

## Discussion.

Mr. Berkley. Mr. GEORGE BERKLEY, President, said he was sure it would be the desire of the members to pass a cordial vote of thanks to Professor Unwin for his interesting Paper, which he hoped would lead to a useful discussion. He also stated that the following telegram had been received from Lord Kelvin:—"Wish could be present to-night, Civil Engineers, to say how much pleased I am to find Priestman's engine now a practical success, having investigated it and formed very favourable opinion of it four years ago when in experimental stage.—KELVIN."

Professor Unwin. Professor W. C. UNWIN thought that the thanks of the Institution were perhaps due rather to Messrs. Priestman than to himself. They had placed their engine unreservedly at his disposal for experiment, had supplied the diagrams exhibited, and had taken the trouble to place in the room an engine and also illustrations of parts of their engines. It had occurred to him that, as the entire action of combustion in this machine was of a somewhat different type from that in an ordinary motive-power engine, it might be useful to give some illustration of the actions which took place. He wished first to emphasize the difference insisted on in the Paper between what he termed safe and dangerous petroleum oils. He had before him some benzoline, which was a light petroleum oil, and it would be seen that he could ignite it with a taper at a distance of 2 or 3 inches. He had also a sample of the Russolene oil which was used at the trials at Hull, having been taken out of the oil-tank of the engine after running about four days; and it would be seen that it would not only fail to ignite like the other, but that it would extinguish the lighted taper applied to it. He had likewise before him the spray-making apparatus of the Priestman engine. The oil-tank held enough oil for a day's working, and in it a certain pressure was kept up, as shown on the gauge. From the tank, by means of a cock, the oil could be turned on either to a kind of Bunsen blow-pipe, which was used for about five minutes in starting the engine, or into the spray-maker. He would first turn it into the lamp used in heating the vaporizer, and afterwards show the unsprayed oil-jet, the formation of the spray in the spray-maker and its ignition. Members would see what a very small jet of oil was required in working a 5-HP. engine. When the air was turned on, the oil

was sprayed into a cloud of very fine particles, which remained suspended. The experiment would show that the particles of liquid oil were so small as to burn even though not vaporized. Messrs. Priestman exhibited a whole series of spray-maker nozzles, which had been used during experimental trials lasting about two years. The long fine orifices used at first were failures, and ultimately the re-entrant type was adopted. The igniting arrangement could be seen. In order that the members might see how little trouble the battery involved, he showed some of the materials. The little bottle which he held in his hand contained the entire charge for thirty working hours. In another bottle was a small quantity of sulphuric acid, which, added to the battery charge when it became weak, made it work for ten hours longer. The battery in the box was connected with an induction coil. The current passed to a pair of platinum wires, which were carried into the cylinder through two porcelain plugs in a brass block. The block could be unscrewed from the cylinder, if it were necessary to have access to the electrodes or sparking points. Contact, completing the electric circuit at the right moment of the stroke, was made by an eccentric, which brought a contact-piece between two springs and gave the sparking seen in the experiment. So far as his experience went, the points remained perfectly clean. He had never seen a missed explosion which could be attributed to failure of the igniting arrangement. Referring to the 1-HP. engine exhibited in the room, it would be seen that there was only one eccentric, and that this had three functions. First, it worked the compression-pump which supplied the air to the oil-reservoir to force the oil into the spray-maker nozzle; secondly, at the right moment of every second revolution, it opened the exhaust-valve of the engine and allowed the exhaust products to pass away; and, thirdly, a pin attached to the eccentric made electric contact at the right moment of the stroke, causing ignition. In the Paper he had treated especially of the Priestman engine, because he had had the fullest opportunities of testing it in every possible way. He had no desire to discredit other engines, which he should have mentioned more fully if more particulars had been known about them.

Mr. W. W. BEAUMONT rose to thank the Author for his valuable Paper, which, although dealing from the practical point of view chiefly with the Priestman engine, embraced so much that bore upon the principles and actions upon which all the other engines depended, that every one interested in the petroleum engine must feel grateful to the Author. It was unnecessary to say of a

Mr. Beaumont. Paper by Professor Unwin that it was remarkably complete. He noticed that, in addition to giving figures with regard to oils and their behaviour, the Author had made some remarks about the importance of the oil-engine in the future. The facts given by him with regard to their low consumption, and the knowledge they had of the very low price at which shale-oils might be produced, which would probably be further reduced hereafter, lent still greater importance to the oil-engine of the future. The Paper was illustrated chiefly with reference to one engine; but it might perhaps be not out of place if he described another engine, of which he had had occasion to make a trial recently. It was known as the "Trusty" engine, and differed in some respects from that of Messrs. Priestman. Like it, however, it much resembled the gas-engine, in fact it was the Trusty gas-engine with a few minor alterations. To begin with, the oil used in working the engine was sent, drop by drop, from a small column into a jacket formed round a vessel in such a manner as to somewhat resemble a hat stuck on the back of the gas-engine cylinder. The oil was pumped into the receiver by a small pump, with a piston plunger not much more than  $\frac{1}{4}$ -inch in diameter, in a 4-HP. engine; and was taken from any ordinary oil-supply, such as an oil-can standing near the engine, and was received, drop by drop, as the engine wanted it. The little pump was actuated by the hit-or-miss form of governor, by which the engine was governed; as the engine increased in speed, the governor acted so that the oil-pump piston was not moved. When the engine was doing full work, and there were no misses, the pump made one stroke through the medium of the governor, at each second revolution. The oil dropped into a vaporizing-chamber, which formed the back of the cylinder and was heated by the combustion of the vapour in the working-cylinders. The vapour or gas (the Author had said that in those engines the oil was gasified) was allowed to pass from the jacket into the working-cylinder by means of a valve, which was actuated from the same eccentric and lever as that which worked the little pump described above. Then the engine drew in the mixed charge, exactly as a gas-engine did. There was no mechanism of any kind for spray-making beyond what he had described; and the ignition was effected by a small tube, exactly like the igniting tube in most gas-engines, with which every one was familiar. The engine ran at a rather high speed, and the trials he had made, though of short duration, were sufficient to give figures which he considered quite reliable. The oil used

during two experiments was the Broxburn lighthouse oil; and, Mr. Beaumont. during another experiment, a very much heavier oil, the flashing point of which was about 250° Fahrenheit. With the lighthouse oil, which had a flashing point of about 150° Fahrenheit, the amount used per brake HP. was 0·963 lb., but the oil used per I.H.P. was a little less than 0·7 lb.; so that the engine showed a rather low mechanical efficiency, although the performance upon the brake was so satisfactory. The cost of the oil, at 6½d. per gallon, worked out to 0·77d. per brake HP. per hour, and 0·53d. per I.H.P. per hour. The efficiencies of the engine were—brake, 14 per cent., indicated, 20·3 per cent., heat carried away by jacket, 19·3 per cent. It would be seen that these figures were very nearly the same as those given by the Author. With regard to the experiments made with the heavier oils, it was found that there was rather more of what might be called a residuum. With the Broxburn oil there was very little residuum, and never such as to prevent the working of the engine for a great length of time. In any case, the oil being passed into a jacket, or into series of passages, which were easily cleaned out, and the hat which he had mentioned at the back of the cylinder being very easily removed, this would be a matter of very small importance; but, curiously enough, it was found that with the heavier oils the engine, which would work well at a certain horse-power for almost any length of time, would not work for the same length of time unless the brake horse-power were lowered; but that was only for what he might call a mechanical reason—at any rate, a thermal reason that could be easily removed by mechanical means; this was, that the jacket at the end of the cylinder in which the gasification took place became much hotter when using the heavy oil. For instance, an engine which gave satisfactorily, for any length of time, 6 HP. on the brake, worked best at about 4 HP. with very heavy oils, the flashing point of which was 250° Fahrenheit. It was obvious that the difficulty could be easily overcome; and he need hardly say that it would be a matter of great importance to be able to use, in some cases, those denser oils. The difficulty with regard to the separation of oils into the several forms of lighter, and less light, and heavier oils, and so on, which the Author had mentioned, seemed not to occur at all in an engine in which the oil went, drop by drop, into the small vaporizer. Reference had been made to a gas-engine, and figures were given, by Professor Witz, showing that the consumption of fuel was exceedingly small. It might be worth mentioning that in this country very large

Mr. Beaumont. gas-engines were now in use, and that, by means of the Dowson gas, even in London with very large powers, the consumption had been brought down to 1.6 lb. He had recently been present at the trial of another gas-engine, also worked by means of the Dowson gas, in which the consumption of fuel was only 1.16 lb. of coke and anthracite—coke being used in the gas generator, and anthracite and coke in the steam boiler. The engine under trial, which was known as the Cycle engine, was driving a directly-coupled pump. That was at the Uxbridge Waterworks. The pumps were of the Atkinson type, and the fuel used was only 1.65 lb. per actual HP. per hour in water lifted. When, therefore, they saw what oil-engines did at the present day, and what the gas-engines could do, running up to 140 HP., they must begin to admit that a time had arrived already when the steam-engine, in many places, must do what Sir Frederick Bramwell said some time ago it would have to do—take a secondary place as a prime-mover.

