	0.68	0.54	1.38	1.06

fig. I

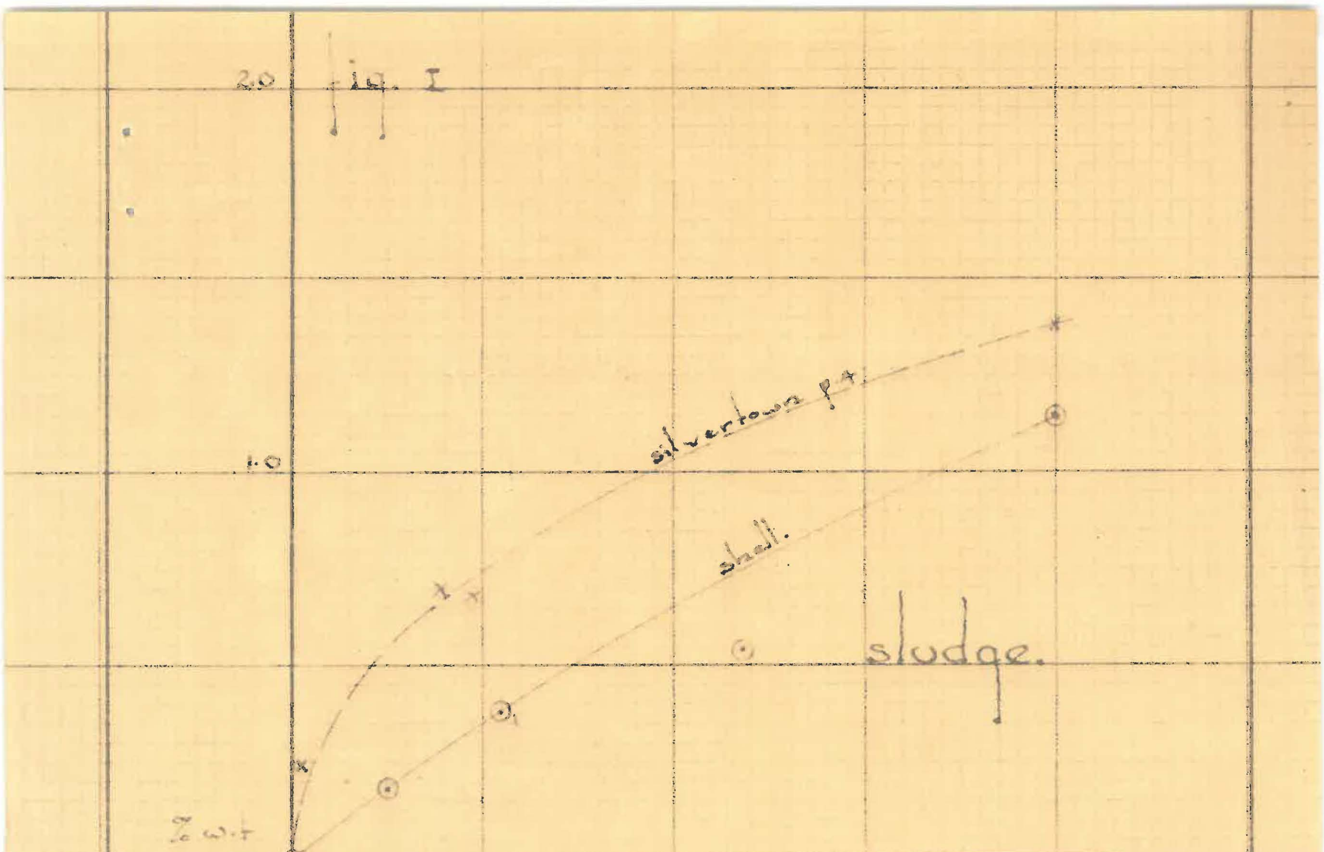
