Report 567-46

METHOD FOR MEASURING OXIDATION RESISTANCE, CORROSION RESISTANCE AND SPREADING OVER METAL SURFACES

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May 1942

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Translation

INTRODUCTION

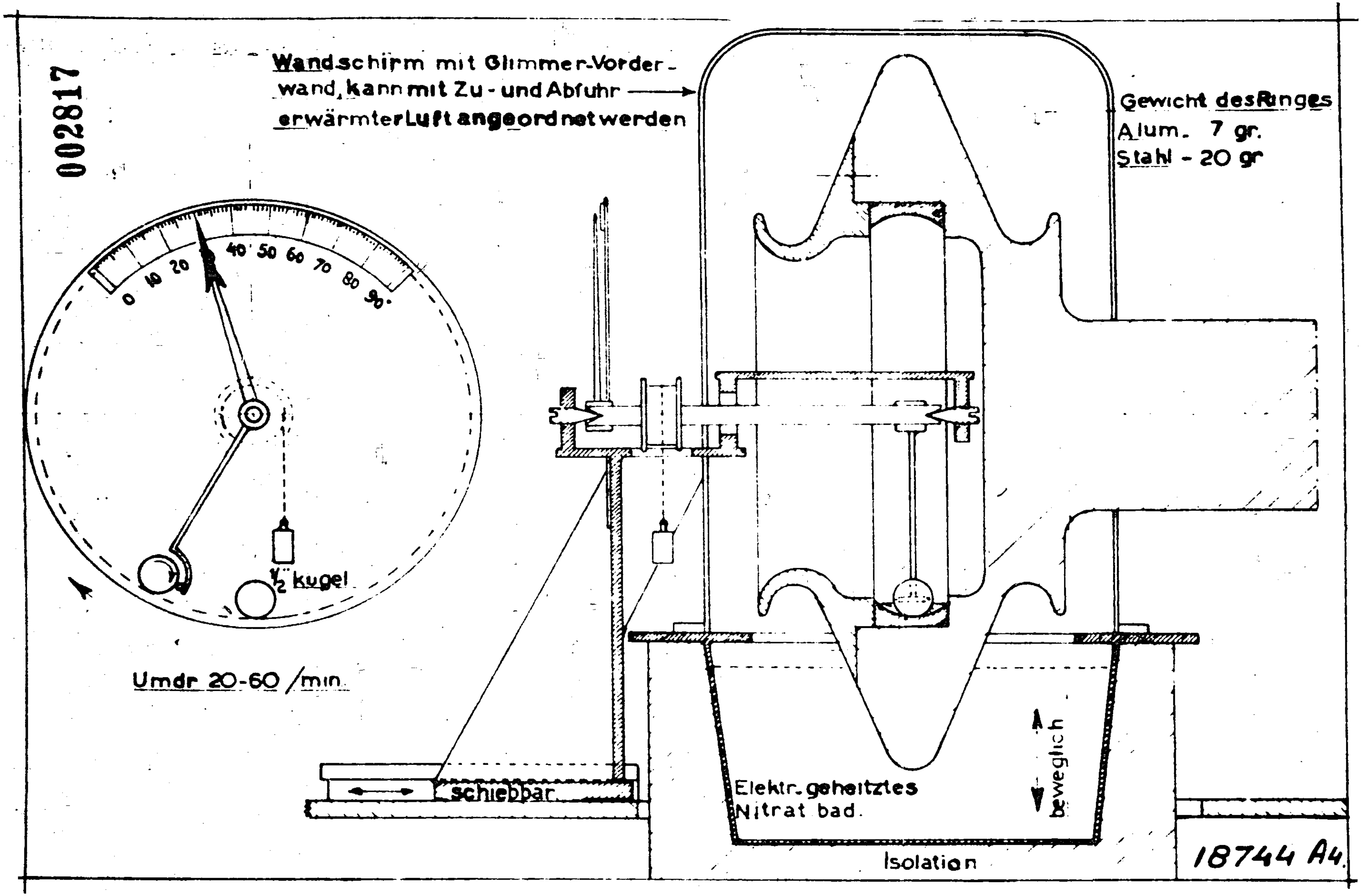
2818

In the investigation of lubricants the samples will be small, in general, according to the work plan. It is desired, therefore, to develop special apparatus in the study of oxidation resistance, corrosion, and spreading over metal surfaces of the products obtained.

Various possibilities have been considered during this month for making such apparatus.

OXIDATION RESISTANCE

While investigating the oxidation resistance of lube oils by the usual method the work is generally done at comparatively low temperatures. It seems, however, that the most important changes in motor oil occur at comparatively high temperatures. It is, therefore, desirable to investigate the products to be tested at relatively high temperatures. Furthermore, it would be useful not, as is the usual case, to work at one definite temperature, but rather at a series of temperatures, since it is probable that the classification of lubricants according to oxidation resistance may vary with temperature.


002817
Wandschirm mit Glimmer-Vorderwand, kann mit Zu- und Abfuhr erwärmter Luft angeordnet werden
Gewicht des Ringes
Alum. 7 gr.
Stahl - 20 gr
0
10
20
40
50
60
70
80
90°
½" kugel
Umdr 20-60 /min.
schiebbar
Elektr. geheitztes Nitrat bad.
beweglich
Isolation
18744 A4

Furthermore, it appears desirable to study more closely the rheological properties of the products which develop with the oxidation of the lubricant.

The apparatus to be developed should, therefore, meet the following conditions:

1. It shall be possible to test very small samples with the apparatus (e.g. 5-10 cc).
2. The temperature at which aging takes place shall be variable over a wide range. A range of 200 C to 300 C was thought desirable.
3. A viscosity or plasticity measurement of the oxidation products shall be possible.

In view of the above requirements the following scheme was 2818
considered: (See diagram)

An aluminum or steel ring, into which a small amount of oil has been poured, rotates through a nitrate bath which has been brought to a specified temperature. A ball lies in the ring and shows increased resistance to the rotation of the ring as the oil thickens due to oxidation. The motion of the ball can be followed by an indicator or a simple telescope. After a given time the loss due to evaporation and the determination of the per cent of materials insoluble in 60-70 benzine can be determined.

We shall see whether such an apparatus can be constructed cheaply enough and whether other designs are possible.

CORROSION

The corrosion of bearing metals by lubricants in general appears only when these metals are in motion and thus strained while the sliding speed of the axle over the bearing is comparatively great.

Evidently a static determination of corrosion by placing pieces of the respective metals in the test oil is not a correct measure of corrosion taking place when in actual use.

We have begun the construction of an apparatus which is essentially an axle pressed against a piece of bearing metal, and lubrication is possible with a small amount of oil.

SPREADING OVER METAL SURFACES

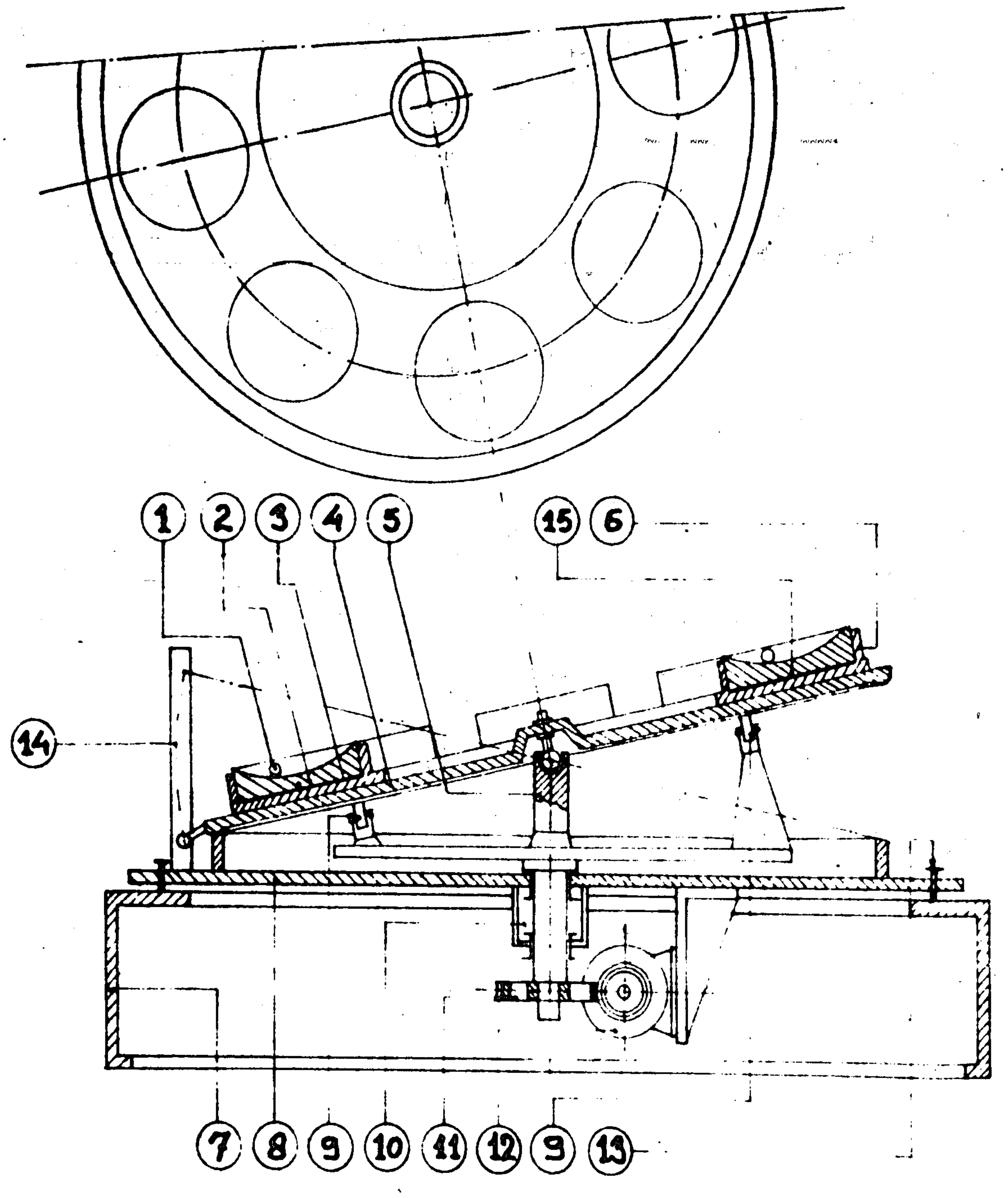
The factors upon which the spreading of various oils over metal surfaces at higher temperatures depend have not yet been established.

Diagram No. 18807-A3

APPARATUS FOR TESTING OXIDATION, WITH 8 TEST CUPS

1. Ball 1/2" dia.
2. Oil brick 140 mm dia.
3. Electrical heater element
4. Rocking plate about 500 mm dia.
5. Ball and socket
6. Insulation
7. Foot
8. Foot plate
9. Rollers
10. Bearings
11. Reduction gear
12. Electric motor
13. Leveling screw
14. Guide plate
15. Thermal element.

