the flame should impinge. By long and somewhat costly experiments it was found that the flame jet should be as thin as possible and placed square across the tube.

MR. PATERSON criticised some remarks of previous speakers, saying that in his great experience of heavy oil engines, he had never had any difficulty with corrosion of water jackets, irregularity of working under varying loads, and other points mentioned.

MR. R. SINCLAIR said he agreed with the Author that the use and development of the oil engine was not advancing so quickly as it might, because it was not understood as well as it should be, either by builders or users. That there were great advantages to be gained by the use of gas or oil engines was beyond question, but one of the reasons why these engines had not been more rapidly taken up, and developed, for other than comparatively small units, was, he thought, the natural caution of many engineers who could not afford to risk hitches, or failures, with either their own or clients' machinery.

He could not agree with the Author in his claim that gas or oil engines were less complicated than steam engines, so far as mechanism was concerned, though they certainly might have less parts, but these parts appeared to be more liable to derangement, more intricate, and required more careful attention than in the case of a steam engine, and the derangement of one small part would interfere with the operation of the whole machine in a manner, which for a similar derangement, would not be seriously felt in the case of a steam engine.

For marine work, the oil engine certainly had the great advantage of dispensing with boilers, condensers, and all the attendant auxiliaries, which compensated somewhat for other complications; but he had not heard of these engines being adopted, so far, for large vessels, or for vessels making long voyages where the engines were required to run continuously for several weeks without stopping. It would be of interest if the Author, or anyone having had experience, would state the longest period of continuous work known for an oil engine to be operated.

If the Author would add to his paper some particulars as to the weights per I.H.P., it would be very useful, as a comparison with steam engines. The lightest weights of the latter were about 40lbs. per I.H.P. in surface condensing fast launches; 50lbs. in torpedo boats; running up to 400lbs. in merchant vessels. These figures could be beaten by oil engines using oil which would vapourise at a low temperature, and especially those of the two-cycle type—as he understood they were the lightest type of oil engine—but as pointed out by the Author, they could not run at a high speed, and were not suitable for larger powers.

The engines of the four-cycle type appeared to be the most reliable, both for marine and stationary purposes, and they were better adapted for the use of kerosene and similar oils. There would always be an objection to the use of benzine, gasoline, and kindred oils, at least in Australia, owing to price, and the difficulty of maintanng a regular supply; and for oil engines to come into common use, they must, he thought, be adapted to use kerosene or crude oil. This would necessitate the use of a vaporising apparatus, either by heat or spraying and ignition, which would add to the weight of this type, particularly where a heating arrangement was adopted, as the compression could not be carried high, in case of premature ignition.

The Author had not mentioned engines in which gas, obtained from a producer, either from solid fuel or oil, was used. These appeared to be under consideration in several quarters, and were, of course, of the same type as the ordinary gas engine, and the oil engine described by the Author, but without the producer. For marine work they were likely to come into use, as the production of gas was not stopped instantly with the engine; while by the adoption of that type of producer in which the gas was drawn direct to the engine, without a reservoir, a great reduction of the weight could be made.

The President said that the paper, in which the Author had given a clear description of the principles connected with the working of oil engines generally, had brought about an interesting and instructive discussion.

Some of the speakers had contended that the oil engine was more liable to, and would be more affected by even slight derangement of parts than the steam engine; mention had been made of the evil effects caused by leakage, either in the valves or through defective pistons, and such questions as the supply of a uniformly explosive mixture, the various methods of ignition, and the necessity for exact timing of the ignition spark, had all been enlarged on. In order to secure the highest efficiency, it was obvious that these matters required special attention. But there were similar and (although more generally familiar) equally important points to be watched, so as to get the best results from any other type of engine or motor, and if a comparison was to be made which would be really useful, it was necessary that the engines or motors selected, and the method of application of the fuel or motive power (whether coal, or oil gas) should be as good as possible of their respective class. However, many questions arose which would tend to make such a comparison well nigh impossible.

It was evident that the question of locality might so greatly affect the cost of fuel or water, or both, in the case of a steam engine, as comnared with that of oil in the case of an oil engine, that the most economical motor under certain conditions might easily be the most expensive under others. One of the previous speakers (Mr. Christie) had shown that, as far as a heat engine was concerned, a triple expansion steam engine compared favourably with an oil engine, and that for such work as launch propelling on commercial lines in Sydney Harbour, even a high pressure steam engine was far ahead of its oil rival. That speaker had assumed the consumption of oil in an oil motor at one-eighth gallon per horse power per hour, and the cost of oil at 1s per gallon, which was equal to a cost of 1½d per horse power per hour. If that was compared with the cost of running an ordinary high pressure steam engine using as much as 6lbs. of coal per horse power per hour, and the comparison could be fairly made by only taking into consideration the cost of the fuel, it would be seen that the oil motor would not have an advantage unless the price of coal exceeded 46s 8d per ton.

