

INSTITUTE OF MARINE ENGINEERS INCORPORATED.

Patron: HIS MAJESTY THE KING.



SESSION

1920-21.

President: LORD WEIR OF EASTWOOD.

VOLUME XXXII.

Oils for Internal Combustion Engines.

BY MR. J. L. CHALONER (Member).

READ

Tuesday, November 16, 1920.

CHAIRMAN: MR. G. J. WELLS (Vice-Chairman of Council).

The CHAIRMAN: I hope you will not be alarmed at my surroundings this evening, but it is in keeping with the opening of the new course of lectures. You will agree, when I state that marine engineers must keep abreast of the times, and the Council, in arranging this series of lectures, are endeavouring specially to deal with the latest progress of the application of the old engine,—or, as I should say, the internal combustion engine,—to marine purposes. The marine engineer is a little bit troubled, especially those like myself and others who have been brought up with the steam engine. It seems difficult at first sight to realise that it is possible to take the furnaces out of the boiler, and put them into the cylinder, then clap on the cover and expect the engine to work. By doing this one puts away a lot of gear, but still it is rather a startling proposition to expect to get the same result, that is rotation of the screw. With the marine engineer himself rests almost entirely the responsibility of keeping the engine turning, and that responsibility means that in the event of something going a little astray he must know immediately what is the trouble and remove it. Most of us have had considerable experience with the troubles of the steam engine,

but the troubles of the oil engine are not so generally well-known. The Committee appointed by the Council felt that a special series of lectures should be arranged, the main object of which was not to air special grievances or special experiences, but rather to turn to the practical side, the working of the engine, and, if possible, to lay stress on those points that are likely to give trouble, so that those on watch will have an opportunity of giving consideration to these points, and learn how to put them right. More important will be the fact that with this knowledge they will be led to the anticipation of these troubles, and thus will be able to prevent them arising. That, perhaps, is the ultimate goal. The Committee thought it would perhaps help if one began at the beginning of the subject, and thus we should give first attention to the fuel, and then to chase the fuel through the engine to the exhaust. What are the troubles of getting suitable oil? How will you test a sample? How will you make up your mind as to the relative advantages of an oil out of two or three grades that may be offered you? These are some of the points for consideration, and in the second paper to be read this evening I anticipate there will be given some good suggestions on these points of selection and final determination of the oil you will purchase. Another trouble is storage. You may have a good thing and make it worse by putting it into bad circumstances. Next there is the pipe system between the bunkers and the engine. Following that is the principles of combustion, the problem of efficient combustion. We hope by the end of the session our members will have obtained a very great and substantial help in their knowledge of the working of the internal combustion engine. I had expected that the author of the first paper would have been late in arriving, and I think that as he is here I may ask Mr. Chaloner to open this series of lectures. It is a privilege to start a new thing going, and I hope you will give us a good send off, so that at the end of the session we may be able to look back upon a valuable addition to our Transactions.

I would like to invite everybody present to take part in the discussion, for Mr. Chaloner will, I am sure, do all that he can to help you out of any difficulties. Mr. McKenzie will be making some of the simpler tests in front of us, and thus afford us a good opportunity of increasing our knowledge of the essential points. I would like to suggest to you that you take full advantage of this opportunity of making yourselves acquainted with the peculiarities of the oil engine, so that if need arises and the

opportunity offers you will be able to accept an opportunity of sailing in a ship fitted with internal combustion engines.

INTRODUCTION.—The use of the internal combustion engine on board ship both for main propelling and auxiliary purposes has brought the Marine Engineer in close contact with the many problems connected with oil fuel.

Oil fuel is practically found all over the world and the world's map in Figure No. 1 illustrates the position of present and prospective oil fields. The curve in Figure No. 2 shows the development of the world's production of petroleum, from which it will be noted that whereas progress has been very rapid the total available production of oil to-day is only 3 per cent. of the total production of coal.

Whilst in former days it was never the practice to use crude oil very extensively for industrial purposes, yet the commercial and economical position did not warrant any detailed splitting up of the crude oil into its various products. To-day, however, during the refining process of petroleum, the following yields of the various products are obtainable:—

Petrol	...	...	...	...	...	26%
Kerosene	...	...	...	...	...	10%
Gas Oil	...	...	...	...	...	5%
Lubricating Oil	...	...	...	...	...	6%
Fuel Oil	...	...	...	...	...	40%
Residue (asphalt wax)	...	...	...	...	...	12%
Loss	...	...	...	...	...	1%

Needless to say the percentage of the different yields varies considerably with the origin of the oil fuel, but for general purposes the above data represent fairly average records. (See Figure 3).

Modern engineering has found a specific function for each grade of distillate or residuum, and the general tendency is towards using the cheapest class of fuel in each case, provided, of course, that at the same time a high degree of reliability is retained together with an average maximum efficiency. As is indicated on the world's map, oil is found in practically all parts of the world, and it may be anticipated that there must be a fundamental difference in the constitution of the oil which will have an important bearing on the suitability of the various fuels. Broadly speaking, the oils found in the world may be one of

WORLD'S PRODUCTION OF CRUDE
PETROLEUM FOR 1919

	TONS	%
AMERICA (U.S.)	49,116,280	65.4
MEXICO	13,581,832	18.1
RUSSIA	5,000,000	6.7
DUTCH E. INDIES	1,800,000	2.4
BRITISH INDIA	1,100,000	1.5
PERSIA	1,000,000	1.3
ROUMANIA	919,850	1.2
GALICIA	614,000	0.8
PERU	350,000	0.5
JAPAN	350,000	0.4
GT. BRITAIN	300,000	0.4
TRINIDAD	300,000	0.4
EGYPT	258,000	0.3
ARGENTINE	198,000	0.3
GERMANY	100,000	0.1
VENEZUELA	60,000	0.1
CANADA	33,000	0.0
ITALY	5,500	0.0
OTHER COUNTRIES	50,000	0.1
TOTAL	75,096,462	

%AGE OF WORLD'S PRODUCTION

0-1 SHOWN ○
 1-5 " ●
 7 " ●
 18 " ●
 65 " ●

PROSPECTING AREAS SHOWN ⊗

OILS FOR INTERNAL COMBUSTION ENGINES. 219

three bases, viz., Naphthene base, Paraffin base, and Asphaltic base. The Naphthene bases are generally confined to the Eastern and Mid-European countries, the Paraffin bases are usually obtained from America, whilst the Asphaltic bases are mainly obtained from the Mexican and South American oil

CURVE No. 2.

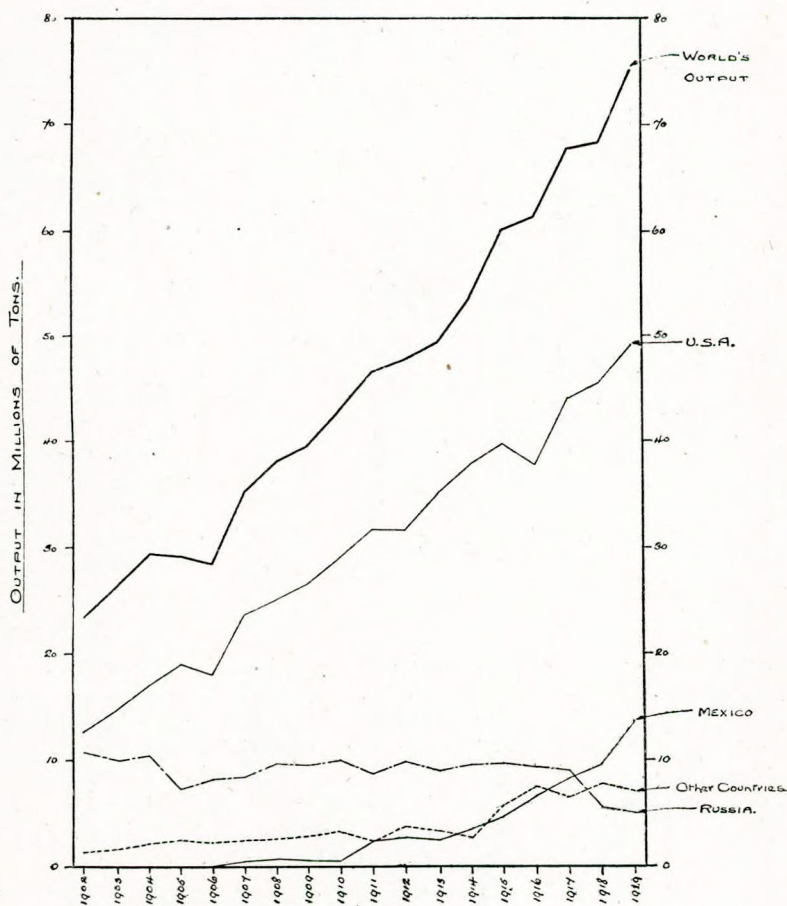


Fig. 2.

fields. To-day's refined products will, therefore, be of one of three above bases, and the suitability generally will be co-relative to the base of origin.