002826



OXYDATIONSPRUEFAPPARAT MIT 8 PRUEFGEFÄSSEN.

1 Kugel 1/2" ϕ
2 Oeltiegel etwa 110 mm ϕ
3 Elektr. Heizelement.
4 Schaukelplatte etwa 500 mm ϕ
5 Kugelgelenk.
6 Isolierung.
7 Fuss.
8 Fussplatte.
9 Führungsrollen.
10 Lagerbüchse.
11 Verzögerer.
12 Elektr. Motor.
13 Stellschraube.
14 Führungsplatte.
15 Thermoelement.

18807-Aa.

It is difficult in the present state of knowledge to sketch a usable apparatus for investigating the spreading of lube oils over hot metal surfaces.

We shall therefore begin with the simplest attempt and use a heated cast iron plate to see how well the common lube oils can be classified according to the time it takes for the lubricant to spread over the cast iron.

June 1942

INTRODUCTION

2827

In the report of the previous month the plans were given for various pieces of apparatus suitable for the investigation of small samples of lubricants.

OXIDATION RESISTANCE

From a discussion of the investigation of lube oil samples, it appeared desirable to add a few requirements listed in the previous report (pp. 2-3), namely, the possibility of investigating many samples simultaneously. This would greatly accelerate the investigation, which is of particular importance with the apparatus for determining the oxidation resistance since this property is to be determined at various temperatures. The apparatus, which was pictured schematically in the May report, does not include the above mentioned added requirement. To be sure, it would be possible to place several rings in a bath, but the whole would then become expensive and difficult to handle. It was desirable, therefore, to design a different apparatus which simultaneously fulfills all the above requirements.

Such an apparatus is given schematically in the accompanying diagram (Fig. No. 18.807-A5).

A number of cups are placed in a circle on a table which executes a rocking motion. Aluminum cups are used for good thermal conducivity. Since the oxidation resistance of oils in contact with iron is considered of greater interest than with aluminum, the aluminum cups were lined with iron cups which are light enough to be weighed easily. The radius of curvature of the cups is relatively large so that only a small amount of the test substance is necessary and the heating, by means of a heating element placed underneath the cups, is as uniform as is possible.

In the cup lies a ball which will describe a circle due to the motion of the table. The radius of curvature of this circle will be determined by the fluidity of the fluid in the cup. (With a trial model using a certain angle of tilting and radius of curvature of the cups, the difference in radius of the circle described by the ball was appreciable, for example, with oils E50 = 25 and E50 = 20 they were approximately 60 mm and 10 mm respectively.) 2828

In this manner it will be possible to get an estimate of the viscosity of the oxidation products formed.

It is the plan to provide a separate heating coil for every cup and connect these in series. When the measurement of the cups and the thermocouple are made as nearly as possible at the same time, one can expect that the temperature variations between the various individual cups will be small.

CORROSION

The accompanying diagram shows the apparatus to be made with which 4 samples can be run at the same time (Fig. No. 18.806-A3).

SPREADING OVER HOT METAL SURFACES

In order to attain an overall view of how oil spreads over a hot surface a simple apparatus was constructed (See accompaning schematic diagram 18766-A4).

A cast iron plate was heated electrically in the center. The temperature was measured by means of a thermocouple placed 2 1/2 mm below the surface. The plate was polished respectively with abrasive paper 1 F, 3/0 and 5/0 and then cleaned with fine muslin and alcohol/benzene.

It appeared that when a drop of oil was allowed to fall on one part of the plate where there was a temperature gradient (somewhat to one side) the oil moved relatively more rapidly toward the coolest place. There may be some point to studying this phenomenon further.

However, when a drop of oil was dropped in the middle of the heated plate, it spread slowly and concentrically up to a definite maximum. As soon as the spreading has ceased one can measure the spot.

The size of the drop had comparatively minor influence as is shown by the following figures:

Temperature of the plate 300 C
Diameter of oil spot due to

	1 drop	2 drops
Oil E50 = 8 1/2	4.3 cm	5.1 cm
Bright Stock	3.8 cm	4.2 cm

The weight of the drops of various oils as delivered by the same burette was but slightly different, e.g. spindel oil J2, 20 mg; CY2, 19 mg; Bright Stock, 18 mg.

Thus to drop the oil on the plate is sufficiently accurate when a drop is allowed to fall from one and the same burette.

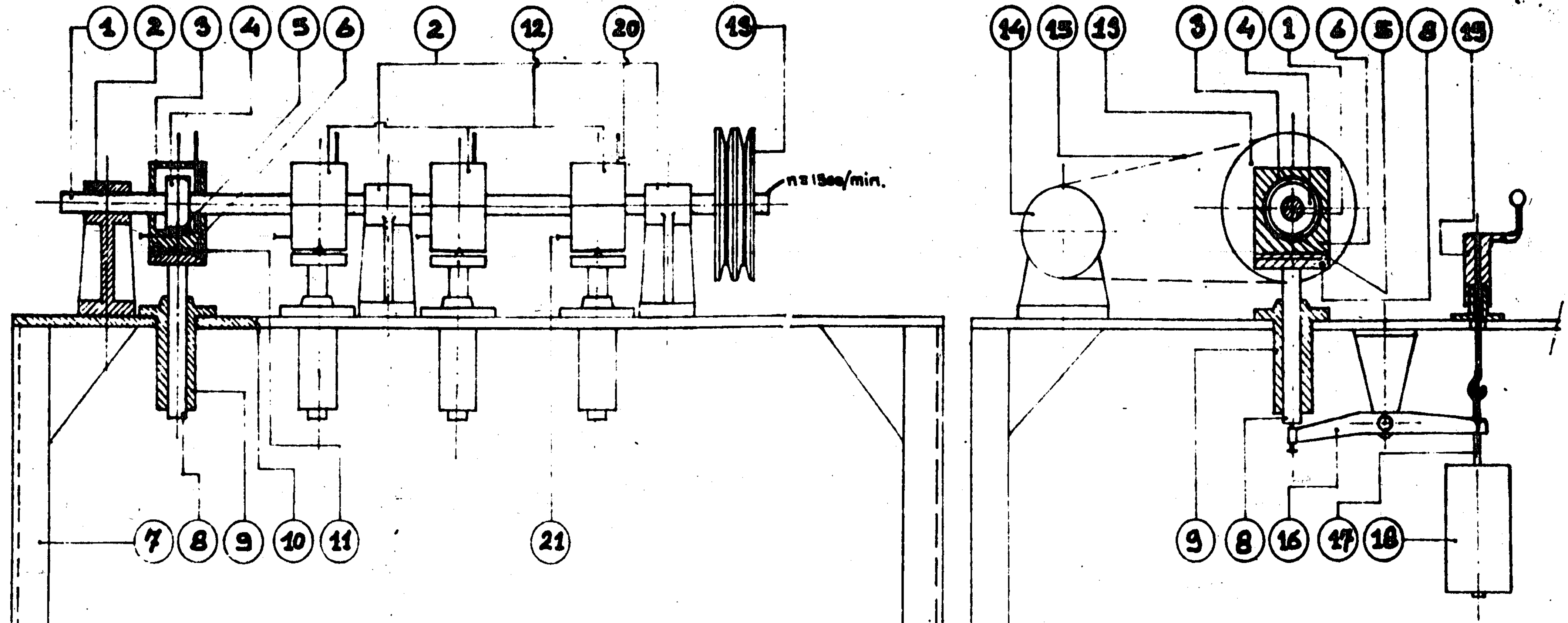
Diagram No. 18806-A3 2829

BEARING CORROSION APPARATUS FOR 4 SAMPLE CONTAINERS OF SMALL OIL CONTENT

1. Axle 20 mm dia.
2. Bearing for axle
3. Dirt catcher
4. Test ring 50 mm dia.
5. Test plate 20 x 20 x 5 mm
6. Holder for test plate and test oil
7. Table leg
8. Cover
9. Guide for 8.
10. Table top about 120 x 70 x 1 cm
11. Spiral spring
12. Complete test units
13. Pulley
14. Electric motor
15. V-belt
16. Lever
17. Rod for hanging weights
18. Weight
19. Means for raising weights
20. Thermometer
21. Thermal element

Diagram No. 18766-A4 2830

HOT PLATE FOR TESTING THE SPREADING OF OIL OVER HOT METAL SURFACES



LAGERKORROSIONSAPPARAT FUER 4 PRUEFGEFÄSSE

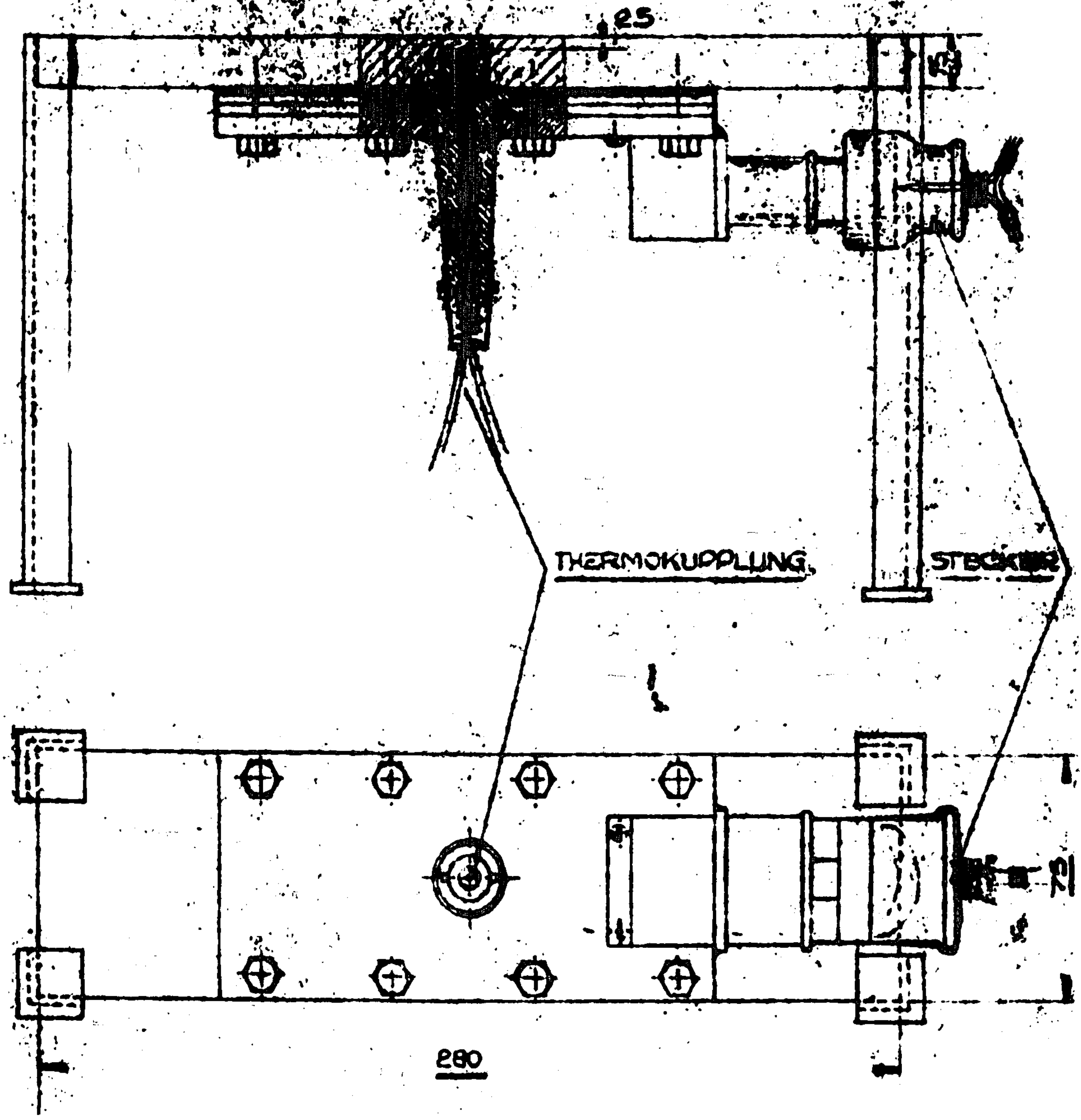
MIT KLEINEM OELINHALT.

