sing the smoothness of bearing surfaces—that is, by filling up the minute depressions that always exist on such surfaces. Ordinary graphite is apt to settle out of its fluid carrier, and causes trouble by accumulating in bearings, also by quenching the spark in oil engines.

Deflocculated graphite, as discovered by Dr. Acheson, has the useful property of remaining suspended in oil or water for an indefinite period. In a bearing under a pressure of 70 lbs. per square inch, and lubricated with aqueous deflocculated graphite, a co-efficient of friction of .01 was maintained over an extended trial. Its discoverer, experimenting with a Panhard car, claimed that the addition of his graphite to the cylinder oil reduced the oil consumption from 1 gallon per 200 miles to 1 gallon per 750 miles.

Further experiments with this lubricant may be looked forward to with interest, especially as it promises to assist in the solution of the most difficult of all lubricating problems, the lubrication of the cylinders of internal combustion engines.

Bibliography:—

(a) *Lubrication and Lubricants*—Archbutt and Deeley.

(b) *Lubricating Oils, Fats and Greases*—Hurst.

(c) *Petroleum and its Products*—Sir Boverton Redwood.

Discussion.

Mr. A. W. Tournay-Hinde (in proposing a vote of thanks to the lecturer) said: I feel sure that all of us have listened with very much interest indeed to Mr. McEwin's paper on lubrication. Lubrication, although it is a subject to which every engineer has, necessarily, to give attention, is probably one of the most vexed and most discussed subjects amongst us. So far as my knowledge goes, there is no really good text-book published on lubrication, that treats the matter from an engineer's standpoint, or is, one may say, of material use to the engineer in his daily work, or practice. I hope Mr. McEwin will not mind my saying that his paper on Lubrication seems to me to fall into the same category as the text-books. All of us who have been up alongside a hot bearing, where one had to keep the job running, have thought frequenly of what has been suggested in text-books, or what one has read, but the application of it at such times of stress never seems to have any very effective result. No doubt, the general theory of Lubrication is, of course, correct, but owing to the impossibility of working with the degree of mathematical accuracy necessary to provide the proper shaped film of oil, or sometimes owing to having to ask the machine to do more than it is intended to do, lubrication takes on quite a different aspect.

I am inclined to think that Lubrication does not necessarily depend entirely on oil, but, to some extent, also, on the design of the bearing; hence, varying results may be had with the same oil; that is possibly why certain oils seem to suit certain jobs, although, theoretically, they they should not do so.

Taking Table 1, which the author has inserted in his paper, this gives various metals of which the bearing and shaft may be composed, with the admissible working load per square inch, respectively. The particulars given as to the admissible load under the conditions of contact there stated, should be, I think, subject to the correction that they are only true at some defined speed. With lower speeds the pressure may be higher, and with higher speeds the pressure may be lower. Take the case of a large, heavy bearing, revolving, possibly, six or seven revolutions per minute; such as a bearing carrying a pair of heavy crushing rolls, used for crushing ore or sugar; the pressure per square inch on the bearing is usually very much higher than that given in the Table. On the other hand, if you take weaving spindles, dynamo bearings, or turbine bearings, the converse is true, and the pressures per square inch usually met with in practice are lower than shown in the Table which the author gives in the paper.

In connection with this table, the author does not state what portion of the semi-circular half of the bearing is to be computed as the area upon which the pressure is presumed to act, and which is to be taken into consideration in determining the pressure per square inch. It is obvious that it would vary considerably according to the circumferential length of the shell included. I should like to know if Mr. McEwin has any data that would suggest whether one-third of the circumference, or two-fifths ,should be taken into consideration in computing the area of the bearing, as carrying the load. I remember a large heavy fan running where the pressures on the bearing were well within the limits; the bearings were of anti-friction metal, viz., white metal—lead with a little tin and antimony—not a zinc white metal; and considerable difficulty was experienced in keeping the bearings cool. It was hardly a question of alignment or poor fit, because at every possible opportunity we had we endeavoured to ease them. Ultimately the white metal shells were replaced with gun-metal ones, and they ran satisfactorily. There is no very obvious reason why the gun-metal bearing in this case should operate better than the other.

The next thing which arrested my attention during the reading of the paper, was Figure 2. In Figure 2 the author shows on the left-hand side of the figure an axle bearing; the direction or rotation is such that the car—I take it to be the axle bearing of a truck, or railway carriage—is moving towards the left of the diagram. Now, in the case of a railway carriage, the bearing virtually pushes the axle along, and therefore the pressure between the axle and the bearing would be greatest on the right-hand side of the diagram, but yet the oil wedge is shown with the widest side on the right-hand side. It may be, owing to some conditions of which I am unaware, that the axle would so place itself within the bearing, but I rather fancy that the greater space would be on the left-hand side if the car were pushing the axle along. The oil wedge would probably be as shown in a self propelled tramcar where the axle propels the car. I would like Mr. McEwin, if he could, in his reply, to enlighten me a little more as to whether the condition shown does take place in a vehicle drawn after a locomotive, or some other source of traction.