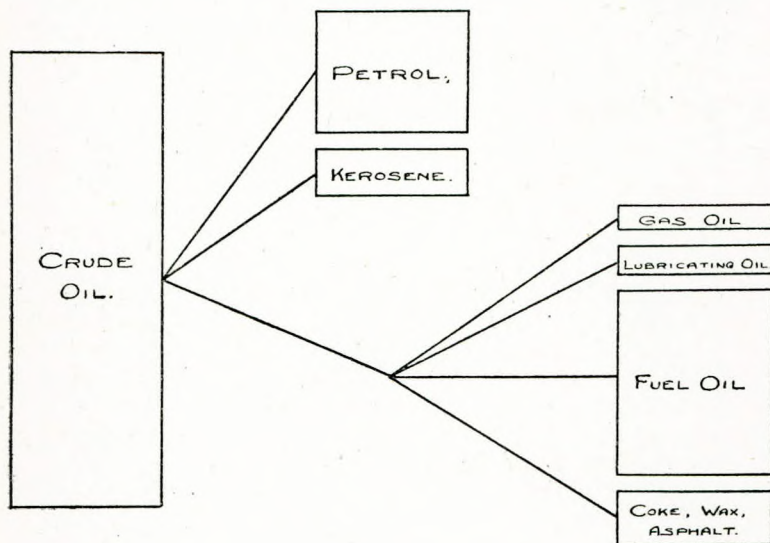


Fig. 3.

Whilst from a technological point of view the determination of a complete specification is a highly scientific procedure, the commercial specification confines itself to the determination of such physical and chemical properties which have been considered as a sufficient guide in the selection of a suitable fuel. It is customary to refer to oil fuels as white and black oils, in which case Petrol and Kerosene are known as white oils against Gas and Fuel Oils which fall under the black oil category.

For the purpose of indicating the scope of the investigations which may be carried out in conjunction with the determination

OILS FOR INTERNAL COMBUSTION ENGINES. 221

of the physical and chemical properties of oils the following table has been compiled:—

Physical Properties.		Chemical Properties.	
White Oils.	Black Oils.	White Oils.	Black Oils
Specific Gravity. Specific Heat. Vapour Tension. Flash Point. Burning Point. Ignition Point. Viscosity. Fractionation. Calorific Value. Oil Gas Formation. Heat of Vapourisation. Mechanical Impurities. Co-efficient of Expansion. Setting Point.		Ultimate Analysis (Carbon, Hydrogen, Sulphur, Oxygen and Nitrogen). Litharge Test. Copper Test. Iodine Value. Unsaturated. Compounds.	Water Contents. Ash Contents. Coke Contents. Bitumen Contents.

From a commercial point of view and of particular interest to the Marine Engineer, however, is that specification which will make possible a quick determination as to the suitability or unsuitability of any particular fuel for any specific purpose. In connection with commercial specifications therefore, attention is confined to the following properties:—

WHITE OILS.

- (a) *Physical Properties.*
 Specific Gravity.
 Calorific Value.
 Flash Point.
 Viscosity.
 Fractionation.
 Vapour Tension.
 Water Contents.

BLACK OILS.

- (a) *Physical Properties.*
 Specific Gravity.
 Calorific Value.
 Flash Point.
 Viscosity.
 Mechanical Impurities.
 Water Contents.
- (b) *Chemical Properties.*
 Coke or Bitumen Contents.
 Sulphur Contents.
 Ash Contents.

I. *Physical Properties.*—1. *Specific Gravity.*—The specific gravity has hitherto always been considered as a definite guide with regard to the suitability of a fuel. Whilst such an assumption was correct when comparatively few oil fields in the world were in operation, it is becoming more and more evident that the

specific gravity by itself forms no criterion for an oil. This property is, however, useful for converting tons into gallons, and in this connection it is used very frequently.

Whilst in this country the specific gravity unit is employed, in the United States the Baumé scale is used to a far greater extent. The following formula is quoted to convert the one standard into the other and *vice versa* :—

$$\text{Specific Gravity} = \frac{140}{130 + \text{Baumé reading}}$$

$$\text{Baumé} = \frac{140}{\text{Specific Gravity} - 130}$$

As will become apparent, the gravity depends on the temperature and it is customary to specify the gravity at 60°F. or 15°C. Whenever the gravity is determined at any other temperature the following adjustment should be made to obtain the approximate specific gravity at the standard normal temperature :—

Temperature Correction.	Specific Gravity Range.	
	From '62 (White Oils)	to '97 (Black Oils)
For every degree above 60°F. subtract	·0001	to ·0005
For every degree below 60°F. add ...	·0001	to ·0005

2. *Calorific Value.*—The calorific value has an important bearing on consumption in internal combustion engines and this value is therefore of considerable importance to the Marine Engineer when drawing up his heat balance sheet. The average value of the various constituents of oil fuel are as follows :—

	Gross Calorific Value. per lb. of fuel.	Actual Calorific Value. per gallon.
Petrol	21,000	142,800
Kerosene	20,050	160,400
Gas Oil	19,500	169,700
Light Fuel Oil ...	19,100	173,900
Heavy Fuel Oil	18,750	178,200

The specification usually quotes the gross calorific value, as that is the value which is determined when testing the fuel for its heating value. From a consumption point of view, however, the net calorific value is of greater importance and the general

rule for finding the net calorific value from the gross is by using the following formula:—

$$\text{N.C.V.} = \text{G.C.V.} - (97 \text{ H} + 173 \text{ H}_2\text{O})$$

where H is the percentage of Hydrogen, and
H₂O the percentage of water.

The following table gives the approximate hydrogen contents in the various distillates and residuums:—

Petrol	...	...	...	14.5% of Hydrogen.		
Kerosene	...	...	...	14.2%	„	„
Gas Oil	...	...	...	12.7%	„	„
Fuel Oil	...	...	...	12.4%	„	„

It is not always possible to determine the hydrogen contents and the net calorific value in such a case can be determined approximately by the following formula:—

$$\text{N.C.V.} = \text{G.C.V.} - (\text{K} + 173 \text{ H}_2\text{O})$$

where H₂O is as before the water contents, and
K = a value depending on the specific gravity of the fuel.

The relationship between the specific gravity and K is given in Curve No. 4.

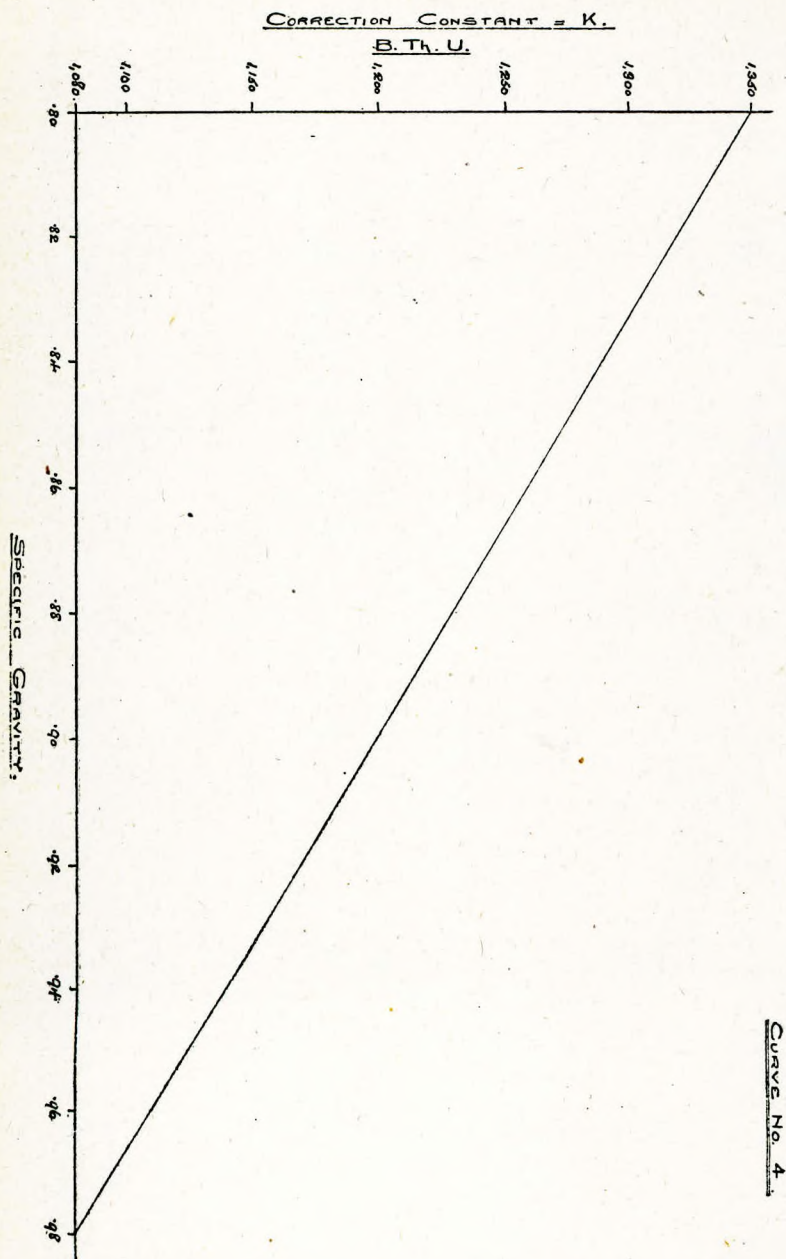
In addition to the above formulæ the calorific value may also be approximately calculated from the chemical analysis of the fuel and the following formula is quoted:—

$$\text{Calorific Value} = 146 \text{ C} + 620 \left(\text{H} - \frac{\text{O}}{8} \right) + 45 \text{ S}$$

where C = Percentage of Carbon.
H = Percentage of Hydrogen.
O = Percentage of Oxygen.
S = Percentage of Sulphur.