Dr. Anderson. Dr. W. ANDERSON said the telegram just received from Lord Kelvin reminded him that, as engineer to the Royal Agricultural Society, he had examined a good many petroleum-engines before 1888; but none of them were of a practical kind, and he believed that none had since come to anything. The Priestman engine was first exhibited in 1888 at the Nottingham Show, and it became his duty to test it. The result was that it gave a brake HP. for 1.73 lbs. of oil, which agreed very closely with the results obtained by Lord Kelvin. The engine, on that occasion, obtained the Society's Silver Medal. In 1889 the same sort of engine was shown, but in a portable form, for use as a farm engine, and it then gave a brake HP. for 1.42 lbs. of oil. It was tried again at Plymouth, where it performed the same work for 1.243 lbs. Finally, in the Paper, the Author gave a result of 0.946 lbs. So that year by year the performance of the engine had steadily improved. It was now in a state in which it could compare favourably even with coal. The engine of 1888 had the defect of the oil being not wholly consumed, so that when a sheet of paper was held over the exhaust pipe a considerable spattering of unconsumed oil became apparent. That was completely cured in the second engine. The defects of this class of engine were that, in the first place, in common with most gas-engines, it only gave one effective stroke out of four; and in the second place, a great deal of heat was lost in keeping the cylinder cool, and by the high temperature of the products of combustion passing out of

the exhaust pipe. The percentages of loss given by the Author Dr. Anderson. showed at once the direction in which improvement should be sought; and he could not help thinking that a combination of the direct-combustion engine with the petroleum spirit-engine would probably turn out to be the best for economising the heat.

Sir JAMES N. DOUGLASS desired, before dealing with the Priest-  
man oil-engine which the Trinity House had had under trial  
during the past twelve months, to refer to his own reasons for  
taking a peculiar interest in this subject. He had been in-  
terested for many years in coast fog-signalling, and had been  
using small motors, both ashore and afloat, of nearly all de-  
scriptions from  $\frac{3}{4}$ -EHP. up to 10 EHP., and for many years  
he had longed for a good petroleum oil-engine. Many engines,  
as Dr. Anderson well knew, had appeared, which were not  
petroleum oil-engines, but petroleum spirit-engines, and these  
were exceedingly dangerous to use. When a man had a spirit  
fuel to deal with, he was hampered not only in its transport, but  
by the danger attending its use. As far back as the last London  
meeting of the Royal Agricultural Society, a petroleum spirit-engine  
was exhibited; and, since that time, others had appeared, but they  
were not in reality petroleum oil-engines. The credit of producing  
a reliable engine for burning safe petroleum oil was doubtless due  
to Messrs. Priestman. In the Trinity House service, for fog-  
trumpets, they had been using the old hot-air engine of Ericsson  
with great success for many years. The first Ericsson engine was  
introduced to the Trinity House by Dayboll, of Washington, the  
inventor of the first practical coast fog-trumpet. He brought an  
engine and apparatus of  $\frac{3}{4}$ -EHP. to this country, which was tried  
by Faraday in 1862 for the Trinity House, and was found to be a  
very efficient instrument for its power. The engine was doing  
good work on board a lightship after thirty years' service. The  
Ericsson engine was at first despised by engineers. No doubt it  
was a cumbrous machine for the power developed, but it was remark-  
ably economical in fuel; and there was no more risk of explosion  
with it than with an ordinary fire-grate. For fog-signal purposes  
it had been found very useful. Dayboll told an amusing story  
of the first introduction of the engine by Ericsson himself. Day-  
boll had set up a fog-signal at Beaver Tail Island, Providence.  
He was seeking for a motor, and a donkey was suggested, and was  
installed at the lighthouse establishment. On the American  
coast, however, they had fogs even longer in duration than those  
in this country. Of course, therefore, the donkey gave way, and

Sir James  
Douglass.

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when Dayboll told his story to Ericsson, he said, "My machine is the very thing for you." Dayboll then invested in an engine and brought it to this country with his trumpet. It turned out to be a most useful apparatus. The Ericsson engine was succeeded by an engine by Brown, of New York, which was found to be a great advance; one important feature being that it could be started in a much shorter time. The former was slow in starting, the time occupied, unless it were previously heated, being about two hours; but the latter could be started in between fifteen and twenty minutes. For coast fog-signal purposes it was found to be a very handy machine, and more economical in fuel than the Ericsson engine. The Bucketts hot-air engine had also been adopted for coast fog-signals; and lastly, the French Benier hot-air engine is now under trial. In all those cases steam certainly compared unfavourably with fuel, because the powers were low. With caloric engines they got good work with an expenditure of about 3 lbs. of ordinary gas coke per brake HP. There was one circumstance connected with the petroleum oil-engine, which was apt to be forgotten—namely, the difficulty under which they laboured a few years ago, in obtaining reliable highly-refined petroleum. There was a want of uniformity in the oil, owing to the want of perfect distillation; but now the best paraffin made in Scotland and the best petroleum imported were as pure as sound old whiskey, and at all times perfectly reliable. That was a very fortunate circumstance in connection with the introduction of the petroleum oil-engine. They were apt also to compare the petroleum oil-engine unfavourably with the steam-engine. He thought that, for many purposes for which the petroleum-engine was used and would be used, it had a considerable advantage over steam. They should not forget that a steam-engine required an attendant, whilst a petroleum-engine, if it were a good one, and well constructed, might be left like a gas-engine working for several hours without attention, provided that lubrication was carefully attended to. This was an important feature, especially in the Trinity House service, where many of the engines were afloat. They were not worked by mechanics, but by trained seamen afloat, and by trained lightkeepers ashore. Those men, after good training, generally managed the apparatus in their charge as well as a mechanic. A mechanic, however, was sent whenever important repairs were required. With regard to economy, they had had a 5 EHP. engine by Messrs. Priestman at Dungeness for the last twelve months, and he was perfectly satisfied with its performance. They had obtained the same real economy

as that stated by the Author of the Paper, the figures being remarkably low. It was superior in that respect to any steam-engine of equal power that could be met with. There were two points, however, which perhaps he ought not to mention, as he might be considered too exacting in referring to them. If he were to say that they had experienced nothing but success that would not be precisely true. On one occasion a fire occurred, but it was a very unimportant one, and was due to the attendant breaking a gauge-glass, and allowing the air and oil from the oil chamber to squirt out upon the flame of a hand lamp. That frightened the keeper, and he left it, and could not return until the two or three gallons of oil in the chamber had been consumed. In another case, during the hard frost of last winter, the water-jacketed cylinder was split by frost. A recurrence of this had been prevented. He only mentioned those circumstances because he would be wrong in saying that everything had gone on with perfect success. Generally speaking, however, the engine had been successful at Dungeness, and, for similar purposes, he did not know anything that was comparable with the Priestman oil-engine. He referred especially to the Priestman oil-engine because he was not practically conversant with the details of many others lately introduced; all of which appeared to be as yet in a condition of development. They had nothing at present which appeared to be absolutely perfect, but he attached very great importance to the spray-maker. With good oil they had complete combustion at all times, with great regularity. Further than that, the interior walls of the cylinder of the Priestman oil-engine were perfectly lubricated. They might take off the cylinder cover, and examine the cylinder after a month's run, and everything would be found in a satisfactory condition—a circumstance which was very gratifying. With regard to economy, his feeling was that it was greater than that of the gas-engine. Taking petroleum for driving the engine, and converting it into gas, it would be found that about three times as much would be required to do the same amount of work as if the oil were used direct. The relative economy of oil and oil-gas for engines had been practically proved in the service of the Commissioners of Northern Lights by Messrs. Stevenson. At Dungeness, soon after the engine was started, it was found necessary to stop it every four hours to renew the charge in the oil- and compressed-air chamber. They had since introduced an underground tank for the mineral oil, with a small pump for transporting the oil from the lower tank to the chamber; so that, the

Sir James  
Douglass.