The next note I have refers to Figure 4, which shows the author's excellent suggestion to make the faces of the slippers, on the crosshead slightly angular, so as to permit of an oil film. The suggestion seems to be quite feasible, but the thickness of the oil film, as stated in connection with the experiment made by the Westinghouse Co., is an infinitesimal portion of an inch—between .0019 and .00314 of an inch—and it would hardly be practicable to machine the slippers to this degree of accuracy. Possibly what takes place in an ordinary bearing with slippers, after the initial trouble of starting is got over, is that the slipper itself wears sufficiently to permit of the angular deviation shown by the author, and thus permits satisfactory lubrication to take place.

There is one matter in Table 2, "Specific Gravities of Various Oils at 60° F.," to which I would like to refer. I notice that the specific gravity of sperm oil is .882, and whale oil is .923. I do not quite know what is the difference between sperm oil and whale oil. I thought sperm oil came from the sperm whale—I am not quite sure if the sperm whale gives lighter oil than some other whales; I think possibly that that may be an error in the Table.

I now come to the question of testing of oils. In the testing of oils most of us, at some time or another, who have had to do with the buying of large quantities of oil for plants, have been at some difficulty to know by what means any particular tender for oils should be selected—whether it should be a question of the price, or whether some other means of testing should be used that would give a fair deal to the company concerned in purchasing the oil, and to the men who had to use it. Generally, all that seems to be done in most cases is to ask the men using the oil if the last oil has been satisfactory, and to accept their word for it. This can hardly be considered the proper way; at any rate it is not a scientific way. A reference to text-books makes the testing of oils appear to the average engineer as a complex subject. The difficulty is further enhanced in this way. The sum of money spent on oils in any concern in a year is not a large proportion of the total power costs, which in themselves are generally only 5 per cent. to 10 per cent. of the total working costs of a factory. The cost of oil would represent half per cent., or less, and sometimes it has occurred to me whether it is really worth worrying about, and yet the oil bill itself may amount to perhaps £100, or £200, a year, or more. Of two companies with similar plants, one concern may be able to get satisfactory oiling per year for £200, and the other one for £300, and there should certainly be some reason for the difference. In order to try and get a way out of the difficulty, some two or three years ago, I started off by attempting to test samples of oils with a machine something like the one shown on the screen this evening, and I at first, in my innocence, based purchases upon the results of the machine. Curiously enough, when the oils were put into use, the result appeared to be different from what those tests indicated it should have been. I came to the conclusion that this method would not do. My next move was to look up a lot of specifications of large companies buying oils —many being large American and English railway companies, and other concerns—and I noticed that they specified that the purchases were to be made subject to tests relating to viscosity, flash point, and sundry other tests of the nature that Mr. McEwin has referred to somewhat fully in his paper. When I started to draw up a specification for the purchase of oils on a similar basis, I was immediately met with this trouble, that nearly every oil firm used a different viscometer for testing. While one man might say the viscosity should be 560, another one will give a numerical figure of 840 for a precisely similar oil, simply because the viscometer for testing was of a different nature. There are, as Mr. McEwin has said, about a dozen different viscometers. Some are supposed to be the standard in some countries—in England you will find half-a-dozen different viscometers in use. To get over the trouble seemed rather difficult, because one would have to accept the viscosity as given by the sellers of the oils, but on thinking the matter over, it was evident that the viscosity simply amounts to this—it is merely a numerical method of stating the relative fluidity of the oil with water, or some other known and easily available fluid. In most cases rape oil is used as the standard, but even rape oil, if it is not absolutely pure, or supposing it was slightly decomposed, has a slightly different viscosity to when it is pure. To get over that trouble we came back to water, and we finally decided, after experimenting in the laboratory, to specify our viscometer, which was of very simple form, and easily reproduced by anyone. The specification says:—

> "The Viscosity is the time required in seconds at the specified temperature, to pass 50 c.c. of oil through a hole about 1-32 in. in diameter, in the bottom of a vessel, the same vessel and hole passing 50 c.c. of distilled water at 60° F. in 60 seconds. The head of water above the hole to be 1¼ in. The approximate dimensions of the vessel to be not less than 3 in. diameter by 3 in. high."

Whether the hole is exactly one-thirty-second of an inch, or not, does not matter, so long as the hole will pass 50 c.c. of water in 60 seconds at 60° F. When testing oils at higher temperatures than 60° F., the heat was maintained by means of a small electric lamp inserted in the oil to the required depth.