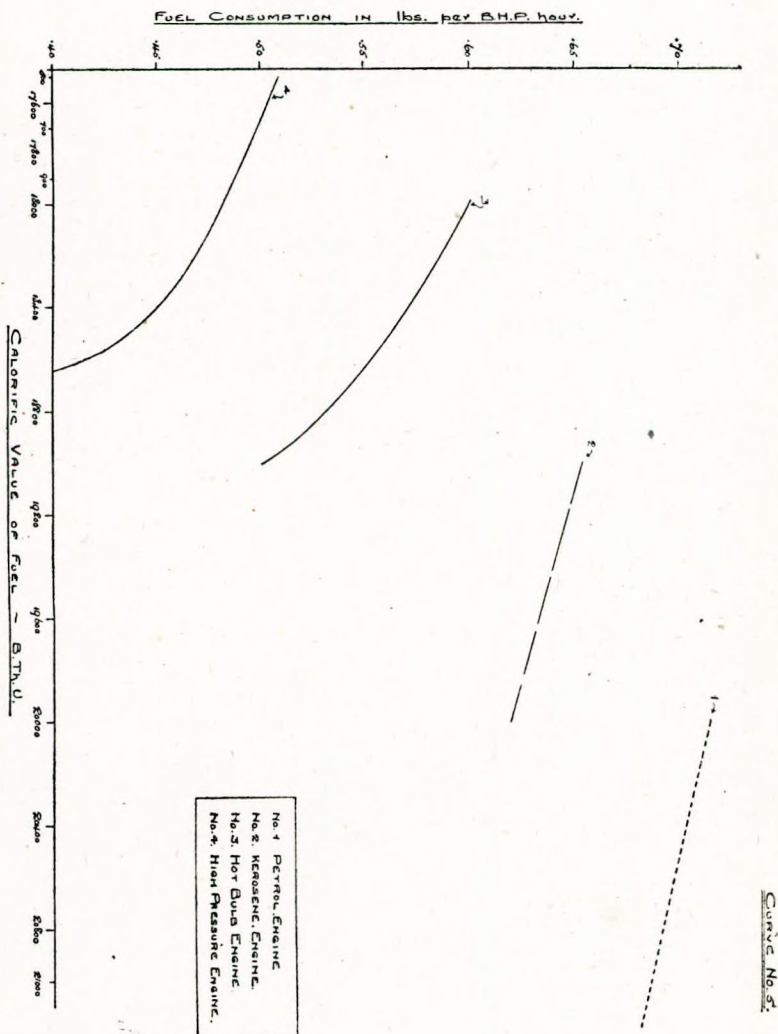
It is generally assumed that the fuel consumption for internal combustion engines is directly proportionate to the calorific value of the fuel and whereas such a statement is approximately correct for white oils and gas oils, actual tests have shown that in conjunction with fuel oils and residuums there is no direct relation. General data are given in Curve No. 5 for the various fuels and adjustments will have to be made depending on the type and size of engine cylinder.

3. *Flash Point.*—The flash point is of specific interest in connection with white oils, particularly so because white oils are usually employed in internal combustion engines with some

OILS FOR INTERNAL COMBUSTION
ENGINES.

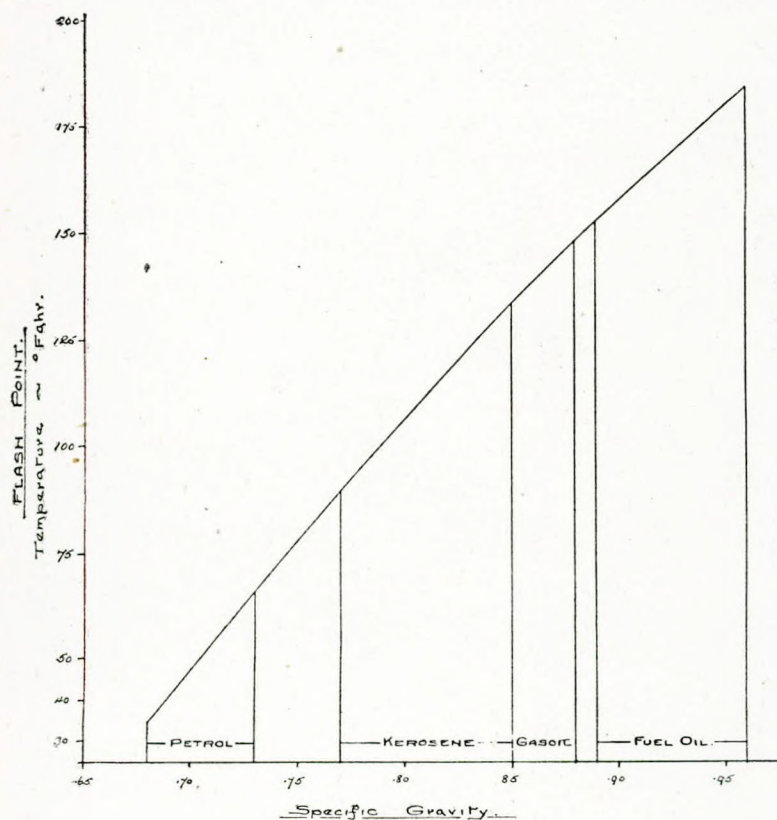
OILS FOR INTERNAL COMBUSTION ENGINES. 225

type of external ignition device. For marine Diesel engines, where, as is well known, the fuel is ignited by the heat of compression, the flash point is of little value with regard to the determination of the suitability of the fuel.



Whilst from a technical aspect the flash point is no criterion as regards the suitability of a fuel, this value is useful to know in conjunction with the regulations which are laid down by the Board of Trade, Lloyd's and Local Port Authorities. It is stipulated fairly universally that a fuel oil must have a flash point above 150°F . In such cases where this regulation is not complied with, definite rules are laid down for the construction and fitting up of bunkering and piping systems generally on board such ships which carry low flash oils.

In Curve No. 6 the relation between specific gravity and the flash point is illustrated. The curve indicates the general ten-



CURVE No. 6.

dency and is subject to adjustments depending on the base of origin of the various fuels under examination.

Crude oils have a comparatively low flash point, and in those cases where the uses of the volatile products are too small to make the refining of the crude oils a commercial proposition, the heavy marine oil engine offers advantages over the oil-fired boiler installation, inasmuch as the crude oil may be used with safety in an oil engine whereas for an oil-fired furnace it is decidedly dangerous.

4. *Viscosity*.—The viscosity of a fuel can be expressed in Redwood, Saybolt or Engler terms, and the following approximate relation between the different values are given:—

Engler 1° to 6° = Redwood No. 1 26·7 seconds to 31·3 seconds.

„ above 6° = Redwood No. 1 31·3 seconds.