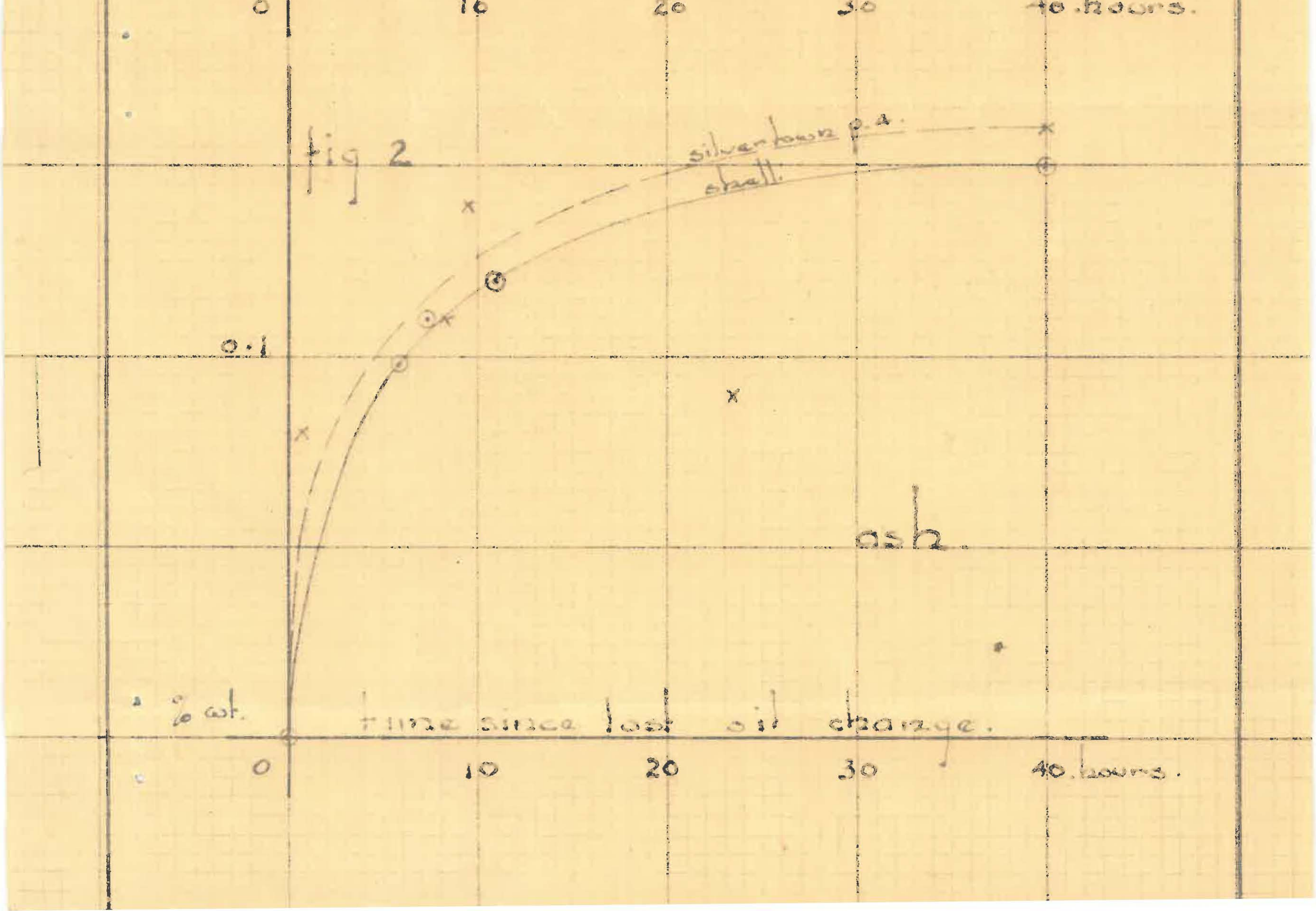