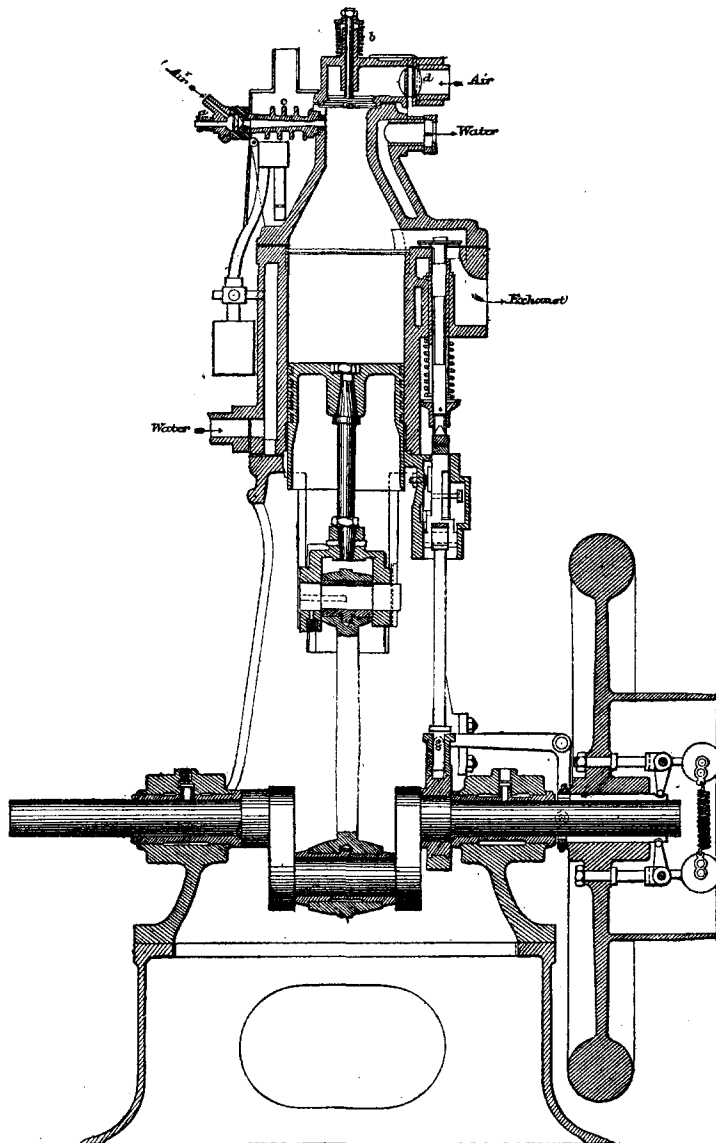
Sir James  
Douglass.

engine could now be run for any number of hours without stoppage; this was very important in the case of a long fog. It might therefore be said that the petroleum oil-engine could run almost automatically for any length of time, up to, say, thirty or forty hours during a fog; this was as near perfection as they could desire to have anything of the kind for such a service. Of course, there were many other services in which a small motor of that kind was required. Dr. Anderson had referred to the experience of the Royal Agricultural Society, when the gas-engine was first introduced. In like manner, he had always found that there was a strong prejudice amongst his mechanical friends against small motors. It was generally considered that for small powers there was nothing like a steam-engine. Formerly, people were not disposed to adopt a gas-engine, and the same might now be said generally of the oil-engine. The drawback with steam was the requirement of a steam-boiler for every motor, small or large.

Mr. Fisher.

Mr. O. FISHER considered that whenever the uses of petroleum in prime movers were discussed, it was of universal interest that all inventions of that class which had met with practical success should be mentioned. The Capitaine Patent Oil Engine (*Fig. 11*) was one of the first in which ordinary petroleum had been employed as the source of motive-power. It had been in use for three years, and had been introduced into this country; it might therefore be of interest to those who were considering oil-engines to have an explanation of the motor, as it differed in some important respects from the prevailing type. The engine consisted of a vertical cylinder, the piston of which was truncated like those of gas-engines. The piston was connected with a cross-head, which, sliding in a guide, further secured a precise motion with the least possible wear. The piston thus turned the horizontal crank-shaft at the bottom by means of the piston and connecting-rods. Surrounding the cylinder was a jacket, in which circulated the cooling-water. The top part of the cylinder formed a compression- and combustion-chamber, which was surrounded with a water-jacket. The ignition-tube, which was formerly attached to the vaporizer, had now been done away with, and therefore there was no need to talk about its life and renewal, as far as the Capitaine oil-engine was concerned. The ignition of the explosive charge took place in the vaporizer, an action which had the following advantages. Formerly, the lamp had first to heat the ignition-tube, but now the heat produced by the lamp was exclusively utilized in the vaporizer, thereby causing greater heat in the vaporizer, which again effected a more complete

Fig. 11.



THE CAPITAINE OIL-ENGINE.

Mr. Fisher. vaporization of the petroleum; in consequence of that the ignition in the vaporizer was more effective, and, after the ignition had taken place, a more powerful flame was forced into the combustion-chamber; therefore the combustion was more complete, and the efficiency of the motor increased, whilst less soot was deposited in the interior of the engine. In engines with ignition-tubes there was no way of avoiding the deposit of retort-carbon in the vaporizer; this ultimately tended to clog the valves, &c., and frequent cleaning was required to overcome the difficulty. When ignition took place in the vaporizer, that was quite different. The ignition-flame forced itself instantaneously through the vaporizer, thereby preventing the formation of retort-carbon; and for that reason vaporizers in which ignition took place never needed to be cleaned, and at the same time the soiling of other parts of the motor proved to be less, and the efficiency was increased. In the Capitaine oil-engine, nearly all the products of combustion escaped through the exhaust-valve, and therefore it was advisable to clean it once a week, provided the engine had been in use sixty hours; but it had proved quite sufficient for the other parts of the engine to be cleaned once a month. The diagram would show that ignition took place at the dead point. Instantaneous ignition at the right time was obtained in the following manner:—The feed-pump injected oil into the valve *a* before the downstroke of the piston, or just before the period of suction commenced. On the downstroke of the piston, the space in the interior of the cylinder was enlarged, causing rarefaction, whence the pressure of the outer atmosphere opened the valves *a* and *b*. The petroleum previously injected into the spraying-valve *a* was met by the incoming air and sprayed into the vaporizer *c*; coming into contact with the cherry-red walls of the latter, it was instantaneously vaporized, and admitted immediately into the cylinder in which the suction took place. The vaporized petroleum issued from the vaporizer long before the end of the period of suction, whereas the air was admitted by the valve *a* into the vaporizer as long as the process of suction continued. Consequently, when the period of suction was at an end, the vaporizer was filled with air; and, as the air inlet-valve *b* was also open during that period, the upper part of the combustion-chamber was likewise full of air. This column of air formed an insulator. It prevented the inflammable mixture from coming in contact with the cherry-red walls of the vaporizer; and, by the up-stroke of the piston, by which the insulating column of air was also compressed, the inflammable mixture moved upwards

until, at the dead point of the piston, it reached the interior of Mr. Fisher's the vaporizer. Ignition took place, and a large flame spread with great rapidity from the vaporizer to the explosive charge in the compression-chamber. The indicator diagrams proved that ignition of the explosive charge was effected at the right moment. It might be seen, from the arrangement of the valves, that only a small quantity of air was admitted through the vaporizer. The air not only served to spray the petroleum, but also swept the vapour into the compression-chamber. The mixture of petroleum vapour and air did not form an explosive charge, and consequently premature combustion could not take place in the vaporizer. The precise action was dependent upon the sizes of the valves *a* and *b*, upon their lift, and, in some degree, upon the tension of the springs; but, as a further means of controlling the air admitted, a throttle-valve *d* was placed in the air-supply inlet, with a pointer attached to it moving on the face of a graduated disk, so that a minute adjustment of the air-supply could be made. By setting the pointer, and thereby partially closing the throttle-valve *d*, more air would be admitted through the valve *a*, and by opening the throttle-valve the reverse would take place. Also, the formation of the layer of inflammable mixture, the ignition, &c., were controlled thereby. It would thus be seen that the inflammable mixture lay in the lower part of the compression-chamber, nearer to the piston. The layer must be such that the part of the charge containing the most vapour lay nearest to the piston. It would be seen that, in the Capitaine oil-engine, the displacement of the mixture in the compression- and combustion-chamber was not, as it was in most of the engines, working on the Beau de Rochas cycle, but just the reverse. In his opinion that was of great advantage in transforming the heat into work. In the Capitaine oil-engine the top plate of the piston would become hotter through the explosion than it did in other motors, and there would be less heat absorbed from the walls surrounded by the cooling water. Heat was conveyed from the hot piston-cover to the interior of the cylinder towards the end of the expansion, causing the diagram to fall more slowly. Comparison of the diagrams with those taken from engines of other design proved this. In constructing the engines, the rapidity of the consecutive explosions, and hence the high speed, had been duly taken into consideration, and had led to the adoption of a short stroke of the piston, broad bearings, and large and well lubricated surfaces of friction; therefore the wear and tear of the parts liable to friction was not greater than in slow-

Mr. Fisher. speed engines. As to the wearing out of the piston, it should be mentioned that the rate of wear was known to be proportional to the distance travelled by the piston per unit of time. Although the Capitaine engine made more rapid short strokes of the piston than slower speed engines with long stroke, the piston travelled over less surface in equal periods of time. The reduced surface over which the piston travelled had been compensated by making the diameter of the cylinder larger. It was found that these engines differed from most others, not only in the quicker speed of the piston but in the quicker expansion. The principle which had been adopted in constructing these engines had resulted in most economical working. The quicker expansions in the Capitaine engines accounted also for the fact that a larger percentage of the developed heat was utilized. The figures obtained in many trials on the brake were extremely low, so far as the consumption of oil was concerned, whilst the heat transformed into work was extremely high. Arrangements were being made to have the figures confirmed by an English authority before publishing them.

