The price of coal was taken at 16s per ton, and it was assumed that an oil motor would consume one-eighth gallon per horse power per hour, the cost of oil being taken at 1s per gallon, which was considered a fair thing, both as to quantity and cost.

On the above basis, and assuming the launches to run 50 weeks per annum, the coal bill would amount to £196 10s; but if they were fitted with oil motors the oil bill would be £1045. He (the speaker) came to the conclusion that it was not so much that power users did not understand the oil motor, and, therefore, did not adopt it, but rather, that they knew they had in the steam engine a much more reliable and economical machine.

Mr. J. Scoular said that the Author, in bringing this subject before the Association had, from a mechanical point of view, very ably described the action of this particular type of engine; and in considering the subject, it occurred to him (the speaker) that the value of the paper would have been somewhat enhanced had it been accompanied by diagrams of tests, and comparisons of the various qualities of oils generally used.

There could be very little doubt that the oil engine was worthy of more than ordinary consideration by engineers, but, no proper comparison could be made of the type referred to, unless the composition and thermal value of the class of oil used was known, and, unfortunately, this information was not given to any great extent in the paper.

If these points could be definitely stated, it would enable its merits to be calculated on a thermal basis, per brake horse power hour, instead of the usual method, so much oil per B.H.P. costing so many pence per gallon, varying with the rise and fall of the market.

If the Author, in his reply, could give the calorific value of the oil used in thermal units per lb., the percentage of heat absorbed by engine friction, percentage of heat utilised for effective work, percentage of heat carried off by water jacket, and percentage of heat carried off by exhaust; then a direct comparison could be made of the thermal efficiency of this type with a steam or gas engine.

Some writers were of the opinion that, speed had little or nothing to do with the economy in oil engines, as it was not an object of conserving the heat, as in steam engines, but rather to get rid of it as early as possible after the explosion had done effective work in the cylinder, and no doubt high speed oil engines would permit of a greater quantity of heat getting away in the exhaust and less through the jacket water, than in slow speed engines. The speeds mentioned by the Author, of from 1200 to 1500 revolutions per minute, for a four cycle engine, appeared to be very high, and it was the opinion of some authorities that useful work could not be obtained when running at such high speeds with the combustion motors.

In calculating the horse power, the Author used a constant of 900 for two cycle, and 1000 for four cycle engines, which was, presumably, a method used for nominal horse power only, but, in working it out, compared with the general rule.

$$\text{I H.P.} = \frac{\text{P.L.A.N.}}{33{,}000}$$

Where P. = M.E.P. in cylinder.
L. = Length of stroke in feet.
A. = Area of cylinder in square inches.
N. = Number of explosions per minute.

For a two-cycle engine running 220 revolutions per minute, 11in. diameter of cylinder, and 1ft. 6in. stroke, when worked out on the Author's basis, would give 34.833 horse power, and, for a four-cycle engine, of the same size and speed, 31.35 horse power; but, if worked out by the general rule, it would be found that the M.E.P. required would be 36.75lbs per square for the two cycle, and 66lbs. per square inch for the four cycle engine, to correspond with the horse power arrived at by the Author's formula, and it was difficult to understand why there should be such a difference in these pressures.

It was claimed by some authorities, that on high class engines, with electric ignition, the consumption would be from 15 to 17 per cent., and it would be interesting to know if this applied to the type of engines referred to by the Author in his paper.

MR. HERBERT E. ROSS (a visitor) said that the paper on oil engines had been brought forward at a most opportune time, and the Author had laid down the principles and the general construction in a plain and simple fashion clear to everyone; but it would seem that the paper was somewhat wanting in details. This was probably due to the Author having purposely left such points for the discussion, and this was his excuse for giving the results of his own experience.

It might surprise some present to know that the estimated world's output of oil engines for the year 1903 was something over 32,000, and that to-day there were probably more oil engines than steam engines at work, notwithstanding that the latter had the start of nearlv a century. Of course, the motor bicycle and automobile was the cause of this immense increase; and it said much for the simplicity of the oil engine that nearly the whole of these engines were in the hands of amateurs without mechanical experience.

He did not propose to discuss at length the type referred to by the Author, as the design of the engine itself would be, in fact, a credit to any country. The intention had evidently been to make an engine "fool proof," and yet to sacrifice nothing of much consequence in doing so. Had he not been aware of this most important phase of the question, he might have found fault with tube ignition on the score of efficiency, and spray vaporiser for the small loss of economy involved; but to alter either would mean possibility of trouble and more attention in the hands of the inexperienced.

Having had a good deal of experience in oil engines generally, which used both light and heavy oils, he might be permitted to discuss some important features in detail.

It may be said that 90 per cent. of the troubles with naptha engines were due to faulty ignition; five per cent. to imperfect mixture, and the balance to general causes, leaky valves, etc., assuming alwavs that the engine was correctly adjused for the several functions of the cycle.

