SOME EXPERIMENTS ON LUBRICATION.

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[*Selected for Publication.*]

The experiments described in this Paper were undertaken as the commencement of an attempt to determine how far some of the mechanical properties of a Lubricant might influence its selection for a particular purpose.

It was recognized at the outset that the field of investigation which the authors were about to explore was a very extensive one, containing lubricants ranging from semi-solid grease down to the lightest spindle oils, while the methods of application of the lubricant and the conditions of operation had also to be considered. The experiments were found in most cases to be long and tedious, so that the actual ground already covered by the authors is only a comparatively small part of the whole field of investigation; but as it was found that the resumption of the experiments could not take place for a very considerable time, it was thought that the results so far obtained might be of some interest.

Professor Osborne Reynolds first gave the theory of the lubrication of a journal, but his analysis is too unwieldy to render the authors much assistance in the present investigation, except as a finger-post here and there. They felt it was probable that a near approach to actual facts might be obtained by the application of elementary principles and a reasonable amount of approximation based upon the result of experiment, and they believe that they have not been unsuccessful along these lines.

As the viscosity of an oil plays such an important part in the action of a lubricant it was thought desirable to determine this

FIG. 1.—Oils used in the Experiments.

Curved lines = Viscosity. Straight lines = Specific Gravity.

for each oil to be used in the experiments, over as wide a range of temperature as will be found in any bearing working under normal conditions. A Redwood's standard viscometer was used.

The oils used in these experiments were: (1) heavy engine oil; (2) engine oil; (3) gas-engine oil; (4) lard oil; (5) olive oil; and (6) sperm oil.

Curves of viscosity and specific gravity for the above oils are given in Fig. 1. The specific gravity was determined with an ordinary glass hydrometer of variable immersion graduated on the stem. The specific gravity curves are straight and nearly parallel. The temperatures are on the Fahrenheit scale.

FIG. 2.—Relation between Viscosity and Temperature.

The viscosity of an oil in foot-lb. and second units is given by:—

$$0.000005125 T \delta$$

where T = time in seconds required for 50 cubic centimetres to flow out of the viscometer,

and δ = specific gravity of oil.

What is known as the commercial viscosity of an oil is obtained by replacing the constant 0.000005125 by 0.205 in the above expression.

It was expected that an algebraical relation between viscosity and temperature would be necessary later, so an attempt was

FIG. 3.—*Relation between Logarithms of Viscosity and Temperature.*

made to obtain one. The transcendental relation obtained by Professor Osborne Reynolds is a little cumbersome. Dr. Nicolson has suggested the relation :—

FIG. 4.—Relation between Logarithms of Viscosity and Temperature.

$$V = \frac{A}{t - t_0} \quad . \quad . \quad . \quad . \quad (1)$$

where t represents the temperature of the oil, V the viscosity, and A and t_0 constants.

This was tested by re-writing the equation in the form :—

$$t = t_0 + \frac{A}{V}$$

and plotting t and the reciprocal of V . The result is shown in Fig. 2 (page 495) for sperm oil and heavy engine oil. It will be seen that the former can be represented by equation (1) but that the latter cannot be so represented. The equation is not then generally applicable to lubricants.

The equation—

$$V = a t^n \quad (2)$$

was next tried by plotting the logarithms of viscosities and temperatures, a and n being constants. It was found that in each case the plotted points lay on a line or two intersecting straight lines. These graphs are shown in Figs. 3 and 4, and the algebraical relations are given in the following Table, the units being lb. and feet, and the range of temperature from 60° F. to 200° F.

TABLE 1.—*Viscosity Constants.*

Kind of Oil.	Absolute Viscosity in lb. and ft. units.
<i>Heavy Engine Oil</i>	
Between 60° and 200° F.	$V = 1786 t^{-2.91}$
<i>Engine Oil</i>	
Between 60° and 150° F.	$V = 3700 t^{-3.16}$
„ 150° and 200° F.	$V = 1591 t^{-2.976}$
<i>Gas-Engine Oil</i>	
Between 60° and 140° F.	$V = 114 t^{-2.566}$
„ 140° and 200° F.	$V = 0.47 t^{-1.45}$
<i>Pure Lard Oil</i>	
Between 60° and 140° F.	$V = 10.86 t^{-2.06}$
„ 140° and 200° F.	$V = 1.49 t^{-1.66}$
<i>Olive Oil</i>	
Between 60° and 140° F.	$V = 3.03 t^{-1.89}$
„ 140° and 200° F.	$V = 0.176 t^{-1.245}$
<i>Sperm Oil</i>	
Between 60° and 125° F.	$V = 12.59 t^{-2.164}$
„ 125° and 200° F.	$V = 0.317 t^{-1.404}$