Mr. Weyman. Mr. J. E. WEYMAN proposed to take part in the discussion rather early, because if the members heard what the makers of the engines had to say, they would then be able to criticise them better. The Trusty oil-engine was that to which Mr. Beaumont had referred, when he said that he had made some trials with it, and that the results had been practically the same as those obtained by the Author with the Priestman engine. Mr. Weyman was glad to say that, in trials extending over two weeks, conducted by a representative of an eminent firm of engineers in the Midlands, Mr. Beaumont's figures had been more than confirmed. The engine differed from the Priestman chiefly in that it had no spray-maker and no air-pressure. The higher compression used enabled them to get higher initial and mean pressures throughout the working stroke. There was also the difference of a heated tube in place of the electric spark. It had been said that the spray-maker and the arrangements of the Priestman engine, which were rather approved by Sir James Douglass, gave a perfect proportion of air and vapour at a proper temperature, and that thus complete combustion was obtained, with entire absence of clogging or furring-up of the working parts. He did not quite follow that. It appeared to him that if the vapour were at a low temperature, the tarry residue would be in the vapour if it was in the oil, and that when combustion took place, the heat developed must throw it down.

The vaporizer in the Knight engine was worked at a temperature of 400° Fahrenheit; yet clogging of the cylinder and piston had never taken place in that engine. He was glad to say that, by simple mechanical means, they had got over all the difficulty of clogging of the cylinder. An engine had been at work for some months without being cleaned at all, and without clogging. An engine had been running under brake-power continually for a week, and was certainly cleaner at the end of that time than it was at the beginning. There was another circumstance about the spray-maker that he always thought somewhat objectionable. Professor Unwin had shown how the benzoline vapour could be lighted by a taper, and also that the vapour from the spray-maker would light, demonstrating that there was a combustible mixture inside the vaporizer. He thought it would be acknowledged that back ignitions could take place in those engines. Then again, the lower temperature of the vapour as used in the Priestman engine, compelled them to use a low compression, which led to difficulty in igniting the mixture, and this was perhaps the explanation of the adoption of the very strong electric spark used by Messrs. Priestman. In running at half-power, the Author told them that some misses occurred, and in running light, more misses, showing what a powerful ignition was required. Of course Messrs. Priestman would always have the credit of bringing out the oil-engine. They were no doubt the leaders, and by their efforts the oil-engine had been brought to the position which it would not have otherwise attained.

Mr. REGINALD BOLTON said that up to the present time the discussion seemed to have ranged chiefly round the merits of the oil-engine, and but little criticism had been bestowed upon it. He wished, however, to introduce one particular point that had not been noticed. He thought the Author might have had the courage of his opinions, and dealt with that point, which was important in connection with oil-engines, namely the smell. There was undoubtedly a prejudice against oil-engines on account of that unpleasant feature. Notwithstanding the great variety of diagrams and pictures exhibited, there was no information given on that point. The colours were particularly specified, ranging all the way from "clear pale straw" to "fluorescence"—a colour he had never met with in his studies—but they were not informed as to the nature of the material that attacked their olfactory nerves. They had had a little demonstration of it, sufficient to show what might be expected from an engine in working order. That bore more particularly upon one special form of engine,

Mr. Weyman.

Mr. Bolton.

Mr. Bolton. which had been shown in diagrams and admirably illustrated—the marine oil-engine. He had had some personal experience of oil-engines in that particular form. Some friends of his in the North had a still more unhappy experience, for they had built a couple of them, and had made very elaborate tests in the effort to produce a successful marine engine, with a view to its introduction on the Thames. In that they had not succeeded, which was perhaps a matter for thankfulness. He had seen the engine running, and it certainly ran remarkably well; but it still possessed the particular feature to which he had referred. There were one or two features about the oil-engine that really rendered it quite unfit for the purpose shown in the diagram, namely, its application to the launch. It would be agreed that on a launch, especially a small craft of the kind exhibited, where everything had to be designed with a view to the convenience of those on board, the oil-engine was out of place. He thought that the record of the little Zephyr engines, the spirit-engines, of which they had seen so many on the river, sufficiently pointed to that. They had not had a very wide use, and he supposed they were not likely to be much used in the future. That point did not seem to be one which was likely to be got over; and he would suggest that the talent brought to bear upon the engine might be worthily employed in some effort to get over the difficulty to which he had referred. He remembered another case in which great talent was brought to bear upon a similar subject; that was, the case of the British water-gas. When that gas was brought out, it would be remembered that there was a great flourish of trumpets. It was stated that they were going to have water-gas in all the houses. It was also stated, but in a smaller print, that water-gas was a deadly poison, invisible to the eye and imperceptible to the nose; and therefore, the talented individuals who brought it out had got over the difficulty by the invention of a certain pungent, irresistibly obnoxious smell, which they had imparted to the gas; so that when it got loose in a house, the inmates would at once know it, and would send for a plumber to stop it. That was one way in which the difficulty could be got over. It might be made so peculiarly obnoxious that they might cut it entirely out of the premises, and have done with it. He had the highest opinion of the engine itself; but he did not think it should be put in a place where it might become necessary to sit by it all day and put up with its inconveniences.

Mr. Dowson. Mr. J. EMERSON DOWSON observed that as the Author had referred to the work done with gas-engines, and had compared them with the

oil-engine, he (Mr. Dowson) would be glad to have a little information upon one or two points. In dealing with the heat efficiency of the petroleum-engine, the Author had, unfortunately for those interested in gas-engines, taken, as a basis of comparison, the mechanical efficiency of a particular gas-engine which was tested at Rouen, in which the friction was abnormally high, owing to excessively heavy gearing and other working parts. The figures were 112 I.H.P., and only 75·8 effective HP.; and that meant that there was over 36 HP. absorbed in friction, thus giving an efficiency of only 68 per cent. That was hardly a proper example to take for the purpose of comparing the oil-engine with the gas-engine, as it was pretty well known that the ordinary friction of a gas-engine was not nearly so high as that. Having tested several engines himself, and having been present at various trials by others, he thought he was right in saying that the friction of a gas-engine of the well-known Otto type, varied from 15 to 20 per cent.; and, if the Author's calculations were based upon those figures, they would be more exact. He would not, however, lay too much stress upon his own opinion on that point, but would refer the Author to the excellent trials made by Professor Kennedy, for the Society of Arts. In those trials there was a 9-HP. Otto engine tested; and, as the oil-engine under consideration followed the Otto cycle, he presumed it would be a fair example to take for comparison. Professor Kennedy gave 0·86 as the efficiency of the gas-engine, or 14 per cent. of friction. He would also refer the Author to a careful trial made by Professor Witz, of an 8-HP. Simplex engine, worked first with Rouen town gas, and then with Dowson gas. Full details of these trials were given in *Engineering*.<sup>1</sup> When the Author dealt with the friction of the Priestman engine, he gave, for the first full-load trial, a mechanical efficiency of 0·91, and for the other two full-load trials 0·824 and 0·826 respectively, or an average of 0·85. In other words, an oil-engine with the Otto cycle, which had an air-pump, and other working parts added to it, was supposed to have about the same amount of friction (in one instance it was less) as an Otto gas-engine of about the same size, and working under the best conditions in a competitive trial. Although he could not understand that, he did not, of course, deny it; but if the Author would be good enough to explain this, it would be satisfactory. It was specially desirable that the points referred to by him should be dealt with, because the Author had used the

<sup>1</sup> See *Engineering*, 26th March, 1886, vol. xli. p. 306.