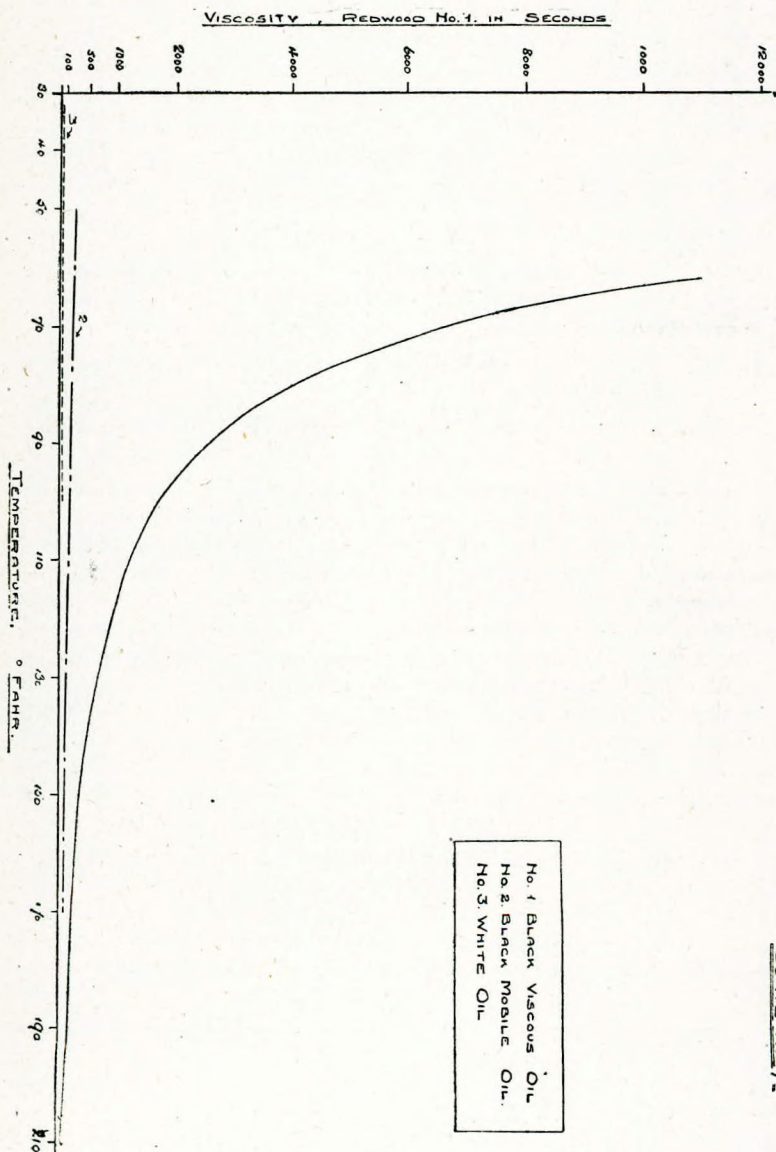
Saybolt 1 second to 120 seconds = Redwood No. 1 ·95 seconds.

„ above 120 seconds = Redwood No. 1 ·84 seconds.

In connection with white oils, viscosity has no importance as all fuels are sufficiently mobile whatever the grade or quality may be. In connection with black oils, however, the viscosity plays a very important part, inasmuch as heating may become necessary with very viscous fuels which in every other respect are quite suitable for use in engines. With these oils the viscosity also varies considerably with the temperature, and whilst any black oil becomes sufficiently mobile once it has entered the piping system on the engine, its viscosity under normal atmospheric conditions may be too high to enable the oil to be handled without any special preparations. As a result the viscosity of a black oil should be known in order to determine whether the fuel can be handled without heating or not.

Curve No. 7 shows the effect of temperature on the viscosity for a black oil which can be handled under all temperature conditions and another one which requires heating in order that it may be handled easily under similar conditions. For comparison a third curve is illustrated showing the viscosity of a white oil.

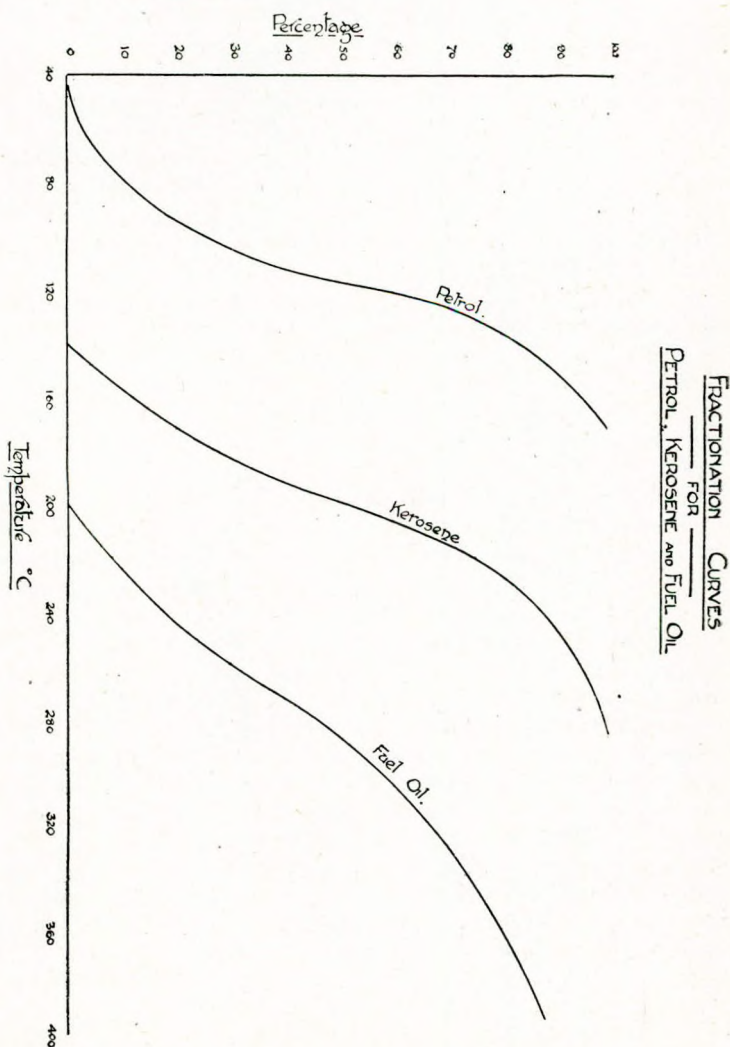
5. *Fractionation*.—Fractionation or fractional distillation indicates the boiling point range and this value is useful for fuels which are vapourised prior to entering the combustion engine. This physical property applies, therefore, chiefly to white oils, and it is desirable that the boiling point range should be a minimum.

OILS FOR INTERNAL COMBUSTION
ENGINES.

The following approximate data are quoted for the various grades of fuel:—

Grade of Fuel.	Boiling Point Range.	
	Initial Boiling Point.	Final Boiling Point.
Petrol	40°	200°C.
Kerosene	150°	300°C.
Fuel Oils	200°	400°C.

Curve No. 8 gives the distillation curves for various fuels indicating the general characteristics.



6. *Vapour Tension.*—The vapour tension is also a property which is of interest in conjunction with white oils as it is a measure of the volatility of the fuel, and from that point of view it indicates the ease when starting from cold condition. There is a close relation, of course, between the boiling point and vapour tension, inasmuch as the lower the vapour tension the higher the boiling point. For black oils this property is of no practical interest.

7. *Mechanical Impurities.*—Whilst in connection with white oils there is very little danger of mechanical impurities being carried over with the fuel, the black oils, particularly on account of their viscosity, retain a certain amount of dirt and incombustible matter which it is advisable to filter out prior to using the fuel in the engine. It is, of course, desirable to get the percentage of such impurities to an absolute minimum, and by suitable filtering arrangements it is possible to remove all dirt and grit which may be contained in the oil prior to using the fuel inside the engine.

8. *Water Contents.*—For white oils the water is easily settled out owing to the fact that the difference in the specific gravities of white oils and water is appreciable. Whilst in the case of Kerosene a small amount of water will not introduce any technical difficulties, water in the carburetter of a petrol engine has been the cause of stoppages. As petrol is handled in bulk when used on board a vessel the water question does not enter as it does in the case where petrol is distributed by cans.

In the case of black oils, however, it is possible to retain water in suspension, particularly in those fuels of high viscosity. Filtering of the fuel itself is not sufficient in this case unless the oil is at the same time heated.

II. *Chemical Properties.*—9. *Sulphur Contents.*—This chemical property is of no importance in connection with white oils as the percentage of sulphur in white oils is negligible. Amongst fuel oils Mexican and Californian oils contain percentages of sulphur. In former days it was contended that a sulphur content in an oil fuel would make that fuel unsuitable for use in internal combustion engines. It is admitted that during the chemical dissociation the hydrogen in the fuel will combine with the oxygen in the air in the form of water which combined with the sulphur will form sulphur dioxide or trioxide, which compound will under certain favourable temperature conditions attack the various engine parts. However, such chemical

combination can only take place when the water is in the form of steam, which means that the prevailing temperature must be below the boiling point of water. In the internal combustion engine low temperatures exist only on very rare occasions, for instance on starting from cold, and the corrosive effect of a sulphurous oil is therefore considered negligible.

In connection with hot bulb engines water injection has always been a drawback when using a fuel containing sulphur, but it is satisfactory to know that the modern hot bulb engine has dispensed with this unnecessary and undesirable auxiliary arrangement.