1 Achse 20 mm.⌀
2 Achslager.
3 Schmutzfänger.
4 Prüfring 50 mm.⌀
5 Prüfplatte 20x20x5 mm.
6 Prüfplattenhalter-Oelbehälter
7 Tischfuss.
8 Deckel
9 Führungsbüchse für 8.
10 Tischplatte etwa 120x70x1 cm.
11 Spiralfeder.
12 Kompl. Prüfgefäss.
13 Seilscheibe.
14 Elektr. Motor.
15 V-Seil.
16 Hebel.
17 Aufhängestange für Gewichte.
18 Gewicht.
18 Hebevorrichtung für Gewichte.
20 Thermometer.
21 Thermoelement.

18806-As

002830

[illegible] PRÜFUNG DER AUSBREITUNG [illegible] HEISSE METALLOBERFLÄCHEN



18756-A

2851

To determine whether there was a difference in spreading between various oils, some oils were chosen, for purposes of orientation, which had approximately the same chemical composition but different viscosity, and some which had approximately the same viscosity but different chemical composition. These oils are to be tested at various temperatures with the above apparatus. It will probably become evident at the same time in what ways the above apparatus can be improved.

July 1942

SPREADING OVER HOT METAL SURFACES

2534

Several oils were investigated with the apparatus described in the June report (p. 4) in order to find if there were any essential differences in the spreading of oils of various composition. The size of the spot made by a drop of oil from a standard burette (about [illegible] mg) was the criterion.

This investigation was carried out in the following manner:

The cast iron plate is polished with 5/0 sandpaper and then cleaned with alcohol-benzene. Then it is leveled precisely and heated to the desired temperature. Then a drop of oil is placed in the center of the plate and the oil spot allowed to attain its maximum size. This may in some cases take a rather long time. The rate of spreading is obviously related to the temperature and the kind of oil.

At present the rate of spreading (which is perhaps of greater interest than the final size of the spot) as well as the effect of a temperature gradient is not considered.

After the final size of the oil spot has been noted the plate is again cleaned with alcohol-benzene and polished if necessary. It seems in general that one could make 5 observations before polishing again. However, before a different oil is tested the plate should be polished.

For purposes of orientation a number of oils of approximately similar chemical composition and of increasing viscosity were investigated at a plate temperature of 200 C and 300 C.

The results of these investigations are summarized in the following table.

Plate temperature 200 C			Plate temperature 300 C		
Kind of oil	Diameter of oil spot in cm in 2 directions at right angles to each other	Average value in cm	Kind of oil	Diameter of oil spot in cm in 2 directions at right angles to each other	Average value in cm
J_2 E_{20} - 7	4.1 - 4.0 4.4 - 4.1 4.3 - 4.3 4.3 - 4.3 4.3 - 4.2	4.2	J_2 E_{20} - 7	3.0 - 2.9 2.9 - 2.9 2.8 - 2.9 2.9 - 3.0 2.9 - 2.8	2.9
BD_1 E_{50} - 3½	4.5 - 4.2 4.4 - 4.1 4.3 - 4.2 4.3 - 4.3 4.4 - 4.3	4.3	BD_1	3.5 - 3.4 3.7 - 3.6 3.5 - 3.5 3.6 - 3.6 3.7 - 3.6	3.6
B_2 E_{50} - 7	5.9 - 4.7 5.7 - 5.1 6.0 - 5.5 6.3 - 5.4 6.5 - 5.8	5.7	B_2 E_{50} - 7	3.8 - 3.7 3.5 - 3.5 3.6 - 3.6 3.5 - 3.4 3.4 - 3.5	3.6
B_3 E_{50} - 11	5.0 - 4.5 4.7 - 4.1 5.3 - 4.6 4.9 - 4.3 5.0 - 4.2	4.7	B_3 E_{50} - 11	3.6 - 3.5 3.3 - 3.3 3.5 - 3.5 3.4 - 3.5 3.5 - 3.4	3.5
B F_3 E_{50} - 14½	6.7 - 5.7 6.2 - 5.3 6.1 - 5.2 6.1 - 5.3 6.3 - 5.3	5.8	B F_3 E_{50} - 14½	3.8 - 3.7 3.7 - 3.6 4.0 - 3.9 3.9 - 3.8 3.9 - 3.8	3.8
Castor Oil	4.3 - 3.0 3.0 - 2.7 3.2 - 2.8 3.1 - 2.0 2.6 - 2.5	2.9	Castor Oil	3.1 - 3.0 3.1 - 2.9 3.1 - 2.9 3.1 - 2.9 3.1 - 2.9	3.0

2836

From the first set of figures it can be concluded that there is no correlation between viscosity and the extent of spreading. However, for higher plate temperatures the evaporation of a volatile oil, as for example J_2, is so rapid that the final oil spot is small. It is noteworthy that B_5 used by us shows lower values at 200 C than the other oils in this series.

Strikingly low are the values for castor oil, particularly at 200 C.

An inspection of the oil spot on the cast iron reveals brown spots which are very dark along the edge. Evidently fairly strong oxidation takes place during the test, and it would therefore be desirable to repeat these investigations at some convenient time in the absence of air (oxygen).

We shall, however, first investigate a number of oils of different chemical composition.

OXIDATION RESISTANCE

The apparatus previously described has been worked out in detail and submitted to the drafting department to be drawn up. The construction of the apparatus will be started soon.

CORROSION

The apparatus previously described has been worked out in detail and submitted to the drafting deparment to be drawn up. The construction of the apparatus will be started soon.

August 1942

SPREADING OVER HOT METAL SURFACES

2837

In continuing the investigations mentioned in the July report a number of oils of various chemical compositions were subjected to similar tests.

Kind of Oil	Diameter of oil spot in cm at 200 C		Diameter of oil spot in cm at 300 C	
Penna Neutral	5.0 - 4.7 5.4 - 5.1 5.6 - 5.2 5.5 - 5.1 5.4 - 5.0	Ave. 5.2	3.9 - 3.8 3.8 - 3.7 3.7 - 3.7 3.8 - 3.7 3.7 - 3.7	Ave. 3.8

(Continued)

(Continued)

Kind of Oil	Diameter of oil spot in cm at 200 C		at 300 C	
Single Shell (Penna)	7.0 - 5.9	Ave. 6.3	4.2 - 4.0	Ave. 4.2
	6.7 - 6.0		4.4 - 4.2	
	6.5 - 5.9		4.3 - 4.2	
	6.3 - 5.9		4.3 - 4.0	
	6.7 - 5.9		4.2 - 3.9	
Double Shell (Penna)	5.9 - 6.0	Ave. 6.0	4.4 - 4.2	Ave. 4.3
	6.2 - 5.7		4.4 - 4.3	
	6.5 - 5.8		4.4 - 4.3	
	6.4 - 5.8		4.4 - 4.3	
	6.4 - 5.3		4.3 - 4.1	
Penna Bright Stock	4.2 - 3.3	Ave. 3.9	3.6 - 3.8	Ave. 3.8
	4.6 - 4.0		3.7 - 3.7	
	4.1 - 3.8		3.8 - 3.9	
	3.8 - 3.8		3.8 - 3.9	
	4.0 - 3.4		3.8 - 3.8	
B. Papan Oil E 50 = 10, TMC, 6996	4.3 - 4.1	Ave. 4.3	3.5 - 3.3	Ave. 3.3
	4.2 - 4.2		3.3 - 3.2	
	4.4 - 4.2		3.4 - 3.2	
	4.7 - 4.1		3.3 - 3.2	
	4.4 - 4.4		3.3 - 3.1	
Rectiflow Heavy TMC 222	5.8 - 5.4	Ave. 5.9	4.4 - 4.4	Ave. 4.4
	5.9 - 5.4		4.5 - 4.4	
	6.1 - 5.5		4.5 - 4.4	
	6.3 - 5.6		4.4 - 4.4	
	6.6 - 5.9		4.5 - 4.5	
Synthetic Oil TMC 8255	4.5 - 4.5	Ave. 4.5	3.6 - 3.2	Ave. 3.4
	4.3 - 4.2		3.7 - 3.1	
	4.5 - 4.5		3.6 - 3.1	
	4.9 - 4.3		3.5 - 3.0	
	4.8 - 4.7		3.7 - 3.1	

These figures together with those given in the report of 2838 the previous month permit no positive conclusions. In general, it seems that the Penna oils spread more than the more aromatic oils, especially at

200 C. In the latter oils there are exceptions, however, for example B_2 and B F_3. Rectiflow Heavy is more or less like Penna Oils. It should be noted that Penna Bright Stock spreads appreciably less at 200 C.

The differences in the oils are more pronounced at 200 C than at 300 C.

PLANS FOR FURTHER INVESTIGATION

We shall now repeat these tests after most careful exclusion of air to prevent oxidation. The present apparatus will have to be revised for this purpose.

October - November 1942 2847

SPREADING OVER HOT METAL SURFACES

It seemed, from the reports of July and August, 1942, that the film which spread over the metal surface underwent oxidation to a considerable extent.

Since the possibility was present that oxidation appreciably influenced the spreading, the apparatus used for these tests has been revised so as to hinder possible oxidation.