Ignition by internal break spark as referred to by the Author was the best for marine and stationary engines as it caused least trouble from leakage of he high tension current required. The induced current required with an ordinary compression of 45lbs., was about 9 million volts, and this great intensity had to be insulated so as to jump the spark at the required place only. Anyway the spark at atmospheric pressure must equal not less than $\frac{3}{8}$ inch long in order to cross 1/50th inch gap under that pressure of 45lbs. in the cylinder; the internal break, moreover, gave a full bodied spark of great temperature, and on that part of the question, he would have something to say later. Further, the use of a simple primary induction coil was safer than a high tension secondary, as the latter was more liable to electrical damage.

There were two remaining systems of electric ignition, both using insulated ignition plugs, and secondary induction coils, one with mechanical, and one with electrical, external, make and break. The latter was the better, and was now finding universal use on motor cars but the use of insulated plug was unsuited for marine work as the spray or moisture would short circuit the current, across the insulating material, and where mechanical break was used there was some danger of an explosion taking place at the wrong time, throwing great stress on the crank shaft, through a drop of such water getting on the contacts.

There was no mention in the paper of timing the ignition point. This was important on all small engines, and, where any degree of economy was desired, it was essential. It might be explained here that the ignition in oil engines did not take place at the end of the stroke (except in large engines), but took place some time before, depending on the length of stroke; for instance, in a 5 horse power engine, running 1200 revolutions per minute, the ignition took place earlier, at slightly over $\frac{1}{2}$ stroke. It was here that the electric ignition was so much superior to the ignition tube.

With the tube, the point of ignition could only be slightly varied by the length of the tube, and was then always uncertain as to timing. The retarding of the ignition, however, was of little consequence at low speeds or in engines of over 9 inch stroke.

An engine tested by him of $4\frac{5}{8}$ diameter, and 6 inch stroke gave 5.1 brake horse power with ignition point 2 inches from end of stroke, but, under the same conditions and speed, only 2.8 horse power when ignited at the end of the stroke. This, he thought, would show the importance of timing the explosion.

The Author had stated that the vaporiser was preferred to the carburetter. It was well that the distinction had been pointed out; however, carburetters such as he mentioned, were no longer in use, and the spray carburetter was in one form or another now universal. But it was known as a carburetter in all its forms, and though the name might be a misnomer, it was well to admit it, as it had come to stay.

In the mixing of the vapour with the requisite quantity of air, he had found that a definite time must be given to the operation, and though he had never heard this fact remarked, it was important and affected the economy of the engine considerably. By this he meant that if a carburetter was put close to an engine, the power for a given quantity of naptha would be less than if the carburetter was placed further away to give the molecules a more definite time to become associated before reaching the cylinder. This was not a matter of mechanical mixing, as it appeared to be the same whatever class of carburetter was used.

There were dozens of different carburetters in use; but for all classes of stationary and marine engine he would favour a spray carburetter, in which a jet of liquid was projected into the mixing chamber by the action of a small, light shutter opening a supply valve, the spray having been, preferably, disseminated on to wire mesh grids, five or six in number, through which the air was drawn. Such a carburetter would not do for motor cars, but was otherwise preferrable to the small chambered valve carburetters or the ordinary float feed type.

Lubrication was, obviously, a most important consideration, and in most high speed engines the crank case was enclosed and air-tight, and a supply of oil therein was splashed about, serving to oil the crank main bearings and piston. The oil was replaced at intervals, as it became thick with use, and the products of combustion. He had recently successfully used a lubricator which in every stroke measured a quantum of oil into the case, a second valve letting a similar amount out, which was caught in a receiver and filtered for a second use.

Apart from constructional disadvantages, this system of enclosed crank case he thought was the best, as, apart from filling the outer reservoir, there was no other lubrication whatever. Of course, an excess of oil was circulated. The valve spindles were lubricated by $\frac{1}{4}$ inch brass tube led from the crank case, and enough oil was carried from the spray of oil in the case to keep these well oiled. He did not find any need for ventilating the crank case, and, although some very high-class marine engineers were entirely without crank cases, he considered them desirable in all engines of a speed of more than 250 revolutions per minute.

The best system of governing was undoubtedly by throttling the exhaust. The engine ran steadier, and the oil was economised, because when the exhaust products were not wholly discharged, the succeeding suction did not take more than a fraction of the full charge. The several systems of governing the inlet or retarding the ignition were neither satisfactory nor economical; an ordinary governor operating a butterfly valve was usually sufficient.

There was not time to discuss the many varieties of kerosene oil engines, but he would like to say a word more on some of the strange and unexplained peculiarities of the internal combustion engines using naptha or gasoline.

(1) A residuum of exhaust gases up to 8 per cent. volume appeared to increase the energy of the explosion. This seemed unreasonable, but it was very evident on trial. It did not apply to gas engines where scavenging had been shown to have the very opposite effect. He attributed the effect to a better association of the air and vapour owing to the heating of them by the hot exhaust gases intermingled. This peculiar effect had an important bearing on two cycle engines.

(2) A small proportion of water or steam, admitted so as to not interfere with the ignition, increased the energy of the explosion very considerably, though one might expect the opposite, but the valve surfaces were rapidly destroyed, and a different series of ultimate products were formed.