2.0
1.0
silvertown p.4.
shell.
sludge.
% wt.
0
10
20
30
40 hours.

fig 2


silvertown p.4.
shell.
0.1
ash.
% wt.
time since last oil change.
0
10
20
30
40 hours.

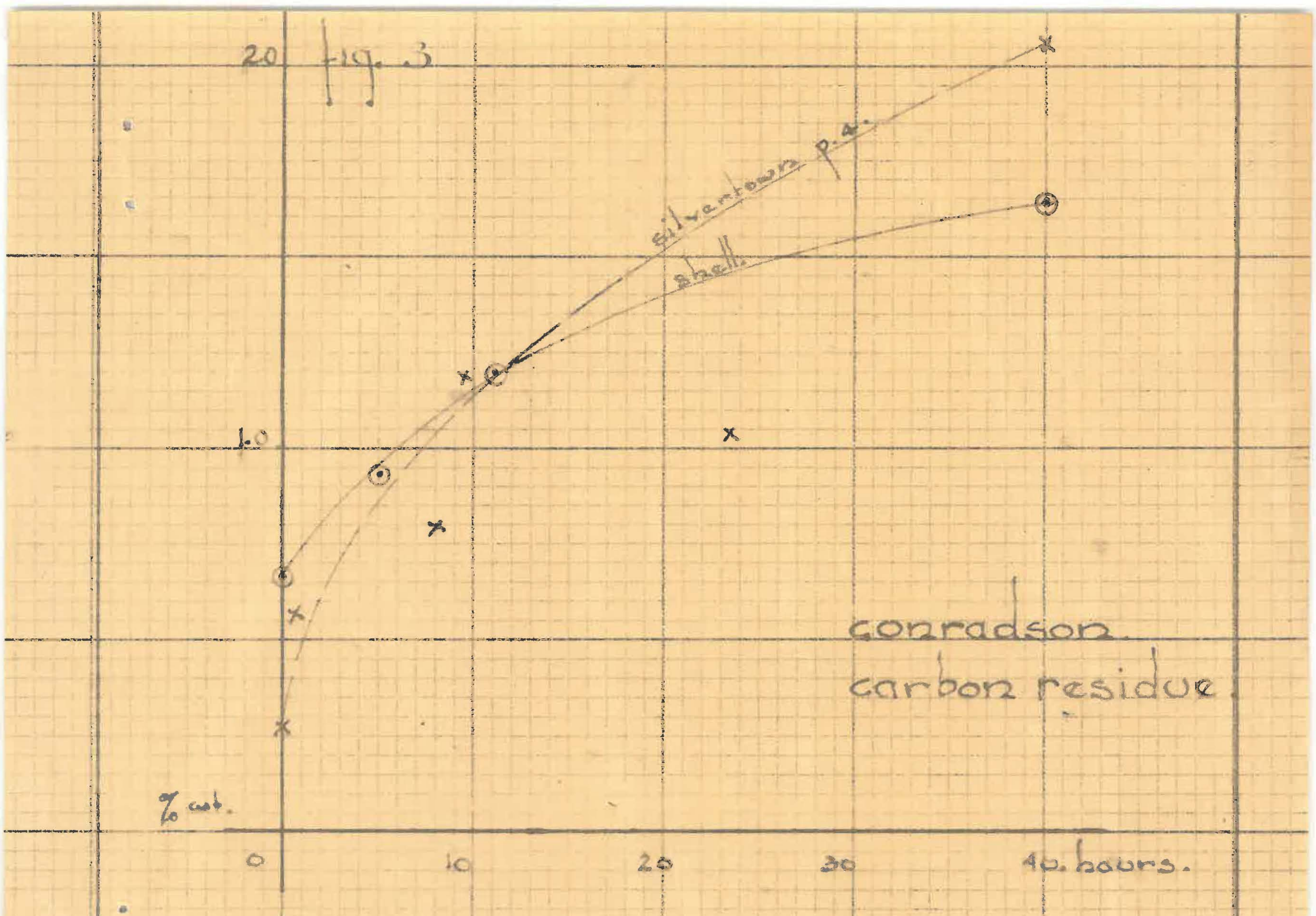


fig. 3
2.0
1.0
silvertown p.4.
shell.
conradson
carbon residue.
% wt.
0
10
20
30
40. hours.