For this purpose the hot plate has been placed under a glass bell jar (a) (See Fig. 19036-A4 and also the description in the June report) which is made tight by a rubber ring. Through the base plate (c) a tube (d) is brought, through which nitrogen is blown into the top of the bell jar. The nitrogen exits through a hole (e) in the base plate, which hole is also used to admit the electric wires.

The oil is brought to the heated plate by means of a burette (f) with a capillary attachment (g) which is admittted through the top of the bell jar. The capillary attachment is so made that the drops falling from it are approximately the same size as were produced by the burette used in the previous measurements (about 18 mg).

We showed that if one passed 100 l. nitrogen through the bell jar in 3 hours the oxygen content was less than could be detected with the Orsat apparatus (<0.2 per cent). We have assumed that this concentration of oxygen is low enough that oxidation of lube oil films should be largely eliminated and its effect on the spreading of lube oil films over metal surfaces should be evident.

The plate is also cooled by passing nitrogen, while after every trial the plate is cleaned with benzene and repolished with sandpaper 00000.

The following readings were obtained with a plate temperature of 200 C:

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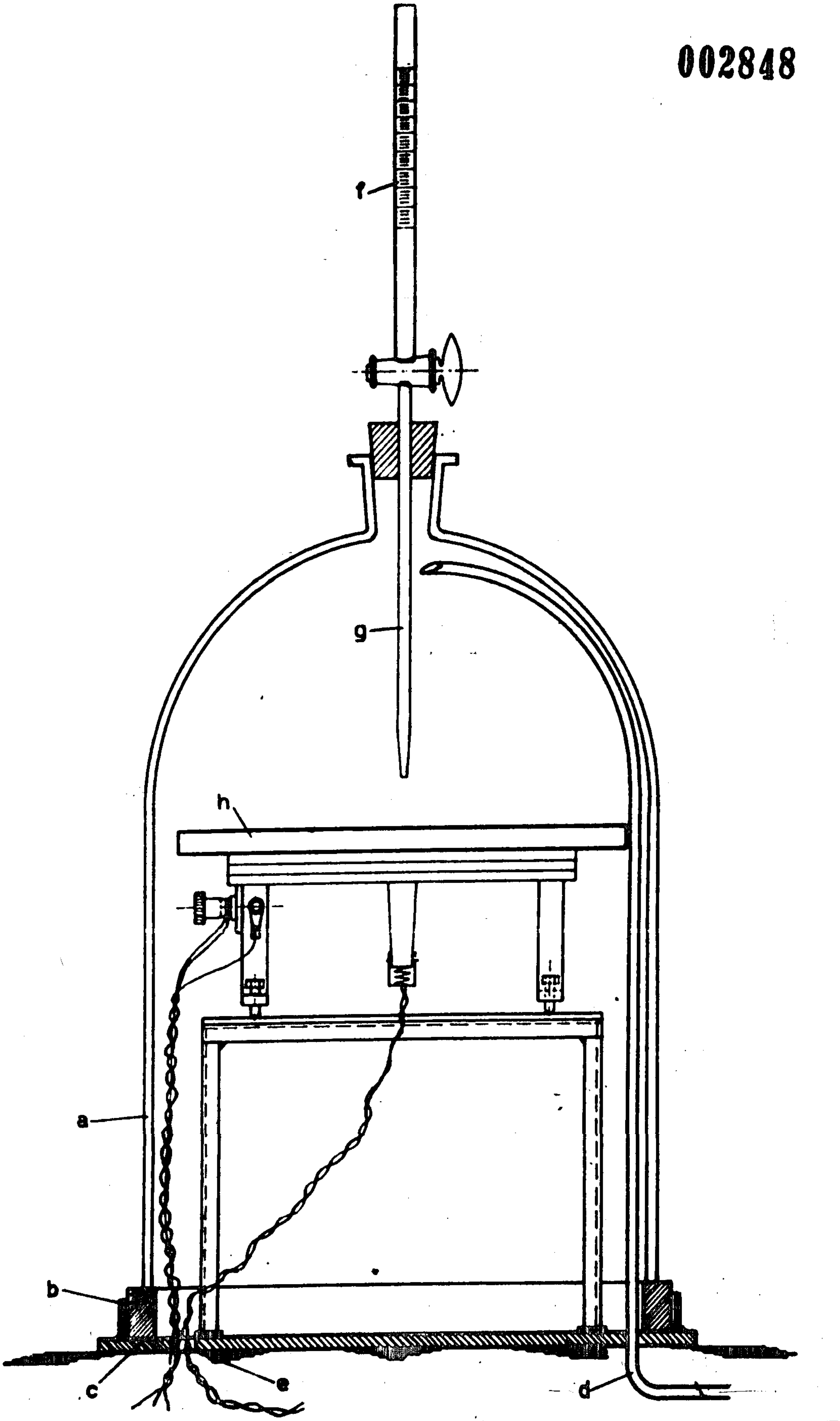

L.B.P.MA.

19036-A4

Diameter of Oil Spot	Measured in 2 directions each other	Average Value in cm
Spindel Oil J2	4.4-4.3 4.3-4.1	4.3
BD 1	5.2-4.5 5.5-4.5	4.9
B 2	5.9-4.9 6.1-5.1	5.5
B 3	5.3-4.8 5.5-4.1	5.0
BF 3	6.8-3.0 6.6-3.1	4.9
Single Shell (Penna)	6.8-5.0 7.2-5.6	6.1
Double Shell (Penna)	7.7-5.7 8.1-6.5	7.0

After the test was complete the oil spot could always be removed readily with benzine or benzene. The spot was of a bright color. This would indicate that the oxidation which occurred by the previous method had been largely eliminated. Further conclusions will be drawn as soon as all the oils which were tested in air have been investigated.

RAPID SPREADING OF THIN OILFILMS ON METAL SURFACES

From the tests on spreading which have been carried out to date it seems that the spreading of a visible oil film over a hot metal surface takes place slowly. The observed spreading is in fact so slow that it is questionable whether, in view of the speed with which the lube oil film is spread mechanically, as for example in a motor cylinder, it is not entirely futile.

The rate at which an oil film spreads on water, where a layer of a few molecules thick is produced, is much greater than the rates we observed. The question arose, therefore, whether a layer of several molecules thick is produced on metal with great speed, which we, to be sure, could not recognize as a lubricating film with the naked eye, but which, nevertheless, had a certain lubricating effect.

It seemed interesting to see whether such an extremely thin lubricating film can also spread rapidly on metal.

We proceeded on the well known fact from the investigations 2850
of Langmuir and Anderson, that a perfectly clean metal surface (except for the adsorbed gas film which can only be removed with difficulty) is entirely wetted by water. If, however, an extremely thin film of oil (for example, one or several molecules thick) is on the metal, water no longer wets it.

We, therefore, used a cylinder of polished steel of 32 mm diameter and 75 mm long. This cylinder was cleaned according to the method used by Hardy* (extracting with benzene and then rubbed under flowing water with carefully cleaned hands) until it was completely wetted by water. The water was then removed with alcohol and the alcohol with ether. In this way the cylinder was dried. After drying it was possible to wet the cylinder completely for a short period. After a time, however, so much dust and oily stuff from the air covers the surface that it no longer is possible to wet it with water. It is necessary therefore after cleaning to perform the test quickly.

Only a small drop of fresh lube oil (Double Shell Penna) was placed on the one side of the cylinder, and immediately afterwards the cylinder was immersed in water up to the drop. There was still complete wetting; nevertheless, the waterfilm was crowded back from the drop of lube oil at a comparatively slow speed (less than 1 cm/sec.). This displacement is caused by an oil film which spreads out from the oil drop. This oil film, which cannot be observed with the naked eye, clings with greater tenacity to the metal than does the water film and consequently displaces it.

This test was repeated several times and showed that the spreading speed varied considerably, but always remained small.

Then we tried lard oil with an acid number of about 10, since there was the possibility that an oil with an appreciable number of polar constituents would give different results.

Nevertheless, the same phenomenon appeared as when Double Shell oil was used, although the rate of spreading on the whole, was somewhat greater than with Double Shell. The reproducibility of the rate of spreading was also satisfactory in this case.

CONCLUSIONS

We have concluded from these investigations that a very thin

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* See "The Analysis of Commercial Lubricating Oils by Physical Methods" Lubrication Research, Technical Paper No. 1. Publication of "Department of Scientific and Industrial Research".

film is formed on metal which film is not visible to the naked eye. The speed with which this film is formed is greater at room temperature than for the visible film in our tests on a hot plate at 200 C or 300 C. The rate at which this very thin film spreads on metal is much less than on water.

PLANS FOR FURTHER WORK

We shall repeat these investigations at a somewhat higher temperature. However, this temperature, because of the criterion chosen (namely, wetting by water) cannot be greater than 100 C.

December 1942 2859

SPREADING OVER HOT METAL SURFACES

INTRODUCTION

As mentioned in the October-November report the spreading tests with oils of various viscosities and chemical composition was repeated in an atmosphere of nitrogen to determine the effect of oxidation. For the apparatus used one is referred to the above mentioned report.

SUMMARY OF THE INVESTIGATION

The data on the spreading tests in a nitrogen atmosphere follow later. (See pp. 14-15)

It is evident from these data that oxidation affects spreading appreciably.

The acids formed by oxidation show a tendency to promote spreading (See the tests with Double Shell and Double Shell + stearic acid). The resinous oxidation products have, on the contrary, a tendency to hinder spreading. This influence can be noticed distinctly, for example, with Penna Bright Stock. This shows that irregularities occur in the tests in air for which reason B F_3 and B_2 appear to spread better than B D_1 or B_3.

The tests in a nitrogen atmosphere show that the spreading we measured is not critically dependent on the viscosity. The paraffin oils, however, show a definitely greater spreading than the more aromatic oils.

PLANS FOR FURTHER WORK

We shall now leave the method of investigation that has been pursued and measure the rate of spreading on metal when a temperature gradient exists.