10. *Ash Contents.*—The ash content is of particular interest in the case of black oils. The ash content of the fuel is determined by the incombustible mineral matter which is retained in the fuel. Whereas with distillates, such as Gas Oil, only a very small amount of incombustible matter is carried over, the percentage in the case of residuums and heavy fuel oil may be considerable, and the nature and condition of that substance, which on combustion forms the ash content of the fuel, is such as to make filtration a most difficult proposition. It is, therefore, advisable to keep the ash contents of the fuel as low as possible, particularly owing to the abrasive effect which this ash may have on the moving parts of the engine.

11. *Bitumen and Coke Contents.*—The tendency for a fuel to coke makes it unsuitable for engines, as the formation of an excessive deposit will necessitate frequent cleaning of the combustion chamber and the parts immediately in contact with it.

The Bitumen content of a fuel should be kept below a permissible maximum percentage, although the general tendency nowadays is to burn fuels with Bitumen content up to 30%.

The Bitumen is a hydro-carbon compound, and can be burnt completely, provided the required temperature conditions are available.

Oils of an asphaltic base represent to-day a very large percentage of the total supplies of fuel oils, and it is pleasing to note that a certain section of the oil engine manufacturers have recognised this fact. The result is that to-day heavy asphaltic oils, such as Mex Fuel Oil, which have proved an excellent fuel for oil-fired furnaces, can be burnt in certain types of heavy oil engines.

The progress of the internal engine is taking place very rapidly indeed, and an oil which to-day is considered as entirely unsuitable for most engines will probably give excellent results in the improved models of to-morrow.



Testing of Oils for Internal Combustion Engines.

By TOM MCKENZIE, A.I.C., F.C.S., M. Inst. P.T.

READ

Tuesday, November 16, 1920.

The CHAIRMAN: I think it will be advantageous to ask Mr. McKenzie to read his paper at once and take the discussion of the two papers together. Of necessity the subjects must overlap, and perhaps Mr. McKenzie will bear in mind what Mr. Chaloner has said.

In order to fully understand the specifications for oil for internal combustion engines just given you by Mr. Chaloner, I think it would be interesting if I were to describe to you briefly the methods adopted for testing these oils, and the instruments used in such tests. Time will only permit me to describe the tests which are of general importance. The testing of petroleum and oil generally may be divided into two sections, namely, physical and chemical. As users, you will find that the physical tests are of much more importance than the chemical.

Before discussing the question of testing oil, it will be necessary to say something regarding the sampling of oil. What is sampling? A sample is a quantity representing the bulk of the oil or, in other words, a reduced scale of the contents of a tank, barrel or wagon. Unless we are sure that the sample is really representative of the bulk, it is a waste of time and money to carry out any tests, as such tests would really be the tests of that particular sample; whereas if the sample is a representative one, the results of the tests are the tests of the bulk of the oil. This is an extremely important point to remember. Sampling is one of the most difficult operations in connection with the testing of oil, yet, in the majority of cases, it is done by anybody handy—usually a workman. These remarks do not apply to oil only, but to any other material. For example, I think one of the

most difficult things to sample is coal. For a number of years I was employed at a works where they burned, roughly, three to four thousand tons of coal weekly, so naturally their contract for coal was one worth having. In the course of my employment, I analysed several hundred samples of coal sent by coal owners and merchants; I could count on my ten fingers the times when the suppliers' samples agreed with the analysis of the bulk cargo. They were not, as you might imagine, always better—in many cases they were worse. They were really not representative samples. I wish to emphasise this point because it is a general belief that taking a sample is a simple matter, and I want to assure you that it is—as I have already said—one of the most difficult things to do properly. Sampling should always be done by trained men only, and for this reason—primarily the sample may be taken for some very simple reason, but one can never tell what the results of that sample may ultimately lead to, and if that particular sample is wrong the results may have very serious consequences. Having now explained how important it is to have the sample properly taken, I shall try to describe to you the correct way to do this.

It matters not whether the bulk be a barrel, tank, or even a steamer. The principle is the same in each case. If oil were really a homogeneous mixture, there would be very little difficulty, but this is seldom the case. For one thing, there is nearly always water present, and as water does not mix with oil under ordinary circumstances, and as the specific gravity of water is usually different from that of oil, we may find this water in pockets, or settled at the foot of the tank, or floating on the top of the oil, if the oil happens to be heavier than water, as with coal tar oils. To take a sample of this oil without the water, or with too much water, would not be representative. The sample must contain the proportion of water that the bulk contains. One way to take the sample, if the bulk is not too deep, is to get a tube $\frac{3}{4}$ to 1 inch in diameter, fitted at the bottom with a wooden plug, from which a wire leads to the top of the tube. This tube is pushed slowly down to the bottom of the tank, the plug is pulled into place by the wire and fixed with a sharp blow on the bottom of the tank. In this way a "core" of oil is obtained. This is done from two or three parts of a tank or wagon, and all the "cores" mixed together thoroughly. If there are a number of such "cores" taken, the sample may be too large to take away, but this is easily overcome by thoroughly mixing the whole and taking a part as the sample.

This method cannot always be adopted; for example, if the tank is 20 ft. high, this means you must have a tube at least 20 ft. long, and you can understand this would not be easy to handle. Very often the depth of a tank is over 20 ft. In cases of this sort, one way is to have a loaded can fitted with a cork to which a wire is attached. The can is put into the tank to any desired depth, the cork pulled out, and then the can slowly drawn up and contents emptied into a receptacle. This is done at various depths, from the top to the bottom, and at different parts of the tank. The whole is thoroughly mixed and a quantity taken as the sample. This method, if carefully done, is quite efficient. Another method, which is only practicable when the oil is being pumped from one tank to another, say for example from the ship's tank to a shore tank, is to draw a small quantity periodically from the pumps. If this is done very frequently during pumping, a good representative sample is obtained. These are the methods generally adopted. Having obtained our sample, we will now proceed to test it.

As I have already stated, testing is divided into two sections, physical and chemical. We will deal first with the physical tests, and I shall endeavour to explain these tests in as simple a manner as possible.

Physical Tests.—To the layman, physical—and more especially chemical—tests are considered somewhat mysterious processes. Chemists are more or less looked upon as the alchemists were in the Middle Ages—men who carry out weird operations more or less—especially more—to the danger of the inhabitants generally. This is quite an erroneous idea. The operations we carry out are really extremely simple. All that is required is care and attention to detail, and of course practice. They look difficult and perplexing, but they are quite the reverse. Physical tests generally adopted for oil are:—

- | | |
|----------------------|---------------------|
| 1. Specific gravity. | 6. Smell. |
| 2. Flash point. | 7. Boiling point. |
| 3. Viscosity. | 8. Calorific value. |
| 4. Setting point. | 9. Water. |
| 5. Colour. | 10. Ash. |

In some cases distillation test.

1. *Specific Gravity.*—The specific gravity is the weight of a given volume of oil compared to the weight of a given volume of water at a given temperature. In this country we usually take this at 60°F. We determine specific gravity in two ways, de-

pending to a certain extent on whether we wish our results to be extremely accurate or only approximately so:—

(a) *Hydrometer*.—This is simply a weighted tube fitted at its upper end with a graduated scale. Many kinds of hydrometers are in use, the simplest being that with which the specific gravity is read directly on the scale. (See Figure 1). The



Fig. 1.

principle of the hydrometer is that the denser the liquid the more does a floating body project from its surface. Hydrometers are made in series, say from .750 to .800, .800 to .850 and so on. Hydrometers cannot be used in very viscous oils.

(b) *Specific Gravity Bottle.*—The most accurate method is by direct weighing of equal volumes of oil and water. This is usually done by means of a specific gravity bottle. This bottle is made of very thin glass, fitted with an accurately ground stopper. The neck of the bottle is narrowed below the stopper and has a mark etched upon it to enable the operator to fill the bottle with the same amount of liquid each time. (See Figure 2). The volume used is usually 25, 50 or 100 ccs. The operation is carried out as follows:—The bottle is filled with water at 60°F. and carefully weighed. The bottle is now emptied, thoroughly dried, and is then filled with the oil to be tested, the tempera-



Fig. 2.

ture of the oil to be at 60°F. and weighed. The weight of oil, divided by the weight of the same volume of water, gives the specific gravity.