Mr. Dowson. statements advanced to show that the thermal efficiency of the gas-engine was inferior to that of the oil-engine. It was mentioned that the indicator spring, or some part of the indicator gear, was faulty in trial No. 1, and, possibly, some source of error might have crept in, in the other trials. With regard to the ignition, he was glad to learn that electricity had answered in that particular engine; but he was astonished to find that the Author sought to confirm the use of electricity for such purposes, by stating that it was used for gas-engines by the largest makers in France. He might be pardoned for correcting the Author on a matter of no great importance perhaps; but, as he knew the gentlemen referred to, he might be permitted to say that they were co-patentees, but not builders of engines or owners of works. He only referred to the circumstance to show that their opinion could not be taken as representative of that of gas-engine makers generally. A further point was this; it was quite true that for the particular gas-engine of which these gentlemen were patentees, they did use electric ignition, but it was used in a special way. The electrodes were enclosed in a little chamber which was only opened at every fourth stroke; consequently they were not exposed to the influence of the gases and whatever else might cause a deposit upon them, to anything like the extent that would be the case, if they were in the cylinder or exposed to the action of the gases during every stroke. It could hardly be said that, because it was used in that particular way and on that particular gas-engine, it was good for other engines. On the contrary, the leading makers of gas-engines, in France and all other countries, preferred gas to electricity. With regard to the consumption of fuel, in Table 5 the Author had made a comparison between the fuel-consumption of the steam-engine, the gas-engine, and the Priestman petroleum-engine. He had told them that the cheapest oil that could be used was Russian, the cost of which might be taken at  $\frac{1}{2}d.$  a lb. That was in Liverpool or London, after deducting the value of the barrels; and, as the Author said, did not include any allowance for carriage. On the other hand, in dealing with steam power, he took coal at 24s., which price included a large sum for carriage. That did not seem to be a fair way of dealing with it; because the Author took the cost of the oil at the port at which it arrived, London or Liverpool, and did not allow anything for the freight of that oil to the place where it was to be used in the engine. It was rather difficult, in these days of great strikes, to fix exactly the price of the coal, but 12s. a ton should cover the cost of the best steam coal at the

pit. The comparison would be more exact if the Author took Mr. Dowson. the cost of oil, say, 100 miles away from the port; or if he took the oil at  $\frac{1}{2}d.$ , he should then take the coal at the price which would have to be paid for it at the pit. It should moreover be remembered that the railway carriage on coal was only one-third that of non-dangerous mineral oil. If the basis of calculation suggested were adopted, results would be found to be very different from those given in Table V. If he might be allowed to refer to work with which he had personally more experience,

MODIFICATION OF TABLE V.—COST OF FUEL ONLY, PER HOUR.

	Per Indicated HP.		Per Brake HP.	
	Quantity of Fuel.	Cost in Pence.	Quantity of Fuel.	Cost in Pence.
1. Large gas-engine with Dowson gas	1·00 lb.	0·06	1·25 lb.	0·08
2. Small " " "	1·33 "	0·08	1·60 "	0·09
3. Large condensing steam-engine .	1·75 "	0·11	2·00 lbs.	0·13
4. Large gas-engine with town gas } @ 2s. . . . .	17 cubic feet	0·41	20 cubic feet	0·48
5. Priestman oil-engine . . . . .	0·85 lb.	0·43	1·00 lb.	0·5
6. Small gas-engine with town gas } @ 2s. . . . .	21 cubic feet	0·5	24 cubic feet	0·57
7. Large gas-engine with town gas } @ 3s. . . . .	17 " "	0·61	20 " "	0·72
8. Small non-condensing steam- } engine. . . . .	5·00 lbs.	0·64	6·00 lbs.	0·77
9. Small gas-engine with town gas } @ 3s. . . . .	21 cubic feet	0·75	24 cubic feet	0·86

NOTE.—The Welsh coal for steam power and for Dowson gas is taken at 12s. per ton (at the pit). Town gas is taken at 2s. and 3s. per 1,000 cubic feet. Russian oil is taken at  $\frac{1}{2}d.$  per lb. at London or Liverpool. The railway carriage of coal averages about one-third that of the non-dangerous mineral oils.

viz., the working of engines with gas made in an apparatus of his own, the figures would again have to be modified considerably. As a matter of fact, the fuel consumption with a gas-engine driven by his gas, was guaranteed by the best makers to be 1 lb. per I.H.P. or  $1\frac{1}{2}$  lb. per effective HP. He thought they should also take into account the very large number of gas-engines which were worked by town gas, costing a great deal less than 3s. per 1,000 cubic feet. The Author assumed 3s. per thousand, but in many cases the price of town gas was something like 2s. per

Mr. Dowson. 1,000 cubic feet. If those circumstances were taken into consideration, there would be a further difference from the figures given in Table V, and he had on that basis drawn up the modified Table given above. He hoped that in making these remarks he would not be understood to wish to detract in any way from the beautiful engine that was exhibited. It was a very ingenious machine, and good for small powers; but it would not do to generalize too much, or to suppose that 1 lb. of oil, even at the cost given by the Author, could possibly compete economically with 1 lb. of coal.

Mr. Douglass. Mr. W. T. DOUGLASS stated that he had conducted a trial last year with a 25-HP. double-cylinder Priestman oil-engine, specially designed for driving the electric-light plant in connection with Queen-Cliffe, Fort Victoria. That engine, when running at full speed, developed 25·5 brake HP., and was so perfectly governed, by a governor similar to the one on the engine exhibited, that when the full load was taken off the brake, the increase in the number of revolutions did not exceed 3 per cent. The amount of oil consumed per brake HP. was 0·88 of a pint. He did not see any reference to that engine in the Tables on the screen, and therefore thought it well to bring it under the notice of the members.

Mr. Willans. Mr. P. W. WILLANS wished to say a few words supplementary to Mr. Dowson's remarks, as to the comparison between steam-engines and oil-engines. He did not desire to detract in any way from the merits of oil-engines. The apparatus described was a most beautiful one, and seemed to have been brought to a degree of perfection that few persons, he supposed, had realized. But he thought that Professor Unwin had been rather hard on both large condensing and small non-condensing steam-engines. He had taken for small non-condensing engines 5 lbs. of coal. He (Mr. Willans) presumed that the figures were supposed to refer to full power, and under trial conditions, as in the case of the petroleum-engine under discussion. He had not had much experience of engines as small as 9-HP., but he should be inclined to take half the figure given, with a compound engine and reasonably high pressure; which would give a great advantage in point of cost for the steam-engine over the oil-engine. For large condensing steam-engines, he thought that  $1\frac{3}{4}$  lb. of best coal was a good deal to assume. They had had many figures less than that. Some of Professor Kennedy's marine engine trials had shown as little as 1·4 lb.<sup>1</sup> He (Mr. Willans) had just been making some trials of small con-

<sup>1</sup> See trials of s.s. "Iona," Proc. Inst. Mechanical Engineers, 1891, pp. 200 *et seq.*

densing engines, indicating 30 H.P., and he had obtained many times Mr. Willans. in succession 13 lbs. to  $13\frac{1}{2}$  lbs. of water per I.H.P. at 130 lbs. pressure per square inch ; which ought to cost much less than 2lbs. of coal even for a small condensing steam-engine. He had lately gone fully into the consumption of steam-engines for low powers as well as for full powers ; and he supposed that few people, until they had tried it, knew how greatly the consumption went up with light loads. In the case of a non-condensing steam-engine, it was found that about one-third of the steam used to drive the engine at full power was used when it was doing nothing ; and in condensing engines about one-sixth. But, in the case of an oil-engine, it would appear from the Paper that, when it was doing nothing, it was actually using from 0.7 to 0.8 of the whole quantity of oil used at full power. That was a very important point, and one that had been forced upon his notice strongly, and he had no doubt that Mr. Priestman had also observed it. He had been struck with the fact that the engine, when running light, took slightly more oil than when running at half-power. He supposed it must be due to something wrong in the combustion. He did not know whether it could be entirely got over. The friction of the engine seemed remarkably low, because he supposed that the 5.1 lbs. mean pressure was not really the power which the engine took to run, but the power after deducting the pumping—the net power after deducting the lower part of the diagram ; and deducting that brought the friction down to about  $3\frac{1}{2}$  lbs. The mean pressure required to run the engine when at full power was 53 lbs. per square inch. With regard to the general question of efficiency, oil-engines and gas-engines ought, of course, to have a great advantage over steam-engines, in the higher range of temperatures used. It was, unfortunately, exceedingly difficult to form an idea of what those temperatures were ; and they could therefore only compare those engines with steam-engines in respect of their absolute efficiency. It was at present impossible to compare what the oil-engine did with what it might theoretically be expected to do, the temperature being unknown. There was a curious difference between the steam-engine and the gas-engine. In the steam-engine they tried to prevent the action of the walls, while in the oil- and gas-engines the action of the walls had to be introduced in order to preserve them. The walls had to be kept cool, whereas in steam-engines they tried to keep them hot. Thus, what could be to a great extent avoided in steam-engines, was a necessary loss in oil- and gas-engines. In cases where power was only required intermittently, an oil-engine must necessarily have the advantage of

Mr. Willans. requiring no such expenditure of fuel as that required for getting up steam in the steam-engine. The length of the run would determine the extent of this advantage.