SPREADING TESTS ON CAST IRON IN AN ATMOSPHERE OF NITROGEN

Kind of Oil	Plate Temperature 200 C		
	In N_2 atmosphere		In air (for comparison)
	diameter in 2 directions	average diameter	
J_2 (E 20 = 7)	4.4 - 4.3 4.3 - 4.1	4.3 cm	4.2 cm
B D_1 (E 50 = 3 1/2)	5.2 - 4.5 5.5 - 4.5	4.9	4.3
B_2 (E 50 = 7)	5.9 - 4.9 6.1 - 5.1	5.5	5.7
B_3 (E 50 = 11)	5.3 - 4.8 5.5 - 4.5	5.0	4.7
B F_3 (E 50 = 14 1/2)	6.8 - 3.0 6.6 - 3.1	4.9	5.8
Penna Neutral (E 50 = 3)	6.1 - 5.5 6.0 - 5.4	5.8	5.2
Single Shell Penna (E 50 = 6)	6.8 - 5.0 7.2 - 5.6	6.1	6.3
Double Shell Penna (E 50 = 9)	7.7 - 5.7 8.1 - 6.5	7.0	6.0
Penna Bright Stock (E 50 = 32)	8.1 - 4.6 9.0 - 6.0	6.9	3.9
Synth. Bright Stock (E 50 = 45)	4.0 - 3.2	3.8 (discontinued after 4 1/2 hrs; spreading still continued)	4.5
Rectiflow Heavy (E 50 = 13)	9.0 - 6.5 8.7 - 6.7	7.7	5.9
Castor Oil (E 50 = 17 1/2)	3.8 - 3.5	3.7 (discontinued after 4 1/2 hrs; spreading still continued)	2.9

(Continued)

SPREADING TESTS ON CAST IRON IN AN ATMOSPHERE OF NITROGEN (CONTINUED)

Kind of Oil	Plate Temperature 200 C		
	In N_2 atmosphere		In air (for comparison)
	diameter in 2 directions	average diameter	
Used Double Shell (Penna), acid number 0.4, sponification number 2.0	8.4 - 6.5 8.4 - 6.0	7.3 cm	-
Double Shell ≠ 1/2 wt. % Stearic acid	8.0 - 6.6	7.3	-
B. Papan Oil (E 50 = 8 1/2)	3.9 - 3.8 4.4 - 4.1	4.0	4.3 cm

January 1943

2872

SPREADING OVER HOT METAL SURFACES

In the report of June 1942 it was mentioned that when a temperature gradient existed, lube oil would move toward the region of lower temperature. We have now begun to examine this phenomenon more closely and built a simple apparatus for that purpose, which is illustrated schematically in Fig.(19162-A4).

A groove is made in a cast iron rod of about 30 x 30 mm cross section and about 300 mm in length. The rod is heated on one side by means of a gas flame and due to the cooling effect of air a temperature gradient is set up. In the road immediately underneath the groove holes (a) are bored about 15 mm apart to measure the temperature. Marks (b) are placed on both sides near the groove; the time required for an oil to crawl from one of these marks to the next one is measured.

In some orientation tests the temperature at the bottom of the groove at the first mark was maintained at 200 C. The temperature on the unheated end was 80 C.

Then we carried out some tests with J 2 and Double Shell. This showed that one drop of oil for such a volatile oil as J 2 was not sufficient since the oil evaporates too rapidly and does not reach the other end. In further tests, therefore, we allowed two drops of oil to fall in the groove in rapid succession.

Nevertheless, the reproducibility of the tests was not good due in part to the fact that the oil spreads very slowly in the coldest part of the groove. This was verified by temperature measurements along the whole length of the groove from which the following diagram (5708-2B4) was made. It is evident from this that the temperature gradient is much smaller for the last part of the groove than for the first part. We, therefore, changed the second mark to the place where the groove temperature was 100 C and again made some measurements. These were much more reproducible, although differences of about 25 per cent occurred.

CONCLUSION 2875

A simple apparatus for measuring the spreading of oil over metal surfaces when a temperature gradient existed has been made. The temperature spread and its effect on the experiment were investigated.

PLANS FOR FURTHER WORK

An attempt will be made to increase the reproducibility of the measurements when the region of most nearly constant temperature gradient is used. Then a number of oils will be investigated.

February 1945 2876

SPREADING OVER HOT METAL SURFACES

It was shown in the January report that the reproducibility of the above mentioned measurements improved appreciably when the readings were confined to the temperature range 200 C to 120 C.

The length of rod along which the temperature drops by this amount is about 95 mm.

We now have the following experimental procedure:

Two drops of oil (about 40 mg) are placed in rapid succession in the accurately horizontal groove at the point where the temperature is 200 C. The time taken for the oil to reach the point at which the temperature is 120 C is measured. After every test the rod is cleaned with benzine and then with alcohol-benzene.

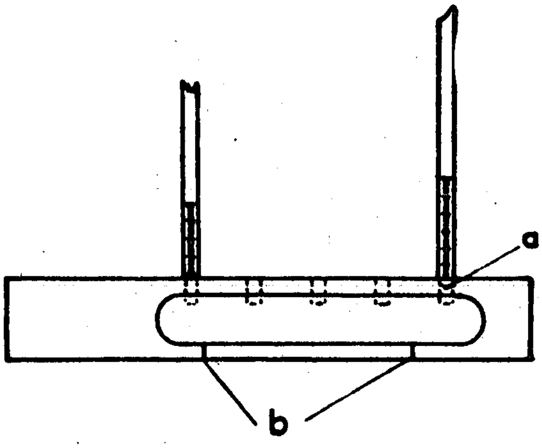
We have undertaken to compare several oils under the above conditions and obtained the following results:

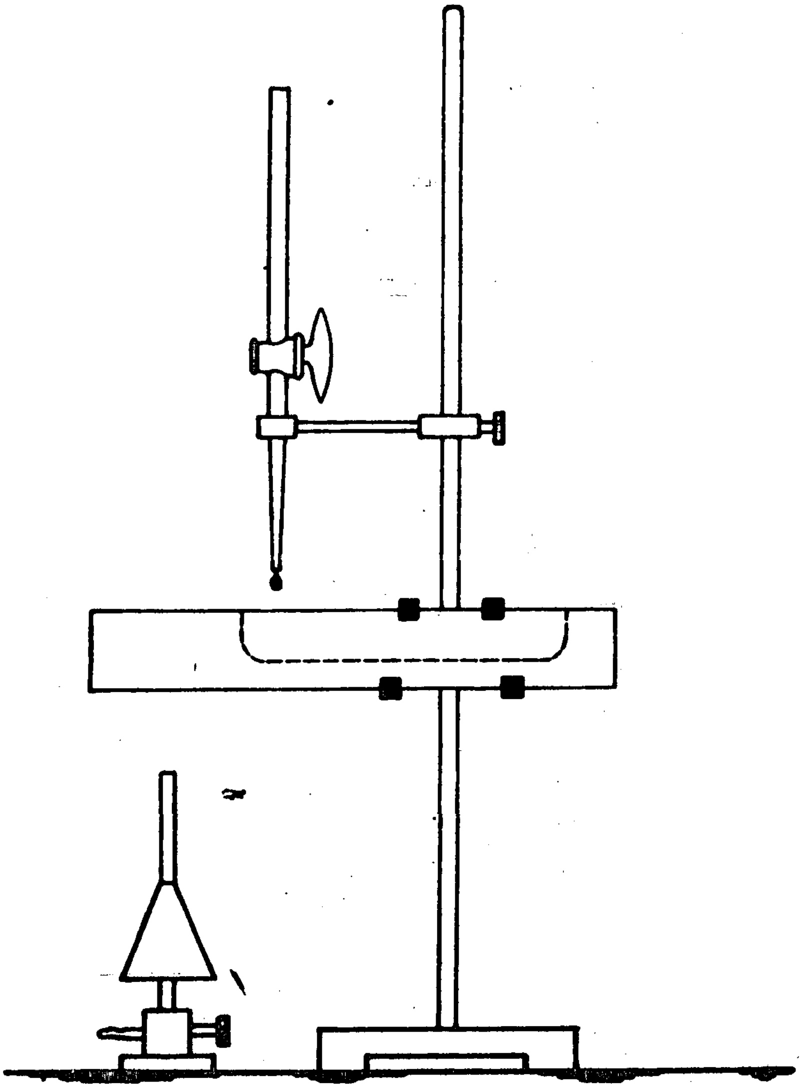
Fig. 19162-A4

2874

APPARATUS FOR MEASURING THE SPREADING OF OILS

002874





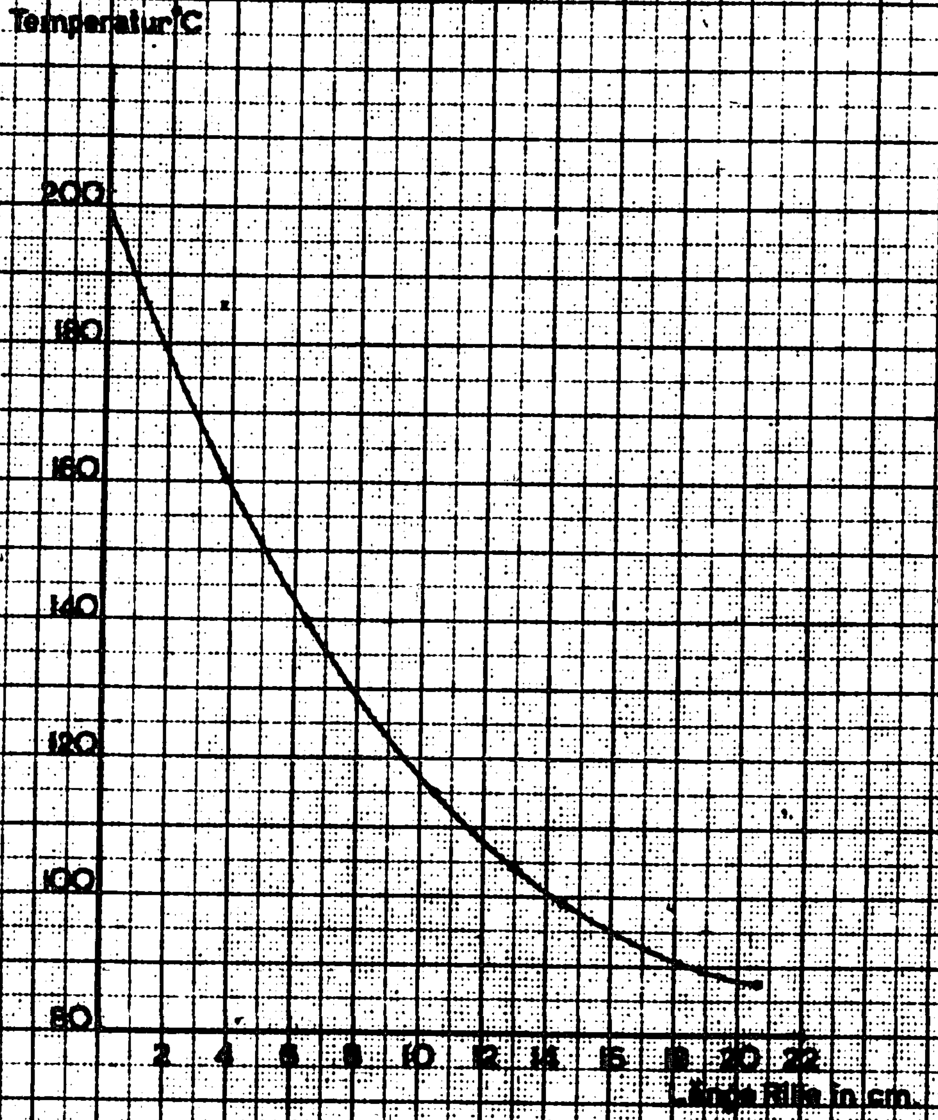
R.B.P.M.A. | BENENNUNG: APPARAT ZUR MESSUNG DER AUSBREITUNG VON ÖLEN | No 19162-A

Fig. 5708-2-B4

2875

CURVE SHOWING TEMPERATURE AS A FUNCTION OF DISTANCE FROM THE POINT OF STANDARD TEMPERATURE (200 C) IN TESTS WITH HEATED ROD

Beziehung zwischen Temperatur und Abstand vom Punkt mit Standardtemperatur (100°C) bei Versuchen mit erhitztem Stab.