2. *Flash Point.*—The temperature at which an oil, on being slowly heated, begins to evolve a vapour in such quantity as, on the application of a flame, a momentary flash due to the ignition of the vapour occurs, is termed the flash point; and the temperature at which, on being further heated, the oil takes fire on the approach of a flame and continues to burn, is termed the fire point. There are a number of instruments used to determine this point, and as they are all similar in principle a general description of one will be quite sufficient to give an idea of the apparatus. (See Figure 3). This consists of a metal vessel or oil cup holding a fixed quantity of oil, which is placed in a hot-air chamber. The oil cup has a closely fitting lid or cover. This cover is perforated with several openings, which are

opened or closed by means of similar openings on a sliding cover. The sliding cover is rotated periodically, and this uncovers the holes in the cover and at the same time causes a small test flame to project on to the surface of the oil. This is done

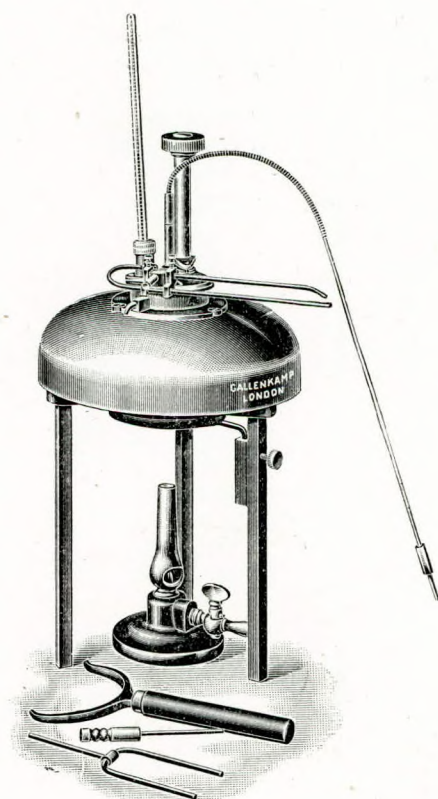


Fig. 3.

at each degree rise of temperature until the flash occurs, and the temperature is then noted. Some apparatus are provided with stirring arrangements to stir the oil during the test.

Open and closed test.—In the former the oil is uncovered, and in the latter covered during the experiment. The temperature is considerably higher in the open test than in the closed test.

TESTING OF OILS FOR INTERNAL
COMBUSTION ENGINES.

3. *Viscosity*.—The viscosity of oil is a measure of its fluidity at certain temperatures. This is an extremely important test for lubricating oils, and also for fuel oils. It is not so important for burning oils. There are many instruments used for the determination of viscosity, and, as in the case of the flash point apparatus the principle of them all is, generally speaking, the same. In this country we use the Redwood Viscometer. (See Figure 4). Engler is used on the Continent, and the Saybolt in the United States. The figures given by all these instruments are arbitrary, and to a certain extent only can they be converted from one instrument to another. For this reason it is always necessary when reporting the viscosity of an oil to state the instrument used. As the Redwood is almost univers-

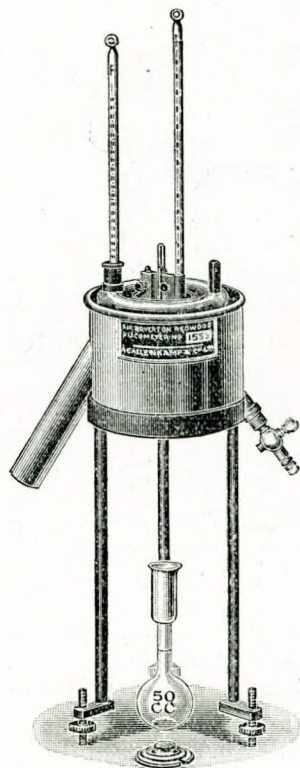


Fig. 4

ally used in this country I shall briefly describe this instrument. It consists of a silvered copper oil cylinder $1\frac{7}{8}$ in. in diameter and $3\frac{1}{2}$ in. deep, having an agate jet fitted in a slightly conical metal seating. The cylinder is fixed in a copper water bath provided with a copper heating tube projecting downwards at an angle of 45° from the side near the bottom, as well as with a revolving agitator carrying a covered shield to prevent splashing, and a thermometer to indicate the temperature of the liquid in the bath. Water or oil may be used in this bath, depending on the temperature at which the viscosity is to be taken. The oil cylinder has a stopper, which is a small brass sphere which rests in a cavity in the agate jet. A thermometer is fixed in the oil cylinder. Inside the cylinder, at a short distance from the top, is fixed a small bracket, terminating in an upturned point which acts as a gauge of the height to which the cylinder is filled. Great care must be taken in the construction of the agate jet to secure uniformity. The test is carried out as follows:—The bath is filled with a suitable liquid and heated to the required temperature. The oil to be tested, which is poured into the oil chamber until its level just reaches the point on the gauge, is also brought to this temperature. A narrow-necked flask holding 50 ccs. is placed beneath the jet in a vessel containing a mixture at the same temperature as the oil. The stopper is raised and a stop-watch started at the same time. The number of seconds taken by the outflow of 50 ccs. is noted. This gives the viscosity in seconds on this particular instrument at the temperature recorded.

4. *Setting Point.*—This is the temperature at which an oil solidifies. This test is important. For example, it would be quite useless to use a lubricating oil having a setting point above 32°F . in a refrigerator or on machinery exposed to low temperatures. The oil to be tested is placed in a test tube. This is stoppered by a cork through which a thermometer is inserted. The tube is then placed in a larger vessel and the whole placed in a freezing mixture. The oil is examined at each degree fall in temperature, and that temperature at which it ceases to flow is the setting point.

5. *Colour.*—The colour of white oils is determined in this country by Wilson's chronometer (see Figure 5) which consists of two similar tubes 16 inches in length and closed at each end by a screw cap carrying a stout glass disc. Light is reflected upwards through the tubes by a mirror. One of the tubes is filled with the oil to be tested, and beneath the other, which

is empty, is placed a disc of stained glass. On looking through the tubes the colour of the oil can be matched with the standard glasses. There are four standards: Water white, superfine white, prime white and standard white. The colour of lubricating oils is generally tested in a Lovibond's Tintometer.

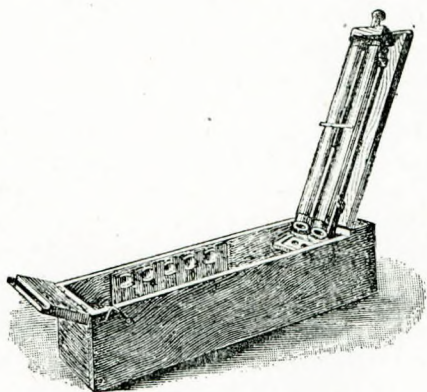


Fig. 5.

6. *Smell.*—This test only requires practice.

7. *Fractionation.*—The fractional distillation is very important when testing white oils for the internal combustion engine. For example, a high boiler-point motor spirit would give difficulty in starting an engine. Again, a low boiling point motor spirit means a loss of a large amount of spirit by evaporation. To carry out this test the oil is placed in a clean dried distillation flask. A distillation flask is a round-bottomed flask with a long neck from which projects a side tube. An example of this style of flask is shown on the lecture table tonight. The apparatus which is put together here to demonstrate the distillation of crude is similar to that which we use to carry out a fractional distillation of a motor spirit or kerosene. The distillation flask has definite dimensions, and in fact the various pieces of apparatus required for this test are all of definite dimensions, and any deviation from these dimensions causes a variation in the results. The flask is fitted with a cork, through which a thermometer is placed. The thermometer is arranged so that the bulb is just opposite the side-tube exit. A water-cooled condenser is attached to the side tube by means of a cork. At the end of

this condenser is placed a graduated vessel to collect the liquid which distills over. Heat is now applied to the flask, and when the first drop falls from the side tube into the condenser the temperature is noted, and this is taken as the initial boiling point. Heating is continued until the flask is dry. The vapour condenses in the condenser and the liquid is collected in a graduated vessel. The temperature at which different quantities are collected is noted, until the distillation is finished.

8. *Calorific Value.*—This is determined in a bomb calorimeter. (See Figure 6). This apparatus consists of a steel chamber called the "bomb" which is enamelled in the interior to prevent corrosion. A small quantity of oil (usually about a gramme) is placed in a platinum capsule, which is placed in the bomb. The bomb is fitted with a screw-down lid. The screw-down lid is furnished with a valve for admitting oxygen and another valve for the release of the gases formed by the combustion. The oil in the capsule is ignited by a current of electricity. This current is conducted to the oil by means of two rods passing through the lid, which are thoroughly insulated from the lid. One of these rods carries the platinum capsule, and to complete the circuit the end of each rod is joined by a thin iron or nichrome wire, which passes through the sample of oil. After weighing the sample the platinum capsule is fixed to one rod and the lid screwed down into the bomb. Into the bomb is now admitted 20 atmospheres of oxygen. The bomb is placed in a vessel containing water. The temperature of this water is accurately measured and noted. This having been done, the electric current is passed through and causes the oil to ignite, thus raising the temperature inside the bomb. The heat developed is transmitted to the water outside the bomb, the rise in temperature is carefully measured and the calorific value of the oil ascertained from this data by a somewhat complicated calculation. In this test the thermometer is an extremely accurate and delicate one, capable of measuring 100th of a degree Fahrenheit.

9. *Water.*—The presence of water can be detected by means of an apparatus called a "Water-finder." This simply consists of strips of non-absorbent paper treated with a material which is soluble in water but insoluble in oil. These strips are put into the sample of oil and if water is present it dissolves the material on the paper, leaving the latter white.