Mr. Chapman. MR. W. W. CHAPMAN claimed to be the first user of the Priestman petroleum-engine on wheels. He bought the engine, and put it on a wagon-frame with four wheels, and there it had remained. It had been used on general estate and farm work since December, 1888; and, although he did not pretend to know anything about the technical details of the construction of the engine, or the theory of its action, he did know that with the Priestman engine he could work at about half the cost that he could with coal. He had taken the trouble to get out a few figures, and the best example he could give was that of a four-knife chaff-cutter in daily use. With a 4-HP. steam-engine, they could cut in eight-and-a-half hours something like from 10 to 10½ tons. He had a letter from the maker of a chaff-cutter saying that if they could cut 10 tons in that time, it was very good work. So that an engine working at about half the cost of steam was doing the same amount of work as a 4-HP. steam-engine. All those who knew anything about the working of a steam-saw would know, that a man must be constantly in attendance on the engine; and the moment the saw had run through a baulk of timber, the engine began to race and rush off at a tremendous speed, unless it were well looked after by the attendant. In his experience of ten or fifteen years with steam-engines he had rarely seen an engine that did not race somewhat; but with the Priestman engine there was not the least sign of racing. An important point was the adaptability of the machine when placed in the hands of an ordinary workman. His driver had never had anything to do with an engine before, and was instructed for only two days. Ever since then he had been working with the engine; and, although some slight accidents had happened with it, due to such causes as trying to make the pump go when it was frozen, they had never had a breakage of any account. There had been a few stoppages, occasioned by moving the engine from one farm to another. Small sediments of oil might have been found, but those things had been few and far between. Frequently, from week to week, and from month to month, the engine had worked without the slightest accident happening. Reference had been made to the engines sometimes missing fire, or rather, to the explosion not taking place in the cylinders at the proper time. That had happened in his experience. Of course, it could be understood that his engine was not one of the latest productions, and that these engines had been improved. He had

thought that the failure was sometimes caused by the oil, in its progress through the engine, becoming too cold to explode with the electric spark. Before finding that out, he had some trouble in wind or rain, when the engine was working out of doors. The wind blowing on the pipe that conducted the fluid into the cylinder, or the rain falling upon it, cooled the pipe so that they could not get sufficient heat. That was remedied by covering the pipe with asbestos, and after that no difficulty had arisen.

Professor WILLIAM ROBINSON said the cause of non-explosion in the case referred to was obvious—namely, the rain beating against the air-inlet of the cylinder. There was a special device in use to remedy this, consisting mainly of gauze covered with cotton wool through which the air was drawn. This gauze cleared away any dust, dirt and grit; but, if it got thoroughly wetted, it could not perform its functions so readily, and consequently some moisture or aqueous vapour might be introduced into the cylinder, and become deposited on the points between which the electric spark was supposed to play. Herein lay one important difference between ignition in a gas-engine and ignition in an oil-engine. Oil was an insulator, consequently, if any deposit took place between the flashing points in the cylinder, it did no harm. As a matter of fact, if there were a little deposit it was cleared away by the burning charge in the cylinder, and the electric spark was as good as ever. The best electric spark they had, he supposed, was the arc lamp, in which the spark played between two carbon points; but if water were deposited in the cylinder on the ignition-plug, the points became short circuited; consequently there was not the same tendency for the spark to pass between the points, when a path of smaller resistance was provided by the water. By keeping the air dry, or by preventing any possibility of the deposit of aqueous vapour, the spark would act with certainty. With such very high temperatures there was certain to be ignition when the charge was compressed; but they could not obtain ignition very readily in the vaporizer, because the charge was not compressed there, neither was it at a very high temperature. In small engines, such as a 1-HP. engine, the temperature of the mixture in the vaporizer, before entering the cylinder, was only about 170° Fahrenheit. In the trials recorded by the Author, the temperature of the vaporizer was only about 300° Fahrenheit; and every one knew that was far from the temperature of ignition of the charge, even if it were in the proper proportion for complete combustion. He felt great interest in the Paper from the fact that he had been examining the different oils that were used, as well

Mr. Chapman.  
Professor  
Robinson.

Professor  
Robinson.

as a few others, as to their performance in the cylinder of that very engine. A year ago Messrs. Priestman were good enough to conduct for him a whole series of tests in a small engine. He thought it was not exactly fair to merely compare the ultimate analyses of the oils, exhibiting the proportion of carbon to hydrogen, in order to get an idea of the heat produced or efficiency of the working of any oil in the engine cylinder. It would be seen from the Paper that the proportion of carbon to hydrogen varied very slightly; whereas the Author distinctly indicated in another part of the Paper that Daylight oil gave a very much better result than Russolene. The physical properties of oils, and their composition as shown by fractional distillation, afforded important indications as to their behaviour in the cylinder of the engine. In treating the oils in different engines, it was important to notice that they might at a low temperature merely vaporise the oil, and, in another case, if they raised the temperature, they might produce a certain amount of carbon deposit. Going still further, and using a retort at a red heat, the oil was converted into oil-gas and tarry products were formed. The great difficulty encountered in the successful working of these different oil-engines, was caused by the deposits from the tarry products in the different cylinders, which had to be got rid of somehow or other, if the temperature was kept high enough at the gas-making stage.

Last autumn a Priestman oil-engine was ordered for the new Technical Schools at University College, Nottingham; and a special series of tests were made for him on the same type of engine, the trials of which were recorded in the Paper, though under somewhat different conditions of working. The volume of the clearance space was 0·2141 cubic foot, instead of 0·2101 cubic foot. The effect of this small change was very marked in the increased power obtained, due doubtless to the higher compression before ignition, which was only 25 lbs. for Daylight oil, as compared with the Author's 35 lbs. per square inch, and the mean effective pressure was raised from 47 lbs. to 53 lbs. per square inch, increasing the brake HP. from 7·05 to 7·72. This slight reduction in the compression space, by a plate fixed on the piston, might partly explain the rounding or excessive cushioning shown on the full-load indicator diagram, *Fig. 4*. Such rounding might also be caused by premature ignition, the igniting spark passing before the piston had turned the dead-point. In all his diagrams, the explosion line started from the sharp corner of the compression curve, and was slightly inclined to the right of the vertical. Four different kinds of oil were tried, of which Broxburn lighthouse oil came out decidedly the best.

Professor  
Robinson.

TABLE I.—OILS USED.

Name of Oil.	Specific Gravity at 60° Fahrenheit.	Flashing Point (Abel test).	Carbon in 1 lb. of Oil.	Hydrogen in 1 lb. of Oil.	Calorific Value, B.T.U.	Steam Condensed and Cooled, B.T.U.	Effective Thermal Value, B.T.U.	Wholesale Price.
Lighthouse	0·810	° Fahrenheit. 152	0·8601	0·1390	21,097	1,396	19,700	Per Gall. <i>d.</i> 4½
Daylight .	0·796	76	0·8462	0·1486	21,490	1,492	19,998	4½
Russolene.	0·824	82	0·8588	0·1407	21,180	1,413	19,767	3½
Lustre. .	0·825	..	0·8600	0·1395	21,126	1,411	19,715	3½

The thermal values assumed for the oils were higher than those given in the Paper, and the values for efficiency were thereby reduced.

TABLE II.—ABSOLUTE EFFICIENCY OF 5-HP. OIL-ENGINE.

Name of Oil.	Indicated HP.					Effective or Brake HP.				
	Thermal Value. Oil per 1 lb., B.T.U.	Oil used per Hour.	Cost of Oil per HP. Hour.	Thermal Value. Oil used per Hour.	Thermal Value of 1 HP. Hour.	Efficiency.	Oil used per HP. Hour.	Cost of Oil per HP. Hour.	Thermal Value. Oil used per HP. Hour.	Efficiency.
Lighthouse	19,700	0·75	0·45	14,775	2,565	17·4	0·90	0·54	17,730	14·5
Daylight .	20,000	0·76	0·42	15,200	2,565	16·9	0·92	0·50	18,400	14·0
Russolene.	19,750	0·87	0·39	17,182	2,565	14·9	0·958	0·40	18,921	13·6
Lustre. .	19,720	0·897	0·34	17,690	2,565	14·5	0·989	0·39	19,503	13·2

The quantities measured were practically the same as those given by the Author, with the exception of the amount of air. On this point more particulars should be given as to the method adopted in the calibration and use of the anemometer; for, unless the wooden box were very large, the sudden suction of the piston would start the vanes moving rapidly, and their inertia would tend to keep them going, thereby giving too high a record. Thus in Trial IV, 603·6 lbs. of air entered with 13·6 lbs. of oil—that was, at the rate of 44·38 lbs. of air per 1 lb. of oil, or nearly three times the amount of air necessary for complete combustion accord-

Professor  
Robinson.

ing to the chemical analysis of the oil. Hence it would appear that a greater quantity of air was admitted to burn the oil than that usually required for solid fuel. Probably the excess of heated air was necessary to hold the finely divided spray or cloud in suspension.