	Seconds necessary to spread from 200 C to 120 C points		
Spindel Oil J 2	16, 16, 16, 17, 15	average	16 sec.
BD 1	21, 22, 24, 22, 25	"	23 "
B 2	32, 34, 30, 34, 32	"	32 "
Double Shell	40, 44, 48, 45, 42	"	44 "

PLANS FOR FURTHER INVESTIGATION

We will now compare with this apparatus all the other oils, on which work has been done.

March 1943 2904

SPREADING OVER HOT METAL SURFACES

SUMMARY OF THE INVESTIGATION

A series of oils, which have been tested previously with other apparatus (See reports June-December, 1942) has now been tested with respect to the rate of spreading between points at temperatures 200 C and 120 C as described in the report of February (pp. 16-17).

The results of these experiments are as follows:

Oil	Seconds necessary to spread from 200 C to 120 C points		
Spindel Oil J 2 (E 20 = 7)	16, 16, 16, 17, 15	average	16
BD 1 (E 50 = 3 1/2)	21, 22, 24, 22, 25	"	23
B 2 (E 50 = 7)	32, 34, 30, 34, 32	"	32
B 3 (E 50 = 11)	37, 37, 35, 36, 39	"	37
BF 3 (E 50 = 14 1/2)	40, 44, 42, 46, 44	"	43
Balik Papan Oil (E 50 = 8 1/2)	35, 38, 34, 36, 33	"	35

(Continued)

(Continued)

Oil	Seconds necessary to spread from 200 C to 120 C points		
Penna Neutral (E 50 = 3)	19, 20, 23, 22, 21	average	21
Single Shell (Penna) (E 50 = 6)	34, 33, 36, 33, 30	"	33
Double Shell (Penna) (E 50 = 9)	40, 44, 48, 45, 42	"	44
Penna Bright Stöck (E 50 = 32)	94, 92, 85, 85, 87	"	89
Rectiflow Heavy (E 50 = 13)	47, 52, 54, 53, 51	"	51
Synthetic Bright Stock (E 50 = 45)	153, 118, 143, 141, 121	"	135
Castor Oil (E 50 = 17 1/2)	107, 238, 134, 374, 143	"	± 200
Used Double Shell (E 50 = 10) acid number 0.4 sponification number 2.0	52, 54, 49, 59, 56	"	54

CONCLUSIONS

It is seen from the data that the viscosity has an appreciable influence on the speed with which an oil moves from a warmer to a cooler region.

PLANS FOR FURTHER INVESTIGATION

We shall test some more oils and obtain the viscosity at the average temperature (about 160 C) to determine whether viscosity is the only factor which plays a part in this manner of spreading, or if other properties of the oils exert an influence.

April 1943 2916

SPREADING OVER HOT METAL SURFACES

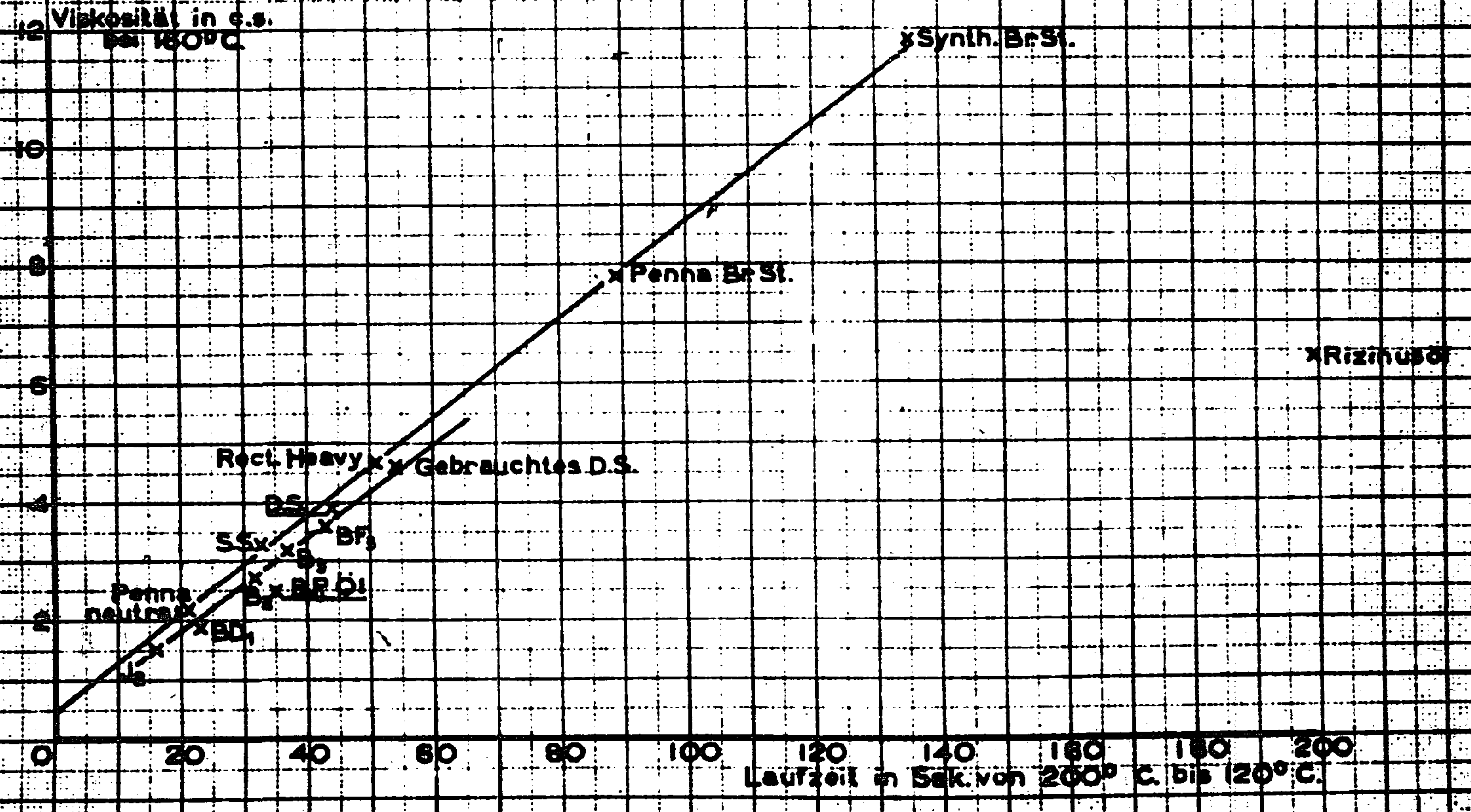
SUMMARY OF THE INVESTIGATION

The viscosities of the oils mentioned in the March report have

Fig. 5759-B4

SPREADING OF OIL IN A HOT GROOVE
BETWEEN 200 AND 120 C

Ausbreitung von Öl in einer heissen Rinne zwischen 200 und 120° C.



been determined at 160 C. These were as follows for the various oils.

		Viscosity in cS at 160 C
Spindel Oil J2	(E 20 = 7)	1.5
BD 1	(E 50 = 3 1/2)	1.9
B 2	(E 50 = 7)	2.7
B 3	(E 50 = 11)	3.2
BF 3	(E 50 = 14 1/2)	3.6
Balik Papan Oil	(E 50 = 8 1/2)	2.5
Penna Neutral	(E 50 = 3)	2.2
Single Shell Penna	(E 50 = 6)	3.3
Double Shell Penna	(E 50 = 9)	3.9
Penna Bright Stock	(E 50 = 32)	7.8
Rectiflow Heavy	(E 50 = 13)	4.7
Synthetic Bright Stock	(E 50 = 45)	11.8
Castor Oil	(E 50 = 17 1/2)	6.4
Aged Double Shell	(E 50 = 10)	4.6

In the accompanying diagram, No. 5759-B4 the time required for the oil to spread from the point at'200 C to that at 120 C to that at 120 C is given as a function of the viscosity at 160 C. This shows that of the mineral oils Pennsylvanian oils and Synthetic Bright Stock spread somewhat more rapidly than the Venezuelan oils; that the Balik Papan oil spreads most slowly. However, the differences are very small. Castor oil spreads much more slowly than would be expected from its viscosity.

CONCLUSION

It is shown that for mineral oils the spreading over a metal surface with a temperature gradient is, almost without exception, a function of the viscosity.

PLANS FOR FURTHER WORK

We shall investigate together with castor oil several other fatty oils and at the same time extend the investigation to glycerin, oleic and stearic acids.

SPREADING OVER HOT METAL SURFACES 2921

SUMMARY OF THE INVESTIGATION

The rate of spreading of several other lubricants were tested in the established manner. Some results follow:

Oil	Seconds necessary for spreading from 200 C to 120 C.		
Double Shell + 1/2 wt. per cent pure stearic acid	51, 43, 45, 46, 39	average	45
Double Shell + 3 wt. per cent pure stearic acid	47, 43, 42, 41, 40	"	43
oleic acid (technical)	24, 31, 24, 34	"	28
paraffinum liquidum	16, 18, 15, 20	"	17
rapeseed oil	136, 100, 91, 133, 101, 102	"	110
lard oil	42, 41, 44, 69, 51, 43	"	48
glycerin	Does not spread at all.		

CONCLUSIONS

Although the viscosity of all these substances at 160 C is not yet known, one can see even now that their behavior is markedly different from that of normal mineral oils.

A highly refined oil such as paraffinum liquidum, which according to literature references does not spread on water behaves as a normal mineral oil under our experimental procedure.

There also seem to be great differences in the spreading properties of the fatty oils.

PLANS FOR FURTHER INVESTIGATION

We shall investigate several more fatty oils and determine the viscosity at 160 C. Furthermore, we are now seeking an explanation for the established facts.

June 1943

2947

OXIDATION RESISTANCE

The apparatus for determining oxidation resistance of lubricants as drawn schematically in the report of June 1942 has been completed. From a few orientation tests it was shown that the rotational speed of the instrument (80 r.p.m.) was too high, since the oil cannot follow the motion of the cups quickly enough, particularly after the oil is thickened slightly by oxidation, and the ball runs dry, more or less, and leads to irregularities.

We shall therefore reduce the speed of the driving shaft 5:1.