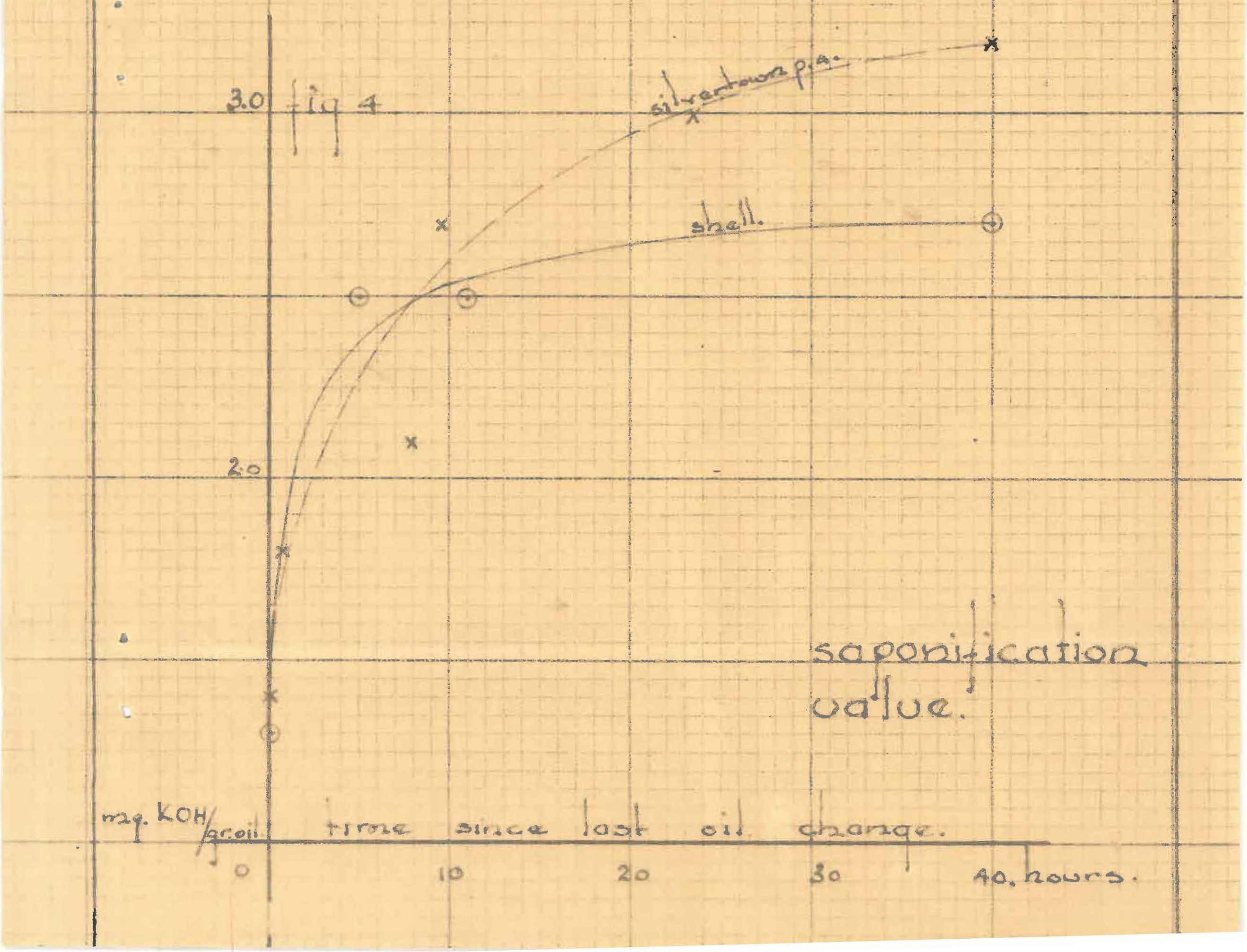


fig 4
3.0
2.0
silvertown p.4.
shell.
saponification
value.
mg. KOH/g oil
time since last oil change.
0
10
20
30
40. hours.

ADDENDUM TO REPORT NO. 19 OF 1939.

The Director,
Geological Survey,
PRETORIA.

EXAMINATION OF SLUDGE FROM CRASHED HURRICANE.

Dr. Vogel handed to me the solid remains recovered from the sump of the aeroplane. This contained, besides carbonaceous matter, visible fragments of mica (from the sparking plug), metal (from the engine) and sand. Samples of sand from the scene of the crash, from the aerodrome, and a dust-sample from the beams of the hangar were also examined. Although the examination of the samples cannot claim to be exhaustive the following facts appear significant:-

(1) The sandy material from the sump as well as the other sand and dust samples exhibit many points of similarity except that the material from the hangar is finer; probably all the sandy material in the sump is derived from the scene of the crash.

(2) The sump-material, however, contained significant amounts of diatoms confined to one characteristic discoid or spherical genus, and this essential difference from the other samples indicates that this material was present in the plane at the time of the crash

(3) The diatoms are composed of opaline silica and their size is of the order 0.01 mm. Opal has a hardness greater than most steels.

(4) The diatoms were readily found as they appear lumped together in small clusters.

(5) Excepting these diatoms no other unusual feature could be observed.

The presence of diatoms can be explained in a number of ways but further information is necessary. It could have been deliberately introduced, as diatoms are essential constituents in the abrasive powder known as "Tripoli" and in some explosives like dynamite (e.g., as Kieselguhr). Diatoms are common fillers (battery-boxes, waxes, paints) and insulators and there may be some part of the plane containing diatoms not known to me: a sparking plug was tested as a likely source of diatoms with negative results. Ths most likely source would appear to be the oil as diatomite (i.e., diatomaceous earth or "clay") is commonly used in filtering media in oil refineries. Lastly, the vleis in this country contain diatoms and the comparative dryness of the climate may give these tiny particles greater freedom of movement than they enjoy in other parts of the world - hence contaminated oil frequently changed may cause these diatoms to accumulate in the sump.

The obvious danger of having diatoms in the oil cannot be too strongly stressed: firstly, they act as an abrasive; secondly, they are so small, probably passing through ordinary filtering media and, thirdly, they appear to possess the property of coagulating and thus blocking oil-feeds. This office will gladly co-operate with the Air Force Officials in such investigations when called upon to do so.

Signed: B. WASSERSTEIN.
SENIOR MINERALOGIST.

Geological Survey,
PRETORIA.
29th November, 1939.