(3) The energy of the explosion depended upon the temperature of the ignition. For this reason, a tube explosion generated less pressure than a hot spark explosion. There were formed different ultimate products in the exhaust, depending upon the temperature at which the explosion started. This was very remarkable and had not, as far as he was aware, been before noticed. It was analogous to the combustion of, say, dynamite, which, when burnt, generated one series of gases slowly, and with little energy, but when detonated, generated an entirely different series of gases with great rapidity. The gain between a hot spark and a mere ignition in a test made was nearly 15 per cent., due to the hot ignition, all other things being equal.

(4) Finally, as to pressure of the compressed charge before igniting, it was, of course, well known that the greater the pressure before ignition, the higher the power value of the oil.

The extreme instance of this was met in the Diesel engine, which compressed the air independently up to and over 600 lb. per square inch, and was able to produce, from crude oil, power at the rate of one-tenth penny per horse power per hour. It might be mentioned here that the ordinary small stationary or marine oil engine had a thermal efficiency in brake horse power of 16 per cent. on naptha, corresponding to a consumption of 1.23 pints of naptha per brake horse power per hour, but the consumption had reached as low as .8 pints, under specially good performance in engines.

The Diesel using naptha on moderate compression had run on ½ pint per hour, showing a thermal efficiency of about 27 per cent.

In such an engine as that referred to by the Author, the cooling water carried away 45 per cent. of the thermal units, the effective power, say 18 per cent., the balance of 37 per cent. passed away in the exhaust at a temperature of from 600 to 1200 degrees.

Mr. Lowe (a visitor) said that some of the speakers in the course of the discussion, had alluded to the question of ignition, and as the Author's paper, and most of the discussion had ranged around the subject of the motor engine, the electric spark was more or less implied.

On the subject, however, of oil engines proper, as distinguished from gasoline or petrol engines, the question of a reliable and economical ignition was of primary importance, roughly defined under three classes, viz.—Electric ignition, from a battery and coil, magneto machine or dynamo; ignition by means of a ball, plate or tube enclosed in the explosion chamber, which having been previously heated by means of a lamp, was kept hot by the constant explosions, and thirdly, ignition by an external lamp and tube as in the case of the ordinary gas engine.

When the fact was taken into consideration that the majority of stationary or portable oil engines were placed where gas was not available, away from towns, and where repairing workshops and men were not available at a moment's notice, one might eliminate the electric ignition, as if it was not well understood, any slight damage to battery or wiring would bring down odium on the engine itself.

In the ordinary oil engine, of which a vast number of different types were now on the market, the majority were fitted with the second class of ignition. In this class, his firm had been interested at one time, and had turned out a large number which were installed and did successful work at home and abroad, but they now claimed to have established, by exhaustive tests, that the method was not economical under all conditions of load.

In the case of a 12h.p. engine installed to drive a threshing plant and various agricultural machines, when working at full load on the thresher, the explosions would be constant, every other revolution, under a consumption of about 12 pints of ordinary store kerosene per hour, or roughly one pint per horse power per hour. But suppose the same engine were switched on to a small chaff cutter, absorbing only one or two horse power, the explosions on economical lines would be so few and far between that the exploding surface, deprived of its source of heat, would rapidly cool down and the engine would stop, unless the meagre dimensions of the bearings and the general design of the engine were such as to throw a considerable load on the mere driving of the engine itself.

By an experiment it was found that taking such an engine and materially increasing the diameter and length of all bearings, so as to reduce the pressure per square inch to a point where the journals were practically floating in oil, while it increased the efficiency at full loads, it became almost impossible to govern the engine correctly, or even to run it at all for any considerable time at loads far below the maximum.

With the tube ignition, however, the engine could be run equally well under full load, and no load at all, and at the same time, by vapourizing the oil outside the cylinder in a suitable vapourizer attached to the back cover, the carbon, vaseline, and other impurities found in ordinary cheap store kerosene were retained in the vapouriser, which was easily cleaned out in a few minutes, instead of being dposited on the walls of the cylinder itself.

The lamp, which simultaneously heated the vapouriser and tube, should work by gravity, and forming its own vapour should burn as a small but fierce gas jet, requiring no assistance in the way of air pumps, it should also be protected by a removable iron screen to prevent it being blown out or deflected by draughts.

The governing of the engine under this system could be controlled by the shaft governor acting through a lever on the combined air, vapour and pump lever, and so delicately and accurately fitted that an engine and dynamo coupled direct on one base should burn one single light as steadily as a full load without the addition or assistance of accumulators.

One of the previous speakers had alluded to the difficulty in cleaning out the water jacket. Considering the carelessness often shown by attendants, and the dirty nature of the water sometimes collected in the tanks, it was surprising to find that means had not been generally taken to render the jackets more easily cleanable. This point had occupied his attention some time ago, with a view to making the top and bottom of the jacket surface flat, and the plates which covered these removable, so as to expose the entire surface to view for purposes of cleaning.

Reverting to the subject of lamp ignition by tube, it was interesting to note the importance of the form of the flame necessary and the exact position on the tube at which