Resistance of the Oil in a Bearing.—If the oil film in a bearing were of uniform thickness, and the bearing of infinite diameter and length, a small portion of the former could be represented in section as in Fig. 5, where the thickness of the film is designated by y feet. The area in contact with either the journal or the brass may be represented by A square feet, and the velocity of the journal relative to the brass by v feet per second from right to left. This motion will shear the film of oil, and the resistance offered to the motion will be $\frac{A V v}{y}$ lb., V being the absolute viscosity of the lubricant in feet and seconds units.

FIG. 5.—Resistance offered by a Film of Oil.

It will be convenient to consider the area of contact A as 1 square foot, and then the resistance may be expressed as:—

$$\frac{Vv}{y} \text{ lb. per square foot} = R \text{ say} \quad (3)$$

Now the surface of the journal is not exactly but is nearly parallel to that of the brass, and therefore the above will only hold for a small element of the film. But if the variation of the thickness of the oil film is not serious there might be some average or equivalent average thickness which could be inserted in equation (3).

This equivalent value of y in any particular case will probably depend to a certain extent upon the shape and dimensions of the

brass and upon v and t . By running a journal in a bearing at a measured constant temperature, varying speed and measuring the resistance at the surface of the journal, the effect of speed upon the thickness y can be obtained. This was done with the six oils

FIG. 6.—*Moments of Resistance of the six Oils used.*

previously mentioned, the temperature being maintained at 90° F., and the pressure on the projected area of the bearing being 45 lb. per square inch. The moments of the resistance are given in Fig. 6 for the six oils used.

Inserting the viscosity of an oil at the temperature of the bearing in equation (3), together with the observed speed and

resistance, the value of the equivalent average thickness of the oil film may be calculated for that speed. Plotting these calculated values of y on a speed base we have the curves in Figs. 7 and 8 (pages 502-3). These again are either single straight lines or pairs of intersecting straight lines, indicating that the equivalent thickness of the film is proportional to the surface speed at constant temperature, and can be represented by an equation of the form:—

$$y = j + h v \quad . \quad . \quad . \quad . \quad (4)$$

or by two equations in which j and h have different values, the change taking place between 4 and 7 feet per second. The values of j and h for the bush bearing used by the authors are given in Table 2 in feet-units, the resistance being measured in lb. per square foot of journal surface.

TABLE 2.

Kind of Oil.	j	h
<i>Heavy Engine Oil</i>		
Between 1 and 6.3 ft. per sec. . .	0.000038	0.00001283
„ 6.3 and 8.5 „ „ . .	0.0000605	0.00000927
<i>Engine Oil</i>		
Between 1 and 5.5 ft. per sec. . .	0.000031	0.00001
„ 5.5 and 9.0 „ „ . .	0.0000445	0.0000075
<i>Gas-Engine Oil</i>		
Between 2.5 and 9.5 ft. per sec. . .	0.000031	0.00000589
<i>Pure Lard Oil</i>		
Between 3 and 4.5 ft. per sec. . .	0.0000283	0.00000395
„ 4.5 and 9 „ „ . .	0.0000319	0.00000529
<i>Olive Oil</i>		
Between 3 and 7.3 ft. per sec. . .	0.0000328	0.00000443
„ 7.3 and 9.5 „ „ . .	0.0000455	0.00000268
<i>Sperm Oil</i>		
Between 2.5 and 9.5 ft. per sec. . .	0.0000283	0.00000395

FIG. 7.

Relation between Velocity of Rubbing Surfaces and Thickness of Oil Film.

The journal used for the above experiments was 3 centimetres in diameter and 5 centimetres long, and was loaded with a pair of equal fly-wheels as shown in Figs. 9 and 10 (page 504). It ran in a ring-lubricated bush-bearing. The oil reservoir was of ample dimensions and contained a horseshoe pipe through which water could be circulated for the purpose of controlling the temperature of the oil.

FIG. 8.

Relation between Velocity of Rubbing Surfaces and Thickness of Oil Film.