However, under favourable conditions, the oil engine had undoubtedly many advantages. In mining, for example, where power was often required at long distances underground from the shaft bottom, or mouth of the adit, the oil engine being self-contained, easily placed in position or removed if desired, and requiring no long, and therefore costly, connections for the supply of the necessary motive power, was peculiarly adaptable. In the case of some collieries, however, where a dangerous quantity of inflammable gas was given off from the workings, it would be evident that the running of an oil engine would be attended by danger. As it was, the safe use of oil in underground oil engines was so important a matter that, in Great Britain, special rules had been drawn up by the Board of Trade respecting its handling.

Instances were on record of oil engines having been successfully applied to provide motive power for underground haulage and pumping, for driving auxiliary fans, and for drilling. It might be of interest to members if he drew attention to one or two cases.

In "The Colliery Managers' Hand Book," Mr. Caleb Pamley mentions that at a mine in the County of Durham, a set of pumps which were originally worked on the tail rope haulage system were replaced by a Priestman oil engine, and a double-acting pump placed at a distance of 2400 yards from the shaft, and at a point 165 vertical feet in the dip. The engine was of 5 nominal horse power, and drove the pump by a belt. The pump had a 6-inch barrel, and a stroke of 18 inches. The water was forced a distance of 320 yards to a total height of 72 feet.

Mr. W. H. Wain, in speaking before the North Staffordshire Institute of Mining Engineers, on 21st March, 1892, described the application of a Priestman oil engine to underground haulage from a pair of exploring headings in one of the Midland Coal Company's pits. There was no available power within 1000 yards of the desired point. The oil engine hauled the coal from the bottom of the dip, and water from the different points at which it was caught. The distance hauled was 491 yards, the weight being about 37cwts., and the average time, 5 minutes 55 seconds. The total cost per hour for stores and wages was 2s 1.58d.

An interesting description of the use of an oil engine for hauling and pumping underground was given by Mr. William Smith in a paper read by him on the subject before the Mining Institute of Scotland, on 12th April, 1900. The paper is published in the "Transactions of the Federated Institution of Mining Engineers," Vol. XV111., pages 396-400. The plant described was erected at the Jellieston Colliery of the Dalmellington Iron Coy., Ltd. The pit is 678 feet deep. A Priestman oil engine with gear was erected to haul 150 tons per day of 8 hours, from a "dook," or dip, 780 feet in length, and having a gradient of 1 in 4½. The cylinder is 10½ inches diameter, the stroke is 12¾ inches, and at 188 revolutions per minute, 9 B.H.P. is given out. The drum is loose on the shaft, it is 2 feet 9 inches diameter, and is fitted with a claw clutch to throw it in and out of gear as required. When in gear and coming up with the full load, the rope travels at a speed of 50 feet per minute; when out of gear, the empty tubs running down the dip unwind the rope with their own weight, and in this way the motion of the engine is required in one direction only. A friction clutch connects the engine to the gearing, so that with the engine runnng at full speed, no shock or jerk is transmitted at the lifting of the load. On one end of the drum-shaft is a crank-disc 3 feet diameter, working a connecting rod 18 feet long attached to a rocking-lever; and from this lever a wire rope $1\frac{1}{4}$ inches diameter is led to the pump, placed near the bottom of the dip. The pump is of the ordinary bucket type, with the working-barrel lying at the same gradient as the dip. The bucket is 9 inches diameter, the stroke is 3 feet, and the speed is 6 strokes per minute. The water is delivered during the up stroke, counter balance weights taking the bucket and rope back. The connecting or dis-connecting of the pump (the means for which are described) takes only a few seconds. The oil engine is placed 480 feet from the pit-bottom, and 90 feet from the dip head. The exhaust gases pass direct into the return air-way, which is immediately behind the engine house, through which 20,000 cubic feet of air per minute passes. By means of a regulator, a current of 3,000 cubic feet of air per minute is allowed to pass from the intake air-way through the engine-house, keeping it cool, and carrying away any disagreeable smell. When the combustion of gases inside the cylinder is complete, no fumes are seen coming from the exhaust pipes; should, however, the internal parts of the engine be allowed to become dirty, then imperfect combustion is the result, and the gases have a strong and unpleasant smell, but they are not inflammable. The engine is fitted with a self starting apparatus, consisting of an iron pipe $\frac{3}{4}$ inch diameter, fitted with a cock; and this pipe conveys the oil and air direct from the tank to the vapouriser without passing them through the spray-maker. When the self starter is about to be used, the vaporizer is made a little hotter than is necessary when it is not used, the fly wheel is turned until the crank has just passed the inside centre, the brass ball on the eccentric rod is then in contact with the fork, and the electric current is ready to explode the charge. The pressure in the oil-tank is raised 7 or 8 lbs. above the regular working pressure, or to nearly 25lbs. per square inch, by vigorously working the hand pump for a few seconds. The cock on the self starter is then suddenly opened, and the engine starts immediately. The cock is thereupon sharply closed, and the oil and air sent in their proper channel through the spray-maker. The governors regulate the speed of the engine by apportioning the quantity of oil and air passing through the spray-maker.