Again, the quantity of heat saved from the products of combustion after leaving the cylinder, and utilized in raising the temperature of the incoming mixture from  $58^{\circ}$  to  $268^{\circ}$  Fahrenheit, was worthy of notice in the Paper. If it were assumed that the oil was in the state of finely divided liquid, and the latent heat of evaporation of this oil (which was nearly the same as for water) were neglected, the total heat saved from the burnt products of exhaust in Trial IV, and turned to good account, was:—

	Thermal units.
Heating air = $603.6 \times 0.2375 \times 210$ . . . . .	30,105
„ oil = $13.6 \times 0.45 \times 210$ . . . . .	1,285
	31,390

or, about 11.8 per cent. of the total heat of combustion of the oil was saved and stored up in the fresh mixture.

In calculating the calorimetric value of the oil the Author had very properly corrected for the water produced, by deducting the latent heat of evaporation; but why had he not also allowed for the subsequent cooling of the condensed water from  $212^{\circ}$  to at least  $60^{\circ}$  Fahrenheit. The heat thus given out amounted to  $1.2663 \times 152 = 192$  thermal units for each pound of oil consumed, thereby reducing the effective thermal value to  $19,957 - 192 = 19,765$ . These thermal values, calculated from the ultimate analyses which closely agreed, were obviously insufficient to give an exact idea as to the best oils for use in the internal-combustion engine cylinder. A far better guide was afforded by the volatility and boiling-points of the various constituents of an oil, as obtained by fractional distillation, showing the range of temperature within which all the oil was distilled over. For example, Daylight and American ordinary oils were found to agree closely in character; of the former 25 per cent., and of the latter 29 per cent. distilled under  $420^{\circ}$  Fahrenheit. Russian ordinary (Russolene) and American tea-rose appeared to be similar oils, and both distilled 22 per cent. under  $446^{\circ}$  Fahrenheit. On the other hand, American Waterwhite and Broxburn lighthouse oils were more homogeneous in composition, and evaporated more rapidly within a limited range of temperature. The Waterwhite oil gave off 56 per cent. under

420° Fahrenheit before the Lighthouse oil had begun to distil ; but, once started, this latter oil came over quickly, 55 per cent. under 470° Fahrenheit, and the whole was distilled under 572° Fahrenheit. This property of oils might be more clearly seen by a diagram of the distillation curves where a vertical straight line for water indicated that, under atmospheric pressure, water boiled at 212° Fahrenheit until the whole mass was evaporated. Now, the more homogeneous an oil, the greater the proportion of it that would boil off within a limit range of temperature. Further, the more rapidly an oil evaporated, the more complete would be its combustion in the engine-cylinder during the early part of the working stroke ; and therefore the greater proportion of its heat would be converted into work, before there was time for loss by conduction through the cylinder walls to the jacket-water. High compression of the explosive charge of oil vapour and air in the cylinder before ignition, also caused the combustion to be more rapid. At the same time this should not be pushed too far, as excessive condensation of the oil vapour might take place, and the temperature of the cylinder become too high. Moreover, premature ignition of the charge was a serious disadvantage, inasmuch as it tended to reverse the direction of the piston's motion ; also, experience proved that slightly late ignition made the engine run more smoothly. In a Paper dealing with petroleum-engines, it might perhaps prevent confusion if oil-engines were classified into at least three distinct types, depending on how the oil was treated. The first type, being that in which the oil was sprayed, or otherwise converted into the state of vapour intimately mixed with air, before being admitted into the cylinder, as in the Priestman engine ; the second type, that in which oil in the liquid state was injected into compressed and heated air in a red hot combustion-chamber, where it was immediately burned, as in the Hornsby-Akroyd oil-engine ; the third type was provided with a vaporizer or gas-generator to convert the oil into gas, or vapour and gas, before it was drawn into the cylinder, mixed with air, and the charge compressed and fired as in the Trusty, Capitaine, Crossley, and other oil-engines. In this latter class the tarry products were troublesome. Hitherto only the Priestman oil-engine had gained the confidence of the public as a useful prime-mover. Time and experience would doubtless lead to improvements and new developments, though only the fittest could survive. There were many positions in which oil-engines might be of great practical utility, and, for small powers, up to 20 HP., replace both steam- and gas-engines.

Professor  
Robinson.

Mr. Curtis. Mr. A. H. CURTIS remarked that the possible application of petroleum-engines to underground operations was a subject of much interest to mining engineers, as it was in some cases impracticable or uneconomical to employ steam or compressed-air as motive-power. The Author had instanced pumping and rock-drilling among the applications of petroleum-engines, but had not mentioned their adaptability, and, indeed, their present employment, for hauling-purposes in collieries and elsewhere. In September of last year he had an opportunity of examining a 7-HP. Priestman oil-engine working in the Walsall Wood Colliery, Staffordshire. The engine was erected at a distance of 1,800 feet from the bottom of a winding shaft, 1,650 feet deep, and was employed for hauling tubs on an incline of approximately 1 in 10. The length of the incline was about 500 yards. There were twelve tubs attached to the endless wire-ropes which passed round the hauling-drum, each tub weighing 2 cwts., and having a capacity of 10 cwts. of coal. The oil used for generating the motive-power was Browning's "double brilliant" petroleum, of which 9 gallons were consumed in a shift of eight hours. The cost of this petroleum was 9 $\frac{3}{4}$ d. per gallon. The hauling-drum could be put out of gear by a clutch lever, and promptly stopped by a brake. At the time of his visit to Walsall, the petroleum-engine had been at work for eighteen months, and had given great satisfaction during that time—the working parts, however, requiring to be kept extremely clean, and the best obtainable petroleum being always used. For hauling up inclines not exceeding 1 in 9, or thereabouts, and for pumping, the Priestman engine was no doubt an efficient machine. On the other hand, it could not be safely adopted for winding in shafts or winzes, owing to the fact that the engine itself should not be suddenly stopped. The winding-drum, when thrown out of gear, could no doubt be stopped by applying a very powerful brake in trial experiments, and under other favourable circumstances; but the ever-present risk of over-winding, consequent upon the engineman being required, first to throw the winding-drum out of gear, and then to stop its revolution by the application of a brake, would in actual practice be considerable; indeed, in the opinion of many engineers, the risk would be so great as to render the adoption of the engine for winding-purposes a most imprudent course. This was to be regretted, because, if a petroleum-engine could be regarded as an absolutely reliable machine for winding in winzes or underground shafts, it would almost certainly be adopted for that work in many mines—more especially metalliferous mines

—where it was inconvenient, uneconomical, or impossible to use steam- or compressed-air-engines. There was no boiler to provide or find space for, or attend to. The cost of driving was small, the engine was compact, and could be brought close to its work; and, with due care and intelligent management, its working was attended with no trouble or difficulty. It would, of course, be understood that petroleum-engines could not be safely used in collieries where naked lights were forbidden. He would be grateful to the Author, or to any other engineer, who would state an instance in which the Priestman, or other oil-engine, was used for winding in shafts or winzes, or for hauling up steeper inclines than between 1 in 9 and 1 in 6.

Mr. J. PRIESTMAN thought it should be stated that the engines referred to by Mr. R. Bolton were not built by his firm. So far from there being in his experience any serious objection due to the smell of their oil engines, they had been complimented on the absence of smell by nautical men who had inspected the launch; and had even been told that there was less unpleasantness than that arising from the lubrication in the case of steam-engines. It might further be stated that the oil-engines were used in creameries, bakeries, and other places, where they could not be used if they were as objectionable as Mr. Bolton had alleged. Mr. Willans had commented on the comparatively large amount of oil used by the engine when running light. This was entirely due to a fault in the V-shaped notch of the petroleum-valve in the engine at the time it was tested by the Author. Messrs. Priestman's attention had been called to the existence of this fault immediately before the Author made his trials, but there was then no time to remedy the defect. Sir James Douglass had referred to two mishaps arising from causes recently fully provided against. A pipe was fitted for discharging water from the cylinder-jacket in frosty weather; and the oil cistern was differently placed, and the gauge-glass protected so as to render accident impossible even with a careless attendant. In reply to Mr. Curtis he might state that the engine had been used for winding. Although improvements might yet be made in the details of the winding gear, yet the engine was used for working hoists with satisfactory results. He had been asked if danger arose from the cylinder becoming too hot. There was no danger, but there might be inconvenience from the piston sticking in the cylinder. If the engine showed a tendency to heat, it could only arise from an insufficient supply of cooling water.