SPREADING OVER HOT METAL SURFACES

We tested several other fatty oils for spreading speed with the usual apparatus while the viscosity of these as well as those mentioned in the May report were determined at 160 C. The complete results were as follows:

	Viscosity at 160 C	Seconds necessary to spread from 200 C to 120 C
Oleic acid (Tech.)	2.2	28
Paraffinum liquidum	1.8	17
Glycerin	2.5	∞
Rapeseed oil	4.6	136, 100, 91, 133, 101 102, average 110
Lard oil	3.7	42, 41, 44, 69, 51, 43, average 48
Neat's foot oil	3.95	48, 41, 42, 40, 39 average 42
Linseed oil	3.3	57, 70, 68, 60, 62 average 63
Sperm oil	2.85	31, 31, 31, 31, 31 average 31
Sesame oil	3.6	38, 37, 47, 36, 38 average 39
Sunflower oil	3.9	69, 61, 59, 55, 56 average 60

CONCLUSIONS

2948

Among those tested there are several oils (for example, sperm oil, sesame oil, neat's foot oil) that have a rate of spreading which is entirely comparable to mineral oils of the same viscosity (See Fig. 5759-B4 in May report).

On the contrary others, particularly rapeseed oil (p. 20) and castor oil (p. 19) spread much more slowly than would be expected from their viscosity. The reproducibility of the determinations is also much worse with these than with the other oils.

PLANS FOR FURTHER INVESTIGATION

We shall investigate whether the deviations of several fatty oils can be attributed to oxidation.

CORROSION

As is well known, many lubricants cause serious corrosion when bearing metals of lead-bronze or cadmuim-nickel are used in the motor. Although the type of lubricants used is in general not harmful, if the bearings do not contain elements that are easily attacked, it seemed desirable in the development of new lubricants to take into consideration their behavior toward Cd and Pb.

We knew from experience that tests in which a piece of bearing metal was placed for a definite time in the test lubricant could lead to erroneous conclusions. For these reasons an apparatus was designed which is given schematically in the report of June 1942. This apparatus has been completed in a somewhat modified form (See Fig. No. 19563 A-3).

It consists essentially of a rotating steel ring against which a piece of Cd-Ni bearing metal is pressed. The whole is placed in a closed housing into which the oil sample can be introduced.

Since in the preparation of materials which shall serve as special oils, only a small amount is available for research, the apparatus is designed so that a sample of 5-10 cc is sufficient to test for corrosion of Cd-Ni.

Several orientation tests were made with this apparatus in which a mineral oil with and without the addition of 1 per cent by weight of oleic acid was used.

It was shown that a felt ring was not sufficient to make the test chamber tight, and that too much of the originally small sample leaked out. This resulted in rather bad agreement between the corrosion numbers of the four series of experiments. After testing a number of ways for making the chamber tight, the simplest solution proved to be to remove the ring and to make a groove in the room provided for the felt ring which caused the oil to flow back.

2949

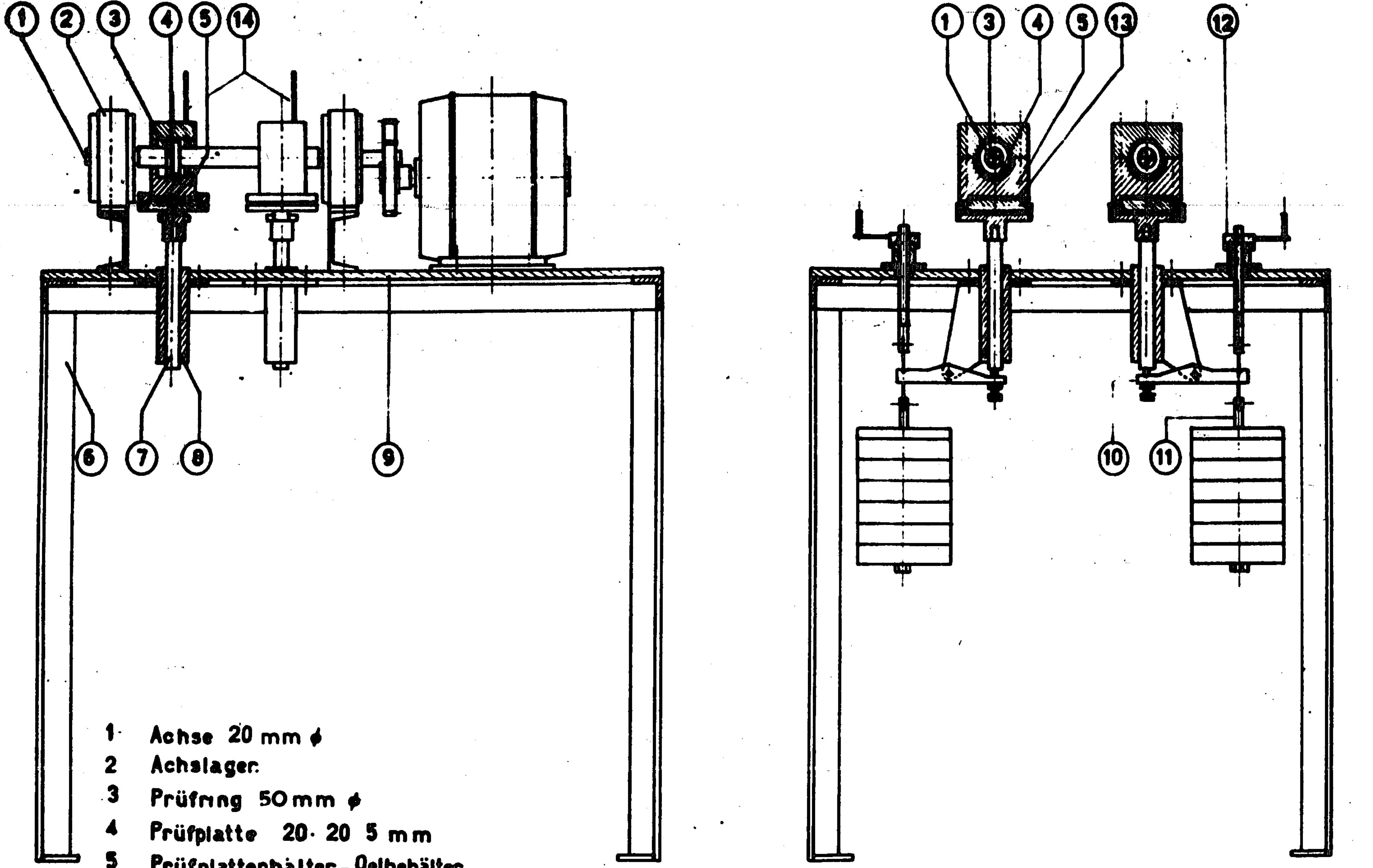
Fig. 19563-A3

BEARING CORROSION APPARATUS FOR 4 TEST VESSELS OF SMALL OIL CAPACITY

1. Axle 20 mm dia.
2. Bearing for axle
3. Test ring, 50 mm dia.
4. Test plate 20 x 20 x 5 mm.
5. Test plate holder - oil container
6. Table leg.
7. Pressure rod
8. Guide for 7
9. Table top
10. Lever
11. Rod for supporting weights
12. Lifting arrangement for weights
13. Heater
14. Thermometer.

002949

LAGERKORROSIONSAPPARAT FÜR 4 PRÜFGEFÄSSE MIT KLEINEM OELINHALT.



1 Achse 20 mm ϕ
2 Achslager.
3 Prüfring 50 mm ϕ
4 Prüfplatte 20 · 20 5 mm
5 Prüfplattenhälter-Oelbehälter.
6 Tischfuss
7 Druckachse
8 Führungsbüchse für 7
9 Tischplatte.
10 Hebel
11 Aufhängestange für Gewichte.
12 Hebevorrichtung für Gewichte.
13 Heizung
14 Thermometer

19563-A3

With this modification we found the corrosion due to a Pennsylvanian oil 0.0-0.2 mg and due to the same oil + 1 per cent oleic acid 10.0 mg when a load of 5 1/2 kg (1.4 kg/cm^2) was used. Reproducibility was good in this case. The work was done at a temperature of 100 C which was the highest attainable. Since this temperature is rather low compared to that of a modern motor bearing we shall change the heating elements, which at present are two units of two elements in series, to a parallel arrangement.

PLANS FOR FURTHER INVESTIGATION

We shall still make a number of tests at various temperatures and loads to get a better idea of the usefulness of the new corrosion apparatus.

July 1943

OXIDATION RESISTANCE

2963

The changes suggested in the report of the previous month have been completed. The speed of rotation is now 21 r.p.m. No tests have been made to date.

SPREADING OVER HOT METAL SURFACES

We carried out some experiments to determine whether the oxidation upon warming the oil in air had an appreciable effect on the rate of spreading. The usual apparatus (See the January 1943 report, Fig. 19162-A4) was covered with glass for this purpose and nitrogen blown in through a supply opening during the warm-up and test period.

We undertook an experiment with castor oil. Although the oil was oxidized but little (as determined from its color), it hardly spread at all. This suggested to us that the nitrogen contained sufficient oil or fat to cause a film to form on the metal surface which hindered the spreading. This might also have been the case in the previous experiments in air when castor oil did not spread well and gave poor reproducibility.

The experiments on the effect of oxidation were temporarily suspended for this reason and some experiments carried out with a surface as clean as possible. Therefore, after cleaning with alcohol-benzene, the groove in the apparatus was scoured with silk and a paste of chromium trioxide and then rubbed with silk under flowing water until the metal was thoroughly wetted by water. Then it was washed with absolute alcohol followed by ether, and after drying immediately covered with glass.

After warming under glass two drops of oil were placed as usual on the warmest spot and the rate of spreading measured.

In this way some tests were repeated with mineral oils and with fatty oils which had been tested previously; the following results were obtained:

2984

Oil		Seconds necessary for spreading from [illegible] C to 400 C point.	
Glycerin		Does not spread.	
Rapeseed oil	55, 50, [illegible]	average	5[illegible]
Lard oil	36, 77, 5[illegible]	"	[illegible]
Linseed oil	55, 57, [illegible], 5[illegible]	"	5[illegible]
Castor oil	56, 52, 6[illegible], 6[illegible]	"	58
Sunflower oil	45, 38, 5[illegible]	"	4[illegible]
Penn Bright Stock	87, 87, 8[illegible], [illegible]	"	[illegible]
Synth. Bright Stock	138, 125, 1[illegible]0	"	[illegible]

It is seen from this that the abnormal spreading characteristics of some fatty oils (particularly castor and rapeseed oil) can be attributed almost entirely to an insufficiently clean surface. When the surface is cleaned in the manner described above we find that the rate of spreading fall on the curve showing the rate as a function of viscosity for mineral oils (See accompanying diagram 8839-84. However, glycerin does not spread even on a clean metal surface.