The engine hauls 28 to 30 sets per day, each set consisting of 9 loaded tubs. The average time taken to haul the loaded set is 15 minutes, the empty set running back in 1 minute. The weight of the load drawn is as follows:—9 tubs at 5 cwt. each=5040 lbs.; coal, 13 cwt. per tub=13,104 lbs.; rope, 130 fathoms at 4 lbs. per fathom=520 lbs. Total 18,664 lbs.

The load due to gravity is 18,664÷4·5=4147·55 lbs., adding for friction 144 lbs. per ton on 8·3 tons=1195·2 lbs.

Total, 5342·75 lbs.

and this is equivalent to

$$\frac{5342{\cdot}75 \times 780}{15 \times 33{,}000} = 8{\cdot}41 \text{ horse power.}$$

In the foregoing calculations, the writer of the paper said that he had not taken into account the work expended in overcoming the friction of the gearing, and that if an allowance was made for that, the engine was developing fully 9 b.h.p.

Ordinary Scotch shale—or parraffin—oil was used, and was taken into the pit, at the commencement of each shift, in two strong 5 gallons vessels, fitted with screwed stoppers. The oil was emptied direct into the engine tank, and the vessels returned to the surface, so that no storage was required in the pit. The consumption of oil was 1.29 gallons per hour, or fully 1 pint per B.H.P. per hour. This quantity for hauling and pumping included, gave a cost of 1.21d. per ton of coal drawn.

The weekly cost of working the oil engine was as follows:—

2 Enginemen, 13 shifts at 4s 10d	£3	2	10
3lbs. cotton waste	0	0	7½
½ gallon lubricating oil at 2s	0	1	0
156 gallons oil for generating power at 7d ...	4	11	0
Renewals of battery per week of 120 hours ...	0	3	5
Up keep and repairs, taken over 4 years ...	0	5	0
	£8	3	10½

On an average output of 900 tons per week, the cost was equal to 2.18d. per ton.

The price of the engine was £384, and including erecting, making of engine-house, seat, brickwork, etc., was completed for £450. Special and stringent rules were drawn up for observance b-- the engine-men and are mentioned in detail by the writer of the paper quoted. The ratio of the gearing between the engine and drum-shaft was not definitely mentioned, but it was evident that it was rather more than 32 to 1.

Mr. G. Ey, in replying to the various criticisms on his paper, said he had to thank all those who had taken an active part in the discussion, and would refer to a few questions which had arisen, as follow:—

1. Why had a 2 cycle engine a constant of 900, as against 1000 for a 4 cycle engine? In the calculating of H.P., the reason was to be found on page 40.
2. Why was an oil engine so heavy? He believed that there were not many machines made which varied in weight more than oil engines, from the light motor cycle to the heavy stationary engine. The weight depended a good deal on the purpose for which the engine was to be used.
3. What was the longest run the author had experienced with an oil engine? A trip from New York to Havanah, made in seven days and several hours, with

out a single stop, with two 75 H.P. engines, which ran equally as well as any steam engine.

4. Re Mr. Christie's tables, giving a comparison of the cost of running the four steam launches of Mort's Dock and Engineering Company, Ltd., by coal, as against oil launches. He (the author) had worked out a table, based on his 15 years' experience of supplying small launches with a power for a given speed, as follows:—

Size of Boat	37 ft. x 9 ft.	37 ft. x 9 ft.	52 ft. x 10 ft.	54 ft. x 12 ft.
Speed of Boat	8.$\frac{7}{8}$ Statute Miles	8·$\frac{7}{8}$ Statute Miles	11·$\frac{3}{8}$ Statute Miles	11$\frac{3}{4}$ Statute Miles
Horse Power	10 B.H.P.	10 B.H.P.	30 B·H P.	40 B.H.P.
Consumption per B.H.P.	$\frac{1}{8}$ Gal. Benzine per hour	$\frac{1}{8}$ Gal. Benzine per hour	$\frac{1}{10}$ Gal. Benzine per hour	$\frac{1}{10}$ Gal. Benzine per hour
Cost of fuel per B.H.P. per hour	1·25 d.	1·25 d.	1·d.	1·d.
Total cost of fuel per hour	12·5 d.	12 5 d.	30·d.	40·d.
Hours actual running	30	25$\frac{1}{2}$	29	24
	Total cost of 30 actual hours running, £1/11/3	Total cost of 25$\frac{1}{2}$ actual running hrs., £1/6/0$\frac{1}{2}$	Total cost of 29 actual running hrs., £3/12/6	Total cost of 24 actual running hrs., £4

Assuming that the launches ran 50 weeks per annum, the cost of the oil would amount to £524 9s 7d, as against £1,045, as stated by Mr. Christie. In the above table the cost of benzine was calculated at 10d per gallon. Lastly, he would like to draw attention to the short actual hours of running as against the long, under steam hours, quoted by Mr. Christie. Again, in an oil engine the man was only required when the engine was actually running, which was a great saving in "stand-by" losses, and this made up for the difference in the cost of fuel.

As to the question of reliability, there was no doubt that if an oil engine was properly constructed, it was just as reliable as any steam engine.