The reservoir could also be heated by a gas flame, and the temperature of the oil raised to considerably over 200° F. if necessary. An electric heating coil is also shown in Fig. 9, but gas was used in the author's experiments. The temperature of

Ring-lubricated bush-bearing 3 cm. $\times$ 5 cm. used in the experiments.

FIG. 9.

FIG. 10.

the oil in the reservoir was measured by a thermometer suspended in the oil. This was the weak spot in the experiment, for the temperature of the oil film in the bearing was probably a few degrees higher than that in the reservoir. As however it is difficult to measure the actual temperature of the film, that of the oil in the reservoir will be sufficient for this particular kind of bearing if the results are used in connection with a bearing of similar design.

The spindle was driven by a couple of dowel pins in the boss of the right wheel, the pins being fixed in a flange on the shaft of a small electric motor. As originally made by Messrs. Lahmeyer,

FIG. 11.—*Method of supporting the Motor.*

the motor was rigidly fixed to the bed-plate of the bearing, Fig 11, and there was no means of directly measuring the moment of resistance of the bearing. The authors removed the feet of the motor so as to make it symmetrical about its axis, and mounted the motor on rollers as shown in Fig. 11, the outer surface of the *bearings* of the motor resting upon the rollers, the former having been previously smoothed. The holes in the rollers were made larger than the pins upon which they were threaded, so that there was chiefly rolling- instead of rubbing-friction there. This made the motor very sensitive, and as the torque measured is that transmitted to the fly-wheels (the losses in the motor not being measured) the contrivance proved admirably adapted for the

purpose of getting journal-friction, except that it included the air-resistance experienced by the wheels.

As the air-resistance would be the same for different oils, some sort of comparison could be made. The torque was measured by the dead weight J on the graduated arm A , or by a sensitive spring balance at S . The transverse section of the journal and oil reservoir is shown in Fig. 9. The torque-speed curves at constant temperature are shown in Fig. 6 (page 500).

It was thought that the thickness of the oil film would also probably depend upon its temperature, and then the equivalent thickness of the film could be represented by

$$(j + hv) \times \phi(t) \quad . \quad . \quad . \quad (5)$$

where $\phi(t)$ represents some function of the temperature of the oil film. If this were so, equation (3) could be rewritten as

$$\begin{aligned} \phi(t) &= \frac{V v}{R(j + hv)} \\ &= \frac{A v}{t^n R(j + hv)} \quad . \quad . \quad . \quad (6) \end{aligned}$$

where A is the coefficient of T in equation (2), and n is positive.

A series of experiments was next carried out on the same machine, in which the temperature was varied at a constant speed of 7.21 feet per second by artificially heating or cooling the oil in the reservoir. The results are shown by the curves in Fig. 12.

It was found that, within the scope of the experiments, heavy engine oil gave

$$\phi(t) = r t^{-1.83}$$

where r is a constant.

After inserting this in equation (6) we find that

$$R = \frac{q v}{(j + hv) t^{1.08}} \quad . \quad . \quad (8)$$

when q is constant.

As the exponent of t in equation (8) is not far removed from unity an expression containing a linear function of t in the denominator was tried, namely—

FIG. 12.

Relation between Temperature of Oil and Torque.

FIG. 13.
Graphs for three of the Oils used.

$$R = \frac{m v}{(j + h v)(t - t_0)} \quad . \quad . \quad (9)$$

where m and t_0 are constants.

Rewriting the equation in the form

$$t = t_0 + \frac{m v}{R(j + h v)} \quad . \quad . \quad (9a)$$

it will be seen that as j , h and v are constants for the variable temperature experiments, if the corresponding values of t and the reciprocal of R be plotted and equation (9) does represent the quantities derived from experiment, the resulting graph will be a straight line, in which t_0 is the intercept on the vertical axis and $\frac{m v}{j + h v}$ is the slope of the line.

FIG. 14.
Graphs for three of the Oils used.

Figs. 13 and 14 give the graphs for the six oils used, and the points belonging to each oil are situated approximately upon a straight line or upon two intersecting straight lines.

To avoid the large number of decimal places in j and h , the slope $\frac{mv}{j + hv}$ has been written as

$$\frac{\frac{m}{h}}{\frac{j}{hv} + 1}.$$

It must be observed that in general there are a critical speed and a critical temperature corresponding to the intersections of the lines, so that a journal may be running: (1) below the critical

speed and below the critical temperature; (2) above the critical speed and below the critical temperature; (3) below the critical speed and above the critical temperature, and (4) above the critical speed and above the critical temperature. This will require four different values for $\frac{m}{h}$. The different constants for the oils used are given in Table 3.