To determine the quantity of water in a sample of oil is a somewhat different matter and there are two methods for doing

TESTING OF OILS FOR INTERNAL
COMBUSTION ENGINES.

this. One is to whirl a known quantity of oil in a centrifugal machine which causes the water to separate from the oil and the amount can be read off. Another method is to distil 250 ccs. of the oil and collect the water.

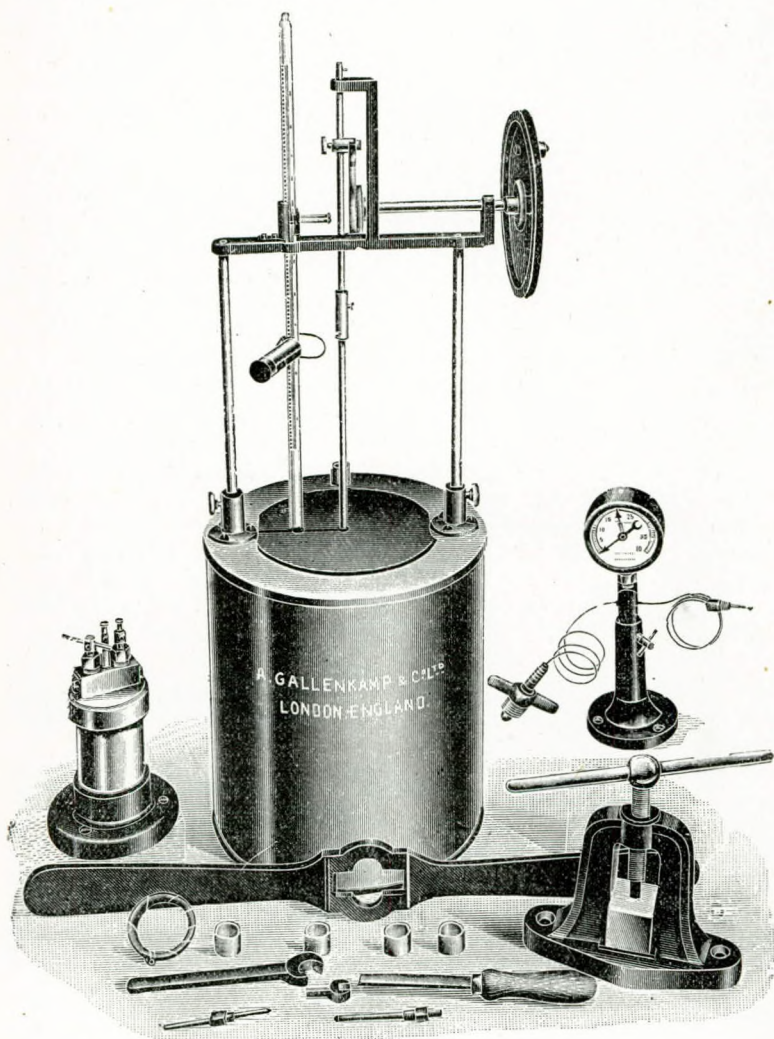


Fig. 6.

10. *Ash*.—The percentage of ash in oil is determined by igniting a sample of oil in a muffle furnace and weighing the ash obtained.

Chemical Tests: 1. *Copper Test*.—To carry out this test we use the same apparatus as for fractionation described above, but in addition a small piece of copper which is absolutely clean is introduced into the spirit in the flask. Heat is then applied to the flask and continued until the copper becomes tarnished. As soon as this occurs the quantity collected in the graduated flask at the end of the condenser is noted, and the result of the test is given on that reading, expressed as a certain percentage “good”; e.g., if 20% had been distilled over before the copper was tarnished, the spirit would be reported as “20% good.”

2. *Litharge Test*.—This test is applied to ascertain whether a spirit has been properly and sufficiently refined. To a small quantity of spirit litharge solution is added and the whole shaken for five minutes. If the spirit has been properly refined there will not be any alteration in its appearance; otherwise there will be a change in colour.

3. *Sulphur*.—The same apparatus and procedure is used as for the calorific value. The products of combustion are all retained in the bomb, and the sulphur is dissolved in a suitable solvent and converted into a compound which is separated and weighed. From the weight of this compound the amount of sulphur in the oil is easily calculated.

4. *Bitumen*.—It is very difficult to accurately determine the percentage of bitumen in asphaltic oils. This is often done by heating a known quantity of oil to a certain temperature, but this method leaves much to be desired, as it is very difficult—if not impossible—to get concordant results by such method. Even when the following precautions have been taken, viz., to always use the same amount of oil, to heat it in the same vessel or a vessel of similar dimensions, to heat at the same temperature and for the same length of time, I have found the results obtained are very varied. The temperature necessary is so great that “cracking”—that is decomposition of the oil—always takes place, with the result that coke is formed. This coke is taken as being bitumen or asphalt.

A much more accurate method for determining bitumen is a chemical one. This is usually done by precipitating the asphalt from the oil with the use of Alcohol and Ether. A known quantity of oil—usually 2 grammes—is shaken with about ten times

its volume of Alcohol and Ether mixture, 1-1, and allowed to stand for 24 hours at normal temperatures. The asphalt separates out and is filtered off. This residue is thoroughly washed with Alcohol and Ether mixture until free from oil, dried and dissolved in Benzene. The Benzene is then evaporated off, leaving the asphalt, which is weighed. This gives the amount of asphalt in the oil. With this test it is also necessary to take very special precautions in order to get concordant results, but if these precautions are taken one is able to get results more in keeping with the actual percentage in the oil than by the other method.

I think it would interest the audience if, in conclusion, I showed them generally the distillation of a crude oil and explained how various products are separated for further treatment. The apparatus which I am using is, of course, for laboratory work, and is somewhat different to that used in large-scale operations, but the principles involved are the same in both cases.

In this experiment the determining factor of the various products will be the temperature, but in large scale operations the determining factor is usually the specific gravity. The reason why I am using the temperature instead of the specific gravity is that, in order to determine the product by specific gravity one would require a very large amount, and that of course, as you will understand, is quite impossible in a laboratory experiment. Needless to say, time will not permit me to treat the various fractions sufficiently to show you the finished product, but you will see from this experiment enough to give you some idea of what is done on a works scale.

I should like to record my thanks to Messrs. Gallenkamp for so kindly allowing me to use their blocks as illustrations of this paper.

The CHAIRMAN: The subject is now open for discussion and I shall be glad to hear any of those present who may like to speak or ask questions. The time is going on, so I hope you will not be long before expressing the points you want to raise.

Mr. W. McLAREN: I have had much pleasure in listening to the two lectures to-night. There is one particular point upon which great stress has been laid: the calorific value. I should like to ask Mr. Chaloner what is the relation of the calorific

value of fuel oil, and the power, or explosion, of impulse conditions of that oil. The calorific value has only been alluded to by the author as high or low, the high, involving the least quantity used per h.p. or s.h.p., and the low calorific value, the greatest quantity of fuel to do the same amount of work. The problem is that we get heat developed and an explosion inside a closed cylinder to push a piston up, or down, or in whatever the direction is desired; and then it has been found from experience that we must be careful to have cooling water round the cylinder in which the explosion is created. I would like it if Mr. Chaloner could enlarge upon this. Mr. McKenzie has shown us a pump attached to the calorimeter. What allowance for difference of room temperature is made in that experiment?

Mr. F. O. BECKETT: The oil supply question has been well demonstrated to-night. We have been told of the flash point as having a variation of 9.5° by testers. Is there not a parallel here between the operator who can make clear ice and the one who makes cloudy ice? The experimenters on the flash point according to their carefulness and expertness in taking the temperatures vary in degrees. On board a ship I cannot quite see how one can arrange, especially where there is any sea on, for demonstrating the points raised. In regard to some spirits, when being conveyed through the Red Sea, with the rise of temperature on the ship's skin tending to give a greater volume, is there any possibility of the temperature so rising as to alter the bulk of the spirit, to become a source of danger to the crew and to those who have to handle the discharge of the cargoes? I think the Institute is to be congratulated in having such a lucid demonstration as we have had to-night to open up the course of the special programme on the internal combustion engine.