Professor UNWIN, in reply, said that the Trusty and Capitaine engines, described by Mr. Beaumont and Mr. Fisher respectively,

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differed from the Priestman engine in one important respect only. In both those engines, the petroleum-oil was injected directly into a hot chamber, instead of being first sprayed and vaporized in a comparatively cool chamber. Mr. Fisher had spoken, indeed, of a spraying-valve and vaporizing-chamber, but, in the Capitaine engine, the vaporizing-chamber was of very small dimensions, and was not equivalent in function to the large vaporizing-chamber of the Priestman engine. To effect the vaporization in the same time, *i.e.*, a fraction of the time of a revolution, the small chamber must be much hotter than the large chamber. There was no reason why engines like the Trusty or the Capitaine should have a lower thermal efficiency than the Priestman engine. The doubt about them was, whether vaporization in small chambers at comparatively high temperatures could be effected, without producing tarry products, which caused trouble in the practical working of the engine. From what Mr. Beaumont had said, it might perhaps be inferred that some tendency to form tarry products had been observed in the experiments on the Trusty engine; and Mr. Fisher spoke of nearly all the products of combustion escaping through the exhaust-valve, and of a need of cleaning the engine once a week. He supposed that meant cleaning the interior of the engine. Undoubtedly, difficulty due to the clogging of engines by tarry products had arisen in some engines. Whether that difficulty had been so far overcome in the Trusty and Capitaine engines as to be practically insignificant could only be fully proved by the continuous use of the engines in practical work. Dr. Anderson had pointed out that the thermal efficiency of the oil-engine would be increased, if the jacket- and exhaust-waste were utilized to produce vapour from a liquid of low boiling-point, to be used in a second working cylinder. Attempts in this direction had already been made, but the complication of binary vapour-engines would always be an obstacle to their use. Very valuable testimony had been borne by Sir James Douglass to the satisfactory working of the Priestman engine at fog-signalling stations. It was very important to have a suitable motor for that purpose, easily started at any moment, and capable of working with little attention. For that particular purpose the oil-engine had advantages over every other motor.

As to Mr. Fisher's claim, that there was a thermal advantage from a stratification of the charge in the Capitaine engine, it was difficult to conceive that any gain was possible, even if stratification existed. Most engineers now disbelieved in the possibility of that stratification of the charge, on which at one time so much stress was laid. Mr. Emerson Dowson had evidently

thought that oil-engines might be serious competitors of engines worked with cheap forms of heating gas. No doubt that was so, but it was not a question which the Author had any intention of raising. There was only one reference to Dowson gas in the Paper, namely, the comparison by Professor Witz of the cost of working an engine with Dowson gas and with steam. The Author gave the results of a test of a large gas-engine worked with Dowson gas. This test showed that the working expenses of such an engine were as low as those of a good large condensing steam-engine. The result was remarkable, and the test was, in the Author's opinion, the most important, accurate, and trustworthy test of an engine worked with Dowson gas, which had been made. The trial was quoted to show the high thermal efficiency of internal-combustion engines. Ordinary gas-engines using lighting-gas were not in question. They used an expensive artificial fuel, and could not compete with good steam-engines in cost of working. When Mr. Dowson had objected to the results obtained by Professor Witz, on the ground that in that trial the mechanical efficiency of the engine was exceptionally low, he had said that it was due to excessively heavy gearing and other working parts. The Author could not discover this gearing in Professor Witz's drawings of the apparatus used. However that might be, the only way to prove that the mechanical efficiency was too low, was to produce an experiment equally careful and independent in which the mechanical efficiency was higher. That Mr. Dowson had not done. In place of it, he made assertions, and confused the efficiency of gas-engines worked with lighting-gas with engines worked with Dowson gas. Further, Mr. Dowson had stated that the efficiency of gas-engines was well known to be 80 to 85 per cent. That was true if the engines were worked with lighting-gas. But Mr. Dowson must have been aware that, when an engine was worked with a gas of less calorific value than lighting-gas (four to five volumes of Dowson gas being equivalent to one volume of lighting-gas<sup>1</sup>), a larger engine must be used for a given power, more work must be wasted in friction, and the mechanical efficiency must be lower. Mr. Dowson did, indeed, refer to some trials by Professor Witz in 1886, of a small engine worked both with lighting-gas and Dowson gas. Very prudently, however, he referred generally to those trials, without quoting the results. If he had given the figures, it would have been obvious that, so far as they affected the point at issue, those trials could not be credited. The Author had re-examined those trials. There were three

Professor  
Unwin.

<sup>1</sup> Dowson, Gaseous Fuel, British Association Report, 1888.

Professor  
Unwin.

experiments in which the mechanical efficiency was determined—two with lighting-gas and one with Dowson gas. The results were as follows:—

TESTS OF AN 8-HP. ENGINE.

	Indicated HP.	Brake HP.	Mechanical Efficiency.
Lighting-gas .	7·39	6·79	Per cent. 91·8
.. .. .	9·10	8·79	96·6
Dowson gas .	8·10	7·22	89·1

Those results indicated that an engine working with Dowson gas had a lower efficiency than an engine working with lighting-gas. But, as they made the efficiency as high, in one case, as 96·6 per cent., an efficiency only claimed, the Author believed, for electrical machines, it was obvious that those values were untrustworthy. In the Uxbridge trial of an Atkinson cycle engine, which worked with Dowson gas very economically, the mechanical efficiency was 64·6 per cent. Then, Mr. Dowson had noted that, in the Author's trials, the mean mechanical efficiency of the oil-engine was 85 per cent., or as high as that of an Otto gas-engine worked with lighting-gas, and had implied that it was impossible for an oil-engine, with an air-pump and other working parts, to have as little friction as an Otto gas-engine. The oil-engine had a very small air-pump, it was true, compressing a small volume of air at 8 or 10 lbs. per square inch into the oil-reservoir. But the working parts of the oil-engine were fewer and simpler than those of the Otto gas-engine. The Author believed that the mechanical efficiency of the oil-engine was a little higher (not lower) than that of an Otto gas-engine using lighting-gas; partly because of the simpler mechanism, and partly on account of the better lubrication of the cylinder. Perhaps Mr. Dowson's other figures did not need any close examination. To take the price of coal "at the pit's mouth," and that of oil in London or Liverpool, was not reasonable, seeing that oil-engines were not generally used at the pit's mouth. The cost of carriage of coal per ton-mile might be one-third that of the non-dangerous oils. But the difference of charge to merchants and consumers did not wholly consist of the ton-mile charge. Welsh coal might cost 12s. per ton at the pit's mouth, and 24s. per ton in Kensington. But the Author had not found a case where there was three times that difference of cost between the price of oil at

the tanks and at the oil-engine. If a comparison of cost of working of oil- and Dowson gas-engines were instituted at all, the cost of attendance in the case of the Dowson gas-producer must be reckoned. As to the small amount of attention required in working the oil-engine, Sir James Douglass's remarks might be referred to as a sufficient answer to the question. It appeared that "Professor Robinson thought that the quantity of heat saved from the products of combustion after leaving the cylinder, and utilized in raising the temperature of the incoming mixture from 58° Fahrenheit to 268° Fahrenheit, was worthy of notice in the Paper." The Author did not know what was meant by the phrase "worthy of notice." That quantity of heat had not been neglected in calculating the heat balance. Nor, for reasons given in the Paper, could that quantity of heat be calculated in the way Professor Robinson had supposed. As the temperature of exhaust was taken after the products of combustion had left the vaporizer, the heat regenerated in the vaporizer was properly deducted from the heat losses. Apparently Professor Robinson thought that water might be deposited on the electrodes in the cylinder. Looking at the temperature of the inside of the cylinder it did not appear how this could happen. Professor Robinson had not understood why the Author had deducted the latent heat of the steam produced and not the so-called sensible heat (from 60° Fahrenheit to 212° Fahrenheit) in estimating the calorific value of the fuel. The latent heat was deducted because it was not generated as heat in the cylinder. The sensible heat was not deducted because it was present as heat, the steam in the cylinder not being at the temperature of 60° Fahrenheit. The small correction for the sensible heat was not properly taken as a deduction from the heat quantities dealt with, it ought to be accounted for in the heat discharged in the exhaust. Professor Robinson's implication that the Author had taken calorific values as a guide to the best oils to use in the oil-engine was quite incorrect. The calorific values were required for another purpose. Whether Professor Robinson's fractional distillation would furnish a guide remained to be proved. Meanwhile, the price per gallon was probably the most valuable guide. Lastly, Professor Robinson considered that the inertia of the anemometer vanes made the Author's records too high. If the inertia had any effect, it would have made the records too low. In the instrument used, the vanes were aluminium, and the volume of air between the anemometer and cylinder was so large, and the throttling there so effective, that there were no such fluctuations of speed as Professor Robinson had imagined.

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