The investigation up to this point shows that the resistance of an oil at a given temperature and surface speed can be represented by equation (9), and the constants in Table 3 when the pressure is constant and equal to 45 lb. per square inch of projected area.

It should be observed that in actual practice there is no special control of the oil-temperature in the reservoir, and that it will go on increasing until the radiation balances the generation of heat. This is what the authors have called the *steady* condition of a bearing, and is the one that needs careful consideration on account of its prevalence in practice. The steady temperature will depend chiefly upon the speed, and its value can be obtained by simply running a journal until the temperature becomes steady. With the bush-bearing machine illustrated in Figs. 9-11 (pages 504-5) this took a long time to bring about, and at the higher speeds it was often two or three hours before the steady temperature was obtained.

If the value of the steady temperature corresponding to a variety of speeds be observed, and an equation obtained which will connect these two quantities, the value of the steady temperature t_s can be inserted in equation (9), and an equation obtained which will give the resistance R_s under steady conditions corresponding to actual practice.

There is a little difficulty in obtaining this equation, from the fact that the resistance will depend upon the actual temperature and the radiation upon the difference between the temperature of the oil reservoir and that of the atmosphere, the latter not being constant from day to day. Also the radiating capacity of a bearing will depend upon its size and design.

An experiment was carried out upon the machine shown in Figs. 9-11, using gas-engine oil, with the result shown by the

TABLE 3.
Bush-Bearing Constants.

Kind of Oil.	Limiting Speeds in ft. per sec.	Limiting Temperature ° F.	m .	$\frac{m}{h}$	t_w .	Slope in Eq. 10.	j .	h .
Heavy engine oil . . .	Below 6.3	Below 186	0.2649	20,650	18	15,000	0.000038	0.00001283
	Above 6.3	Above 186	0.1993	21,500	60	11,285	0.0000605	0.00000927
	„ 6.3	Below 186	0.2649	28,580	18	15,000	0.0000605	0.00000927
	Below 6.3	Above 186	0.1993	15,540	60	11,285	0.000038	0.00001283
Engine oil . . .	Below 5.5	Below 140	0.1694	16,940	21	12,400	0.000031	0.00001
	Above 5.5	„ 140	0.1694	22,590	21	12,400	0.0000445	0.0000075
	„ 5.5	Above 140	0.09765	13,020	67	7,570	0.0000445	0.0000075
	Below 5.5	„ 140	0.09765	9,765	67	7,570	0.000031	0.00001
Gas-engine oil . . .	{ Between 2.5 and 9.5 }	Below 176	0.08466	14,370	14	8,306	0.000031	0.00000589
		Above 176	0.1513	25,690	-96	14,850		
Lard oil . . .	{ Below 4.5 Above 4.5 }	Below 200	0.0888	22,480	12	9,145	0.0000283	0.00000395
		„ 200	0.0888	16,780	12	9,145	0.0000319	0.00000529
Olive oil . . .	{ Below 7.3 Above 7.3 }	Below 180	0.0803	18,170	8	8,956	0.0000328	0.00000443
		„ 180	0.0803	21,530	8	8,956	0.0000455	0.00000268
Sperm oil . . .	{ Between 2.5 and 9.5 }	Below 180	0.0548	13,860	28	6,952	0.0000283	0.00000395

FIG. 15.

Experiment on Machine (page 504) with Gas-Engine Oil, showing rise of steady temperature and resistance plotted on a speed base.

dots about the lower curve in Fig. 15, where the rise of *steady* temperature above that of the laboratory has been plotted on a speed base. The equation which best fitted the results was found to be of the form—

$$\text{Rise of steady temperature} = Uv^w$$

$$\text{or} \quad t_s = Uv^w + z \quad . \quad . \quad . \quad . \quad (11)$$

where $U = 3.5$, $w = 0.83$ and $z =$ the temperature of the laboratory, when gas-engine oil was used.

The curve has been plotted from equation (11) and fits the observed points well except the three situated between 2 and 4 feet per second. These latter were afterwards discovered to have been wrongly observed.

Inserting the value of t , obtained by equation (11) in equation (9), and calculating the resistance per square foot of journal surface, the upper curve in Fig. 15 is obtained.

The dots indicate the observations. The form of the curve agrees well with the observations, but its position is slightly high.