The CHAIRMAN: I am disappointed that so few have found it possible to join in the discussion. The papers in both cases have been well worth discussion, and perhaps Mr. Chaloner will forgive me when I say that Mr. McKenzie's paper has appealed a little more strongly to me, and I think from its character it should have given an opening for comment. Mr. McKenzie has spoken about the taking of samples, and this is the crux of almost everything in the way of testing. Nothing seems more crude than for a man to order steel bars and on delivery say that if one out of every hundred, taken as a sample fulfils requirements, the rest of that hundred shall be taken on the behaviour

of that sample. It seems a very crude way of testing whether a manufacturer has done his work or not. It appears from Mr. McKenzie that there are similar difficulties in the way of the chemist. The second point that occurred to me was in regard to calorific value, and the relative advantage of the internal combustion engine, as compared with the use of oil fuel in the furnaces of the boiler. If we take it that half a pound of oil is equal to one horse power on the engine, I find the efficiency is 25 per cent. We get 25 units out of every hundred; but if we burn it in the furnace of a steam boiler then we obtain about 18 per cent. efficiency, and in the same way the 21,000 units will mean that we shall have to burn one pound of oil to get the same results. This occurred to me, and although the figures are approximate only, it shows that the internal combustion engine offers infinitely superior results for the weight of fuel that is being used. Mr. Chaloner made an observation about a paper such as his being easier to read quietly at home by the fireside, saying that it was better to read the paper thus than listen to the speaker. I am not altogether at one with him there, because there is a personality about the reader of the paper that will frequently make it far easier to appreciate certain points in the paper. Very often this makes the hearing of the paper far more valuable than the reading of it in a quiet chair beside the fire. I think Mr. Chaloner will agree with me there. One other little point, before I close the discussion, and that is the engineers—and particularly those who have the handling of engines—frequently miss an important point, the problem of the conversion of the energy. I think Mr. McLaren's trouble may rest there. The whole thing, I think, can be simplified if you remember that external work is estimated by measuring two things. You observe the magnitude of the force and the distance through which it operates. It means, therefore, that to do work we have to produce external motion. We have to get something that will alternately expand and contract, and to continuously repeat the movements. We pull a spring down with an external force and let it go up again. We can make it go through these consecutive periodical motions which we call the "working cycle." This depends on the effect of heat on some body. You must have expansion and contraction of volume. If we study the thing from first principles, you will find that any substance will form a working substance. Take an iron rod; you can stretch it by adding weight; and it is doing work on the rod by stretching it, and this work is stored in the rod as a strain energy,

which may do work by traction when the straining weight is removed. If you heated that rod instead of loading it, you will produce expansion, and the rod will then act as just described. The iron rod would be very awkward, and impracticable as a working fluid but it illustrates the principle involved. Coming to substances like water, you know that if you boil one pound of water, you obtain a greatly increased volume of steam. There you have heat producing a great change of volume. There was the energy locked up in the fuel and released by the act of combustion, that heat is transferred to the water, changing its state from liquid to gaseous, the steam passes into the engine and expanding produces motion and so external work is done. In order that the steam may do its work again we cool it by passing it through the condenser, and so back to the boiler. In the internal combustion engine the engine does the whole of that trick in the cylinder itself. The pressure is there the same way again as the result of expansion. But the gases are ejected into the atmosphere, which takes the place of the condenser. We shall be very glad now to hear the reply of Mr. Chaloner and his colleague, Mr. McKenzie, to the several points raised.

Mr. CHALONER: It is rather disappointing that the discussion has not been more critical, because it is always accepted that the discussion following a paper is more valuable than the paper itself. Looking at it from a technical point of view one obtains a certain perspective, and with the practical engineer looking at it from the utility point of view certain points of mutual interest are raised.

The future progress of the marine oil engine will largely depend on the energy and resourcefulness that the marine engineer will bring to bear upon this important problem. I remember the case of a marine engineer who came on board a motor vessel knowing nothing or practically nothing of the internal combustion engine, who immediately began to criticise the general outlay and laboured somewhat on the disadvantages of closed in machinery. This is a characteristic peculiar to the marine engineer, and the sooner the designer realises this tendency the better it will be for the progress of the marine oil engine.

We say to-day that the internal combustion engine will return as mechanical energy some 33 per cent. of the total available energy of the fuel. This is somewhat low, but so far thermodynamics have proved that it is never possible to recover even

theoretically more than about 63 per cent. of the total available energy. So, if therefore you can convert 100 per cent. of heat energy into a possible 63 per cent. of mechanical energy, and if out of that we get a continuous return of 33 per cent. it means that we are getting a possible 50 per cent. of the available energy.

An average balance sheet for an internal combustion engine of the Diesel type would give the following data, allowing for the heat in the fuel as 100 :—

	Per Cent.
Heat converted into Mechanical Energy	30
Heat in Exhaust Gases	25
Heat in Circulating Water	30
Friction	12
Radiation and Windage	3
	100

In asking Mr. McKenzie to discuss the apparatus used for testing oils I hoped that it would make the paper more instructive and was very pleased to hear the Chairman's remarks on this point.

Whilst a considerable amount of study has been given to the chemical properties of oils I feel that the physical properties have been neglected, and it occurred to me that a further study of these physical properties will bring forth such information which will be extremely valuable both from the design and running point of view of internal combustion engines. The energy in the fuel is heat which has to be converted into mechanical energy, thereby passing through a good many phases which refer particularly to the physical rather than to the chemical properties. For instance, on a globule of oil being vapourised we are not quite sure as to what percentage of this vapour will be retained as permanent gas and what portion of it may be condensed into liquid again under certain unfavourable conditions. Furthermore the ignition point of fuels under practical conditions is entirely different from the temperatures obtained with the present apparatus and further information is necessary to obtain a clear picture of these properties.

I sincerely hope that the object of the Committee has been attained and that the sea-going engineer will obtain such information and derive such benefits from this course of lectures

as will enable him to become familiar with the different subjects relative to the design, construction and running of the internal combustion engine.

Mr. T. MCKENZIE: Time is passing and I will answer the two questions that have been put to me. Mr. McLaren has asked about the room temperature when using the bomb. We take the temperature of the room and record it. The water in the outer vessel is at the room temperature and the difference between that temperature and the temperature generated by the explosion inside the bomb gives us the figures from which we calculate the calorific value. With regard to the flash point, I am not sure that it is the human element that makes the difference. I think it is more probably due to the fact that we have not yet got the perfect apparatus. The tests obtained are usually pretty much the same when using the same apparatus. If we were able to evolve an apparatus in which the perfect conditions could be obtained, then the different operators would get concordant results. Another reason why I do not think it is due to the operators is that, with skilled operators naturally great care is taken in carrying out the tests, and yet we get these differences, and the differences are not always in the same direction. With regard to the expansion of oil, say in the Red Sea, this is allowed for in the expansion trunks. The coefficient of expansion of the oil is known, and allowance is made for this, so there is no danger to the ship or crew.

Mr. J. B. HALL: It has been a very great pleasure to me, as an old marine engineer, to listen to these two papers. I should like to bring very strongly to Mr. Chaloner's mind the fact that the absence of criticism must not be taken to show that the papers have not been good papers or instructive papers. For the moment it may be taken—I speak as a marine engineer—that the internal combustion engine, going into marine work has, in a manner of speaking, “over-run the constable.” For years and years the internal combustion engine has been used on land, and part of that time in the air. All this time the poor old marine engineer has been at sea getting the best out of the steam engine, and he has not had the chance to take up the study of the internal combustion engine or to take more than a passing interest in it. Then, with the easiest mind in the world, engineers have suddenly decided that these engines can go into steam boats, and they seem to think that one knows all about them. There is no doubt that in a very short time anyone who

calls himself an efficient marine engineer and has been engaged in looking after marine steam engines can, given the shortest amount of time, master the new machines. But we do not, all at once, appreciate the operation of the internal combustion engine, which is on the principle of "Twist the handle and off you go." You want to know something more than this, and I feel quite sure that at the end of this series of papers possibly a general discussion will bring out more criticisms than Mr. Chaloner would like to listen to. Just at present we are feeling our way, many of us, and there is still existing the good old style that we do not want to open our mouths and put our foot into it. I have very great pleasure in proposing a hearty vote of thanks to Mr. Chaloner and Mr. McKenzie for their papers, and to hope that at some future time we may hear, and especially see, more from the testing part of it. That is no doubt a very important matter at all times.

Mr. W. McLAREN: It certainly gives me great pleasure to second the vote of thanks proposed by Mr. Hall. I think he said enough to encourage you gentlemen to come again to enlighten us, even if we have not thrown bricks at you in the discussion. Once the pumps are set away for filling up the bunkers the engineer has very little chance of telling what sort of oil he is getting before he goes to sea, and I should not like the chief engineer to have the responsibility of purchasing the oil; so I say, leave it to the chemist. When the chief engineer gets the oil into his ship he makes the best he can of it. If it is bad he reports so, and that will be a black mark against the Company or individual who sells the oil. But that does not stop the engineer from dabbling in some chemical experiments. It surprised me to think that one would take such trouble for the sake of a hobby. We cannot do without the chemist. I have great pleasure in seconding the vote of thanks.

It was announced that on the 23rd November a paper entitled "Some Suggestions on the Training of Engineers," by Mr. Annsen J. Hall would be read. On November 30th there would be a cinema film on "The Production of Oil," exhibited by the courtesy of the Anglo-American Oil Co.