It has been shown, therefore, that for fatty oils as well as mineral oils (with a slight exception for linseed oil) the spreading rate in the presence of a temperature gradient is a function of the viscosity at the temperature used

PLANS FOR FURTHER INVESTIGATION

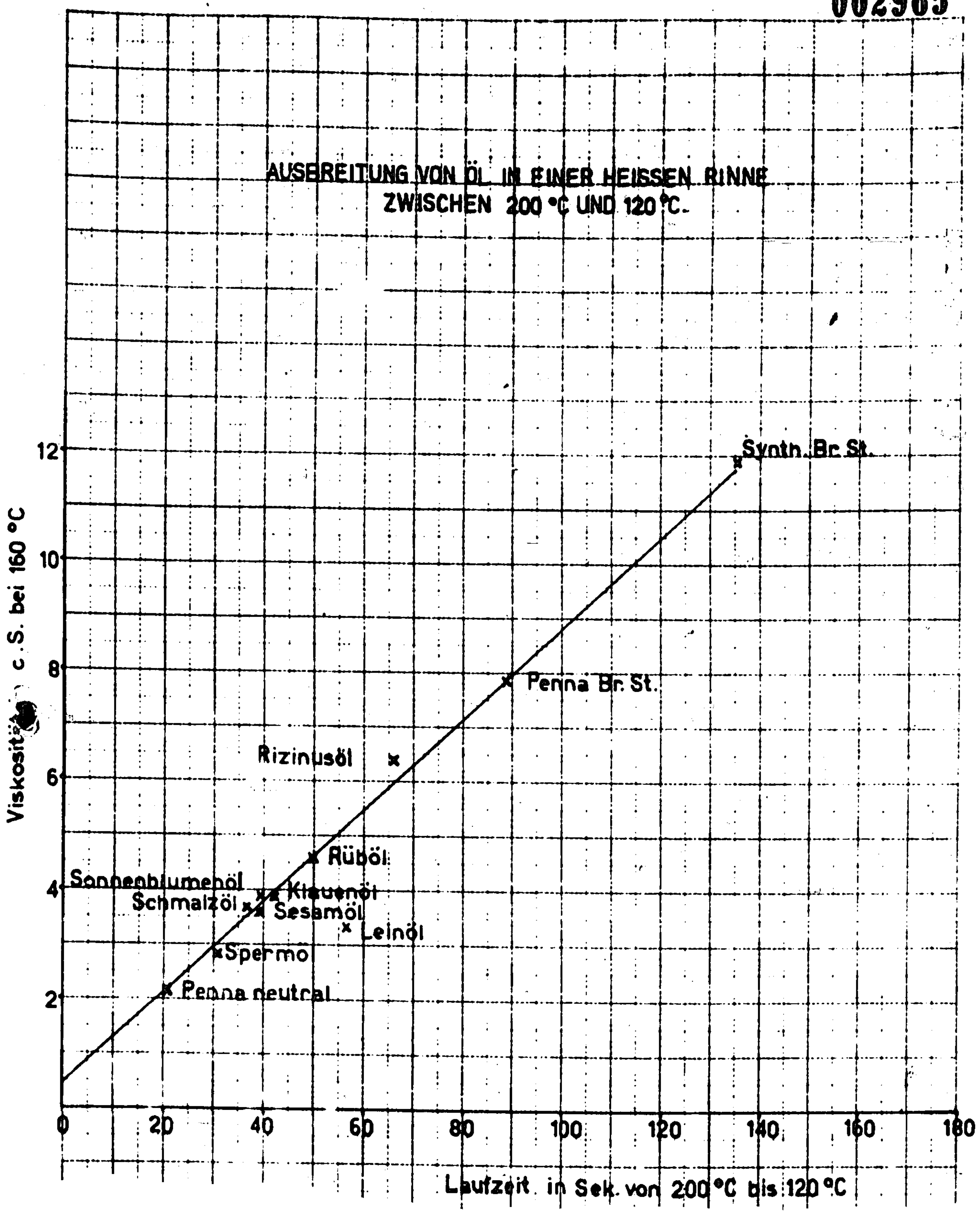
Although the above conclusions are of little practical interest for further investigation we shall, nevertheless, attempt to see whether we can find some explanation as to the cause for spreading when a temperature gradient exists.

Fig. 5809-B4

2965

SPREADING OF OIL IN A HOT GROOVE
BETWEEN 200 C AND 120 C

002965


AUSBREITUNG VON ÖL IN EINER HEISSEN RINNE ZWISCHEN 200 °C UND 120 °C.

CORROSION

We carried out a number of experiments with various temperatures and loads with Double Shell and Double Shell + 1 per cent oleic acid to determine the optimum conditions for observing normal corrosion.

Tests are being continued.

				Corrosion in mg after a testing time of 3 hours (ave. of 4 trials)	
				Double Shell	D.S. + 1% oleic acid
Temperature	110 C	load	5.5 kg	0.1	8
"	110 C	"	17.5 "	0.	12
"	130 C	"	5.5 "	0.8	10
"	130 C	"	17.5 "	0.6	11,15

August 1943

OXIDATION RESISTANCE

2972

After making the changes suggested in the report of the previous month we carried out some experiments with the oxidation apparatus. In one test, we filled all 8 cups with Penna Bright Stock. At a temperature of 250 C (measured immediately below the surface of the cup) a considerable time (> 20 hours) was required before the oil was thickened sufficiently to be measurable by means of a slight displacement of the rotating ball. After 20 hours the experiment was stopped. It was shown that the loss due to evaporation was 20-40 per cent. The cold oil was very thick, still, it contained no components insoluble in 60/70 benzine.

It was seen in these tests that the temperature of the various cups differed considerably (up to 15 C). These differences become even greater when a cup temperature of 300 C was used. At this temperature the oil thickened to the point where the ball was hardly displaced after 10 hours. The thickening differed in the various cups, however, probably due to temperature differences. In the above tests the oil crept over the edge of the cups.

PLANS FOR FURTHER WORK

We shall attempt to eliminate the temperature differences between the various cups. The deviations of the rotating ball will be standarized against oils of known viscosity. The cups will be provided with a higher rim.

SPREADING OVER HOT METAL SURFACES

The experiments on spreading reported last month showed that glycerin did not spread, even on a clean metal surface. Also no spreading was evident with water (at temperatures between 20 and 80 C). It is peculiar that these two liquids do not wet metal sufficiently regardless of how 2973 carefully the metal is cleaned. In both cases one can establish a large angle of contact. Also from the literature it is known that it is very difficult to attain a small angle of contact.

For the other oils we investigated the contact angle is very nearly zero with the cast iron. We attempted, therefore, to improve the wetting properties of glycerine and water by adding 0.1 per cent by weight of an ester salt. We thus obtained a decidedly smaller angle of contact between glycerin and water respectively with cast iron than without the addition. The drops placed in the groove spread slightly more now also; however, spreading from higher to lower temperature did not occur.

Therefore we cannot say whether the lack of spreading of glycerin and water when a temperature gradient exists is due to insufficient wetting of the metal or whether other factors play a part.

One might suppose that the spreading would be influenced by a difference in the specific gravity of a fluid in the drops as a result of the temperature gradient. This point could be shown by taking a fluid whose specific gravity increased with increasing temperature. For this purpose water at a temperature below 4 C was considered. However, because we did not succeed in wetting the metal sufficiently, we could not carry out this experiment.

PLANS FOR FURTHER INVESTIGATION

Since a further investigation to determine the driving force which causes spreading of oils over hot metal surfaces involves much work and would, on the other hand, be of little practical importance, we shall cease work on it for the present.

CORROSION 2974

The experiments with the bearing corrosion apparatus were continued, and resulted in the following data:

						Corrosion in mg after 3 hours in test	
						Double Shell	Some + 1% oleic acid
Temp.	110	C	load	5.5	kg.	0.1	8
"	110	"	"	17.5	"	0.0	12
"	110	"	"	37.5	"	0.7	11
"	130	"	"	5.5	"	0.8	10
"	130	"	"	17.5	"	0.6	11,15
"	130	"	"	37.5	"	0.4	10,16
"	150	"	"	5.5	"	0.0	19
"	150	"	"	17.5	"	0.1	13
"	150	"	"	37.5	"	0.6	27,34

From these experiments it is seen that changes in temperature between 110 and 150 C and loads up to 17.5 have little influence on corrosion.

We propose therefore to standarize corrosion experiments with a load of 17.5 kg (about 4.4 kg/cm^2) and a temperature of 130 C.

Under these conditions the effect of the test time was also investigated. It was shown that almost no corrosion differences occurred when oil containing 1 per cent oleic acid was run for 1 to 6 hours, even with a synthetic oil. There was also no difference with this oil for test times of 3 and 6 hours so we standarized the time at 3 hours.

PLANS FOR FURTHER INVESTIGATION

Some mineral and fatty oils will be investigated by this method.

September 1943 2981

OXIDATION RESISTANCE

In the past month new aluminum cups with high rims were finished at the same time a number of cast iron cups of the same shape were obtained. It was found that the higher rim hindered sufficiently the creeping of oil over the edge.

We tried further to correlate the viscosity of the oil with the diameter of the track made by the ball. This diameter as would be expected depended on how full the cups were. By using over 10 cm^3 this effect was small. For several oils the following diameters at 25 C were obtained:

viscosity. The reproducibility of the determinations is also much worse with these than with the other oils.

PLANS FOR FURTHER INVESTIGATION

We shall investigate whether the deviations of several fatty oils can be attributed to oxidation.

CORROSION

As is well known, many lubricants cause serious corrosion when bearing metals of lead-bronze or cadmuim-nickel are used in the motor. Although the type of lubricants used is in general not harmful, if the bearings do not contain elements that are easily attacked, it seemed desirable in the development of new lubricants to take into consideration their behavior toward Cd and Pb.

We knew from experience that tests in which a piece of bearing metal was placed for a definite time in the test lubricant could lead to erroneous conclusions. For these reasons an apparatus was designed which is given schematically in the report of June 1942. This apparatus has been completed in a somewhat modified form (See Fig. No. 19563 A-3).

It consists essentially of a rotating steel ring against which a piece of Cd-Ni bearing metal is pressed. The whole is placed in a closed housing into which the oil sample can be introduced.

Since in the preparation of materials which shall serve as special oils, only a small amount is available for research, the apparatus is designed so that a sample of 5-10 cc is sufficient to test for corrosion of Cd-Ni.

Several orientation tests were made with this apparatus in which a mineral oil with and without the addition of 1 per cent by weight of oleic acid was used.

It was shown that a felt ring was not sufficient to make the test chamber tight, and that too much of the originally small sample leaked out. This resulted in rather bad agreement between the corrosion numbers of the four series of experiments. After testing a number of ways for making the chamber tight, the simplest solution proved to be to remove the ring and to make a groove in the room provided for the felt ring which caused the oil to flow back.