Split Bearing.—The authors next required to ascertain if a split bearing behaved in the same manner as the bush-bearing and conformed to the same relationships between resistance, speed, temperature, and pressure.

The machine used was of a simple character and is shown in Figs. 16 and 17 (pages 514–5). The brasses were held between a pair of equal levers, the pressure being put on by a spiral spring and hand-wheel, the system resembling in principle a pair of nut-crackers. This arrangement is unlike an ordinary bearing in so far that the pressure is simultaneously applied to both brasses, whereas one brass only is subject to pressure at any instant in an ordinary bearing. This difference will tend to produce a difference between the results actually obtained and those which might be obtained in everyday work. The arrangement was adopted because it enabled the pressure to be easily varied and the journal and brasses to be easily cleaned. At the same time the pressure was not transferred to the shaft bearings. The resistance occurring in this bearing will be double of that measured by Mr. Beauchamp Tower, and will be considerably greater than the resistance of a bush-bearing though not equal to twice that amount.

The test journal-spindle was supported in a couple of specially constructed roller swivel-bearings and was belt-driven from a countershaft or from an electric motor direct; the arrangement permitted of a range of speed from 10 revolutions per minute to about 1,500 revolutions per minute. The journal was 2 inches in diameter and 2 inches long. Views of the brasses are shown in

FIG. 16.
Oil Tester.

Fig. 17. The oil was fed from a sight-feed lubricator by a copper pipe to the on side of the upper brass, and guard-plates A were soldered to the brasses at the joints to prevent the oil from running to waste over the levers and to prevent dust from entering the bearing. As the oil could not easily get away except by being squeezed out at the ends of the journal, and as in all but a few special experiments the oil was supplied liberally, the conditions approximated to what is known as *bath* lubrication, and was

Fig. 17.
Arrangement of Brasses, Oil Tester (page 514).

certainly as good as the best ring-lubrication. The oil that was squeezed out at the journal ends was thrown into troughs B at the ends of the brasses, and drained away into a receptacle in the base of the machine. Oil was never used over again.

The brasses were bedded in the usual manner and then run right through the experiments, the direction of rotation being constant as it generally is in actual practice.

The levers were supported near their centre of gravity by a shackle attached to a graduated lever. The whole lever system

was balanced with the jockey weight at zero by adjusting the balance-weight. A fine pointer fixed to the bracket A was made to coincide with a line scribed on the lever before any observations were made. The resistance of the bearing could be balanced by shifting the jockey-weight along the lever, but it was found that a very delicate spring-balance attached to the shackle was much more satisfactory to use. Fifths of an ounce could be read on the balance, and the thumb-screw permitted a rapid and fine adjustment of the lever system to the zero position before reading the balance. The mean temperature of the bearing was obtained by a pair of thermometers x , Fig. 17. These never differed from one another by more than a fraction of a degree.

The construction of the test bearing of the machine in question did not permit of artificial heating or any control of temperature at all; in fact, it could only behave like an ordinary bearing. For this reason it was impossible to repeat the bush-bearing experiments; but it was an easy matter to run the journal until the bearing attained a steady temperature, and then observe the resistance and temperature at a given speed. If the average thickness of the oil-film varied as the speed, as it did in the bush bearing, then equation (9) would still represent the relation between resistance speed and temperature; but the value of m would probably be somewhat different from that found for the bush-bearing. The speed and resistance could be inserted in equation (9a), and the temperatures and values of $R(\frac{j}{hv} + 1)$ plotted.

If the above assumption were correct, the resulting graph would be straight.

This was tested with the three heaviest oils. It will be convenient to write x for $R(\frac{j}{hv} + 1)$, then equation (9a) can be written as

$$t_s = t_o + \frac{m}{h} x \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad (12)$$

Fig. 18.

Graphs of the three heaviest Oils.

The resulting graphs are shown in Fig. 18, and it will be seen that they are practically straight and may be represented by the equations—

FIG. 19.