I might say that the viscosity of mineral oils is very frequently faked, especially some of the cheap cylinder oils, which are made to look like excellent lubricants, but in which a quantity of paraffin is present. They feel very fat, greasy sort of lubricants to the touch at atmospheric temperatures, but with a very slight rise the paraffin liquifies, and is then valueless as a lubricant. The only way to determine the presence of paraffin, is to freeze the oil, when the paraffin will solidify and show separately from the oil.

Coming now to the flash test, this is a very indeterminate sort of test, unless it is very clearly specified how the test is to be carried out. It is possible to make an oil flash over a fairly big range of temperature, as it depends very largely on the method of heating, the size of the flame, and the distance which the flame is away from the surface of the warm oil it passes over.

We got over the difficulty in this way, by specifying:—

> "Flash point to be determined by open test. The oil to be placed in a crucible and heated at a rate not slower than 20° F. per minute, and a lighted taper passed over the oil approximately one inch above the surface once for every 20° F. rise in temperature."

By that means we managed to get fairly consistent results.

Another test which Mr. McEwin did not refer to in the printed paper, but which was shown in one of the diagrams on the screen, related to carbon residue—more particularly in connection with testing oils for motor car cylinders, than steam engines. With the use of about 100° F. superheat in the cylinder, and the steam at 160 lbs. per square inch, we found some oils used to cause more wear in the cylinders than others, and we made an examination of the portions of the interior of the cylinder beyond where the rings traverse. We found some black greasy material, which was slightly gritty to the touch, and which, when washed in benzine and dried and put under the microscope, appeared in the form of very fine black powder, and, on analysis, was found to be carbon. Some cylinder oils showed a greater deposit than others, and the conclusion was arrived at that the carbon deposit and consequent wear of the cylinder and rings, was due to the amount of carbon that the various cylinder oils produced.

This decided us to attempt to determine by test, as a precaution in buying it, the amount of residue that the cylinder oil would produce, and the method was this: We took ten grammes of oil, and placed it in a glass beaker and raised it to a temperature of 600° until it all evaporated.

After the ten grammes had evaporated, the residue in the bottom of the beaker—a sort of dirty-looking, gummy mass—was thoroughly shaken up, with about 50 cubic centimetres of benzine of 80° F. flash point, and was poured through a filter paper into a vessel, and any oil contained in the filter paper was washed out of the filter paper with additional benzine, and what remained on the paper was considered as carbon residue. Out of 10 grammes of some of the common cylinder oils, it was possible to get about a level teaspoonful of fine, hard, black crystals like glass. The percentage of carbon was thus determined. If we found, when carrying out this test, that the 10 grammes of oil evaporated in less than 1½ hours, we never went further, simply because an oil which evaporated so rapidly usually formed a large proportion of carbon residue, and it was not worth consideration. Some high-class oils would require a period of 8 hours or more to evaporate, and show hardly any carbon residue. I mention this to show the great difference there is in the quality of cylinder oils. Tests such as those described, while not claiming the scientific accuracy usually found in oil testing laboratories, are of very considerable value in determining which oils to select for use. To provide for working tests of the oil, we further specified that the tender would only be accepted provisionally, until we had obtained three months' results of the oils under running conditions.

I notice that Mr. McEwin said that in small factories testing was out of the question, and that the only method is to place one's self in the hands of the oil makers. No doubt that is a very satisfactory way, if the firm be a high-class one.

There is one oil which Mr. McEwin dismisses with a very brief reference, and that is our old friend castor oil. Under certain conditions, castor oil seems to do what very few oils are capable of doing. Personally, I think that castor oil, being a vegetable oil, and subject to decomposition, is not a suitable lubricant for most purposes; but no doubt, under certain circumstances, castor oil seems to have a lubricating property that is not possessed by many other oils. The same thing may be said of very fine sperm oil, although the price is too high to use for ordinary lubricating purposes. Higher class sperm oil, thoroughly freed from acid by the zinc process, will remain fluid when exposed to the air for at least two or three years.

I do not think I have anything further to say. I am afraid I have taken up a good deal of time in my criticism of Mr. McEwin's paper, perhaps more than I ought to have done. I am sure his excellent paper has been very interesting to all of us, as the subject is one which deeply concerns us as engineers. I know that it has been very interesting to me.

I therefore have pleasure in moving a very hearty vote of thanks to Mr. McEwin for his paper.

Mr. G. A. Julius, in seconding the vote of thanks, said:

Mr. McEwin has given us an interesting summary of the conditions accompanying lubrication, and the use of lubricants, which I think might very well be followed by a paper on the abuse of lubricants, which is the general practice in this country.

One has listened with considerable interest to Mr. Tournay-Hinde's experience in testing oil, and it seems that this specification comes down to this: He specified particular oil tests. He does not think they are any good, and falls back upon a practical test, in the end, as being the only thing that can give him the truth.

Mr. Tournay-Hinde: Not quite that!

Mr. G. A. Julius: I think I am right in saying that no user of oil to the extent of tens of thousands of pounds a year would ever make contracts without having oils sub-