*Actual Observations of Speed, Resistance, and Temperature of
the three heaviest Oils under steady conditions.*

$$\text{Heavy Engine Oil up to } 2.7 \text{ ft. per sec. } R = \frac{27000 v}{\left(\frac{j}{h} + v\right) (t_s - 48)}$$

$$\text{above } 2.7 \text{ ft. per sec. } R = \frac{15250 v}{\left(\frac{j}{h} + v\right) (t_s - 70)}$$

$$\text{Engine Oil above } 2.3 \text{ ft. per sec. } R = \frac{13880 v}{\left(\frac{j}{h} + v\right) (t_s - 41)}$$

$$\text{Gas-Engine Oil up to } 2 \text{ ft. per sec. } R = \frac{11840 v}{\left(\frac{j}{h} + v\right) (t_s - 45)}$$

$$\text{above } 2 \text{ ft. per sec. } R = \frac{5640 v}{\left(\frac{j}{h} + v\right) (t_s - 67)}$$

(13)

FIG. 20.

Relation between Logarithms of Speed and Rise of Temperature.

The pressure on each brass of the bearing was 250 lb. per square inch of projected area. The surface speed was varied between 0.35 foot and 13 feet per second. The actual observations have been plotted in Fig. 19.

TABLE 4.

Split Bearing under Steady Conditions. Gas-Engine Oil.

Pressure = 250 lb. per square inch of projected area.

v ft. per sec.	t_o ° F. of room.	t_r calcu- lated	t_r observed.	t_s calcu- lated.	R_s calcu- lated.	R_s observed.
0.75	66.2	5.3	5.5	71.5	55.8	55.8
1.31	65.8	9.2	7.5	75	79.2	79.9
1.92	64	13.4	13	77.4	97.9	98.1
2.54	72.5	17.6	18	89.1	83	84.4
3.93	73	26.7	26.4	99.7	73.4	70.9
5.38	77.2	33.7	32.6	110.9	65	66.4
6.52	78.1	39.3	39.3	117.4	61.7	62.5
7.95	79	45.5	46.5	124.5	59	61.5
9.44	74.8	51.9	52.5	126.7	61	60.4
11.02	71	58.6	58.4	129.6	61.3	61.1
12.85	69.5	65.8	63.2	135.3	59	60.4

It was unfortunate that the temperature of the laboratory could not be maintained more nearly constant. The effect of the temperature of the room is greater than would at first sight be imagined.

The character of the curves of resistance in Fig. 19 indicates that at the higher speeds the resistance does not vary very much. This has previously been noted by Lasche. There are critical speeds at which the law of resistance changes.

Variation of Pressure.—Experiments were next carried out at constant speed and the pressure on the journal was increased step by step, the temperature at each step being permitted to rise to a steady value before the resistance was observed.

The effect of pressure is somewhat peculiar. There appears to be a critical pressure below which the resistance increases very rapidly with the pressure, and above which the resistance first decreases a little and then increases much more slowly as the pressure is increased. At the critical pressure the resistance appears to vary considerably. The pressures at which the experiments were carried out were at some distance on either side of the critical pressure. The authors' experiments on the variation of pressure were not sufficiently exhaustive to place on record in this Paper. The same may be said of some other experiments for the purpose of studying the durability of a lubricant.

Conclusions.

- (1) With profuse or bath lubrication, constant temperature and load on the bearing, the actual curved film of oil of variable thickness can, for the purpose of calculation, be replaced by a plane film of uniform thickness and the same length and breadth as the curved film. The thickness of the equivalent plane film varies directly as the journal speed. It is convenient to refer to this as the equivalent thickness of the oil film. It is the y in equation (3).
- (2) When the temperature of the bearing is artificially varied at constant speed, the equivalent thickness of the oil film varies inversely as some function of the temperature.
- (3) As regards its influence on resistance, the temperature effect upon the equivalent thickness of the oil film tends to cancel some of the temperature effect upon the viscosity, with the result that the resistance per unit area of journal surface varies as the surface speed and inversely as the temperature and inversely as a quantity, which is a linear function of the speed (*see* equation (9)).

- (4) Under the actual conditions of working, where the temperature is uncontrolled by artificial means, the resistance per unit area can be expressed in the manner described in item 3 when the expression for the final steady temperature is inserted (*see* equation (15)). The rise of the temperature is proportional to some power of the speed (*see* equation (14)).
- (5) There are some critical values of the speed, temperature, and viscosity of the oils.
- (6) The resistance of a bush-bearing obeys the same laws as that of a split-bearing, but the constants in the corresponding equations are different.
- (7) The pressure per unit area has very considerable influence on the resistance at low pressures and less influence at higher pressures after a critical pressure has been reached.

The experiments described in this Paper were carried out in the Mechanical Engineering Laboratory of the South Western Polytechnic Institute, Chelsea.

The Paper is illustrated by 20 Figs. in the letterpress.