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HIGH-SPEED TWO-STROKE ENGINES, WITH REMARKS ON INTERNAL WATER COOLING

BY

Mr. T. D. KELLY (MEMBER),

READ ON

Monday, March 4th, 1907,

AT THE

INSTITUTE PREMISES, 58, ROMFORD ROAD, STRATFORD.

CHAIRMAN: MR. WM. McLAREN

Discussion continued Monday, March 18th,

CHAIRMAN: MR. F. COOPER, R.N.R.

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PRESIDENT: JAS. KNOTT, Esq.

VOL. XIX.

58, ROMFORD ROAD, STRATFORD, LONDON, E.,

March 4, 1907.

PREFACE.

AT the meeting of the Institute of Marine Engineers held here this evening, a paper was read by Mr. T. D. Kelly (member) on, " High-Speed Two-Stroke Engines, with Remarks on Internal Water Cooling."

The subject is fully illustrated, and as the paper deals with rudimentary principles in connexion with the internal combustion engine, it should specially commend itself to the entire membership, as the importance of Marine Engineers becoming conversant with the action of engines of this type is more and more manifest as time moves on. The discussion was adjourned to March 18.

JAS. ADAMSON,

Hon. Sec.

High-Speed Two-Stroke Engines, with Remarks on Internal Water Cooling

BY T. D. KELLY (MEMBER)

READ ON

Monday, March 4th, 1907

CHAIRMAN: MR. WM. McLAREN.

Adjourned Discussion on Monday, March 18th.

MAY I preface this Paper by stating that by high-speed engines I mean engines with a high rotative speed of the crank shaft as distinct from high piston speed, which may mean a long stroke but slow speed of the crank shaft. Prob-

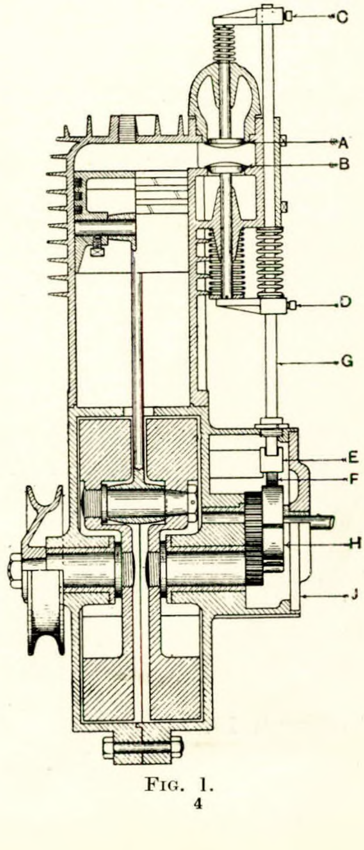


FIG. 1.

ably there are many present who are more familiar with steam than gas engines; therefore, in the hope of my remarks being appreciated by all, I shall at first briefly describe how the ordinary gas or oil vapour engine works, and the difference between four- and two-stroke engines.

Nearly all the stationary gas engines made now are of the four-stroke type (Fig. 1), first specified by a Frenchman, Beau de Rochas, put into practice by a German, Dr. Otto, and financed by an English firm, Messrs. Crossley, who have been suitably rewarded for their pluck and enterprise. It is called the four-stroke type because there are two revolutions of the crank or four strokes of the piston for every power impulse, that is :—

On the first down stroke of the piston, air and gas are sucked in through a mushroom valve (*A*).

On the first upstroke of the piston this charge of air and gas is compressed to about one-third or one-fourth its volume.

On the second downstroke, this charge of air and gas is exploded by a tube kept hot by a gas burner or by an electric spark, and the power of the explosion forces out the piston and turns the crank. This is the power stroke.

On the second upstroke the products of combustion are forced out by the piston through an exhaust valve (*B*) of the mushroom type opened by a cam (*E*) operated from a secondary shaft (*F*).

It will thus be seen that in addition to the piston, connecting rod and crank there has to be a secondary shaft running at half the revolutions of the crank shaft in order to operate the valves at the right time, and the lift of these valves has to be carefully adjusted, timed and watched on account of wear by the hammerlike action of the valve stems. In a single cylinder engine of the simplest type, such as is used for a motor cycle (and here described), there are eleven moving parts, the derangement of any one of which means the stoppage of the engine. This is the type of engine almost universally used for motor-car work, with the difference from the stationary gas engine that the gas is made by the suction of the engine drawing petrol spirit (which evaporates in conjunction with air at a low temperature) through a controllable jet surrounded with air, called a carburettor. The petrol is supplied at a constant level by a float valve somewhat after the manner of the ball valve in the plumber's cistern. By a two-stroke engine is meant that a power stroke is obtained at every revolution of the crank or with two strokes of the piston, like a single-acting steam engine. There are two types, one which was in competition with the Otto engine years

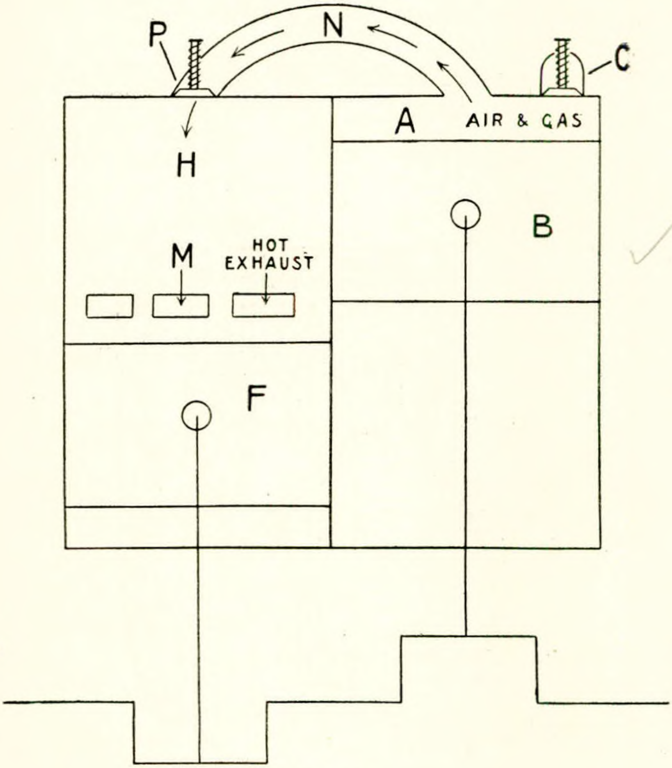


Fig. 2.

ago and known as the Clerk engine (Fig. 2), in which the air and gas were sucked in through a valve (*C*) by a pump (*A*) worked from a throw of the crank set at an angle to the main piston (*F*), and this pump forced the charge into the main working cylinder (*H*) through a valve (*P*) after the main piston had uncovered the exhaust ports (*M*) at the bottom of its stroke, through which the exhaust escaped by its own pressure, and the new charge was forced in by the pump piston (*B*) and displaced the remainder.

A type of two-stroke engine,— which is used a great deal in America, but only for boat work,—consists of a trunk piston working in a cylinder with the crank enclosed in an airtight casing (Fig. 3), and works as follows :—

On the upstroke of the piston the air and gas are sucked into the crank case through the valve *H*, and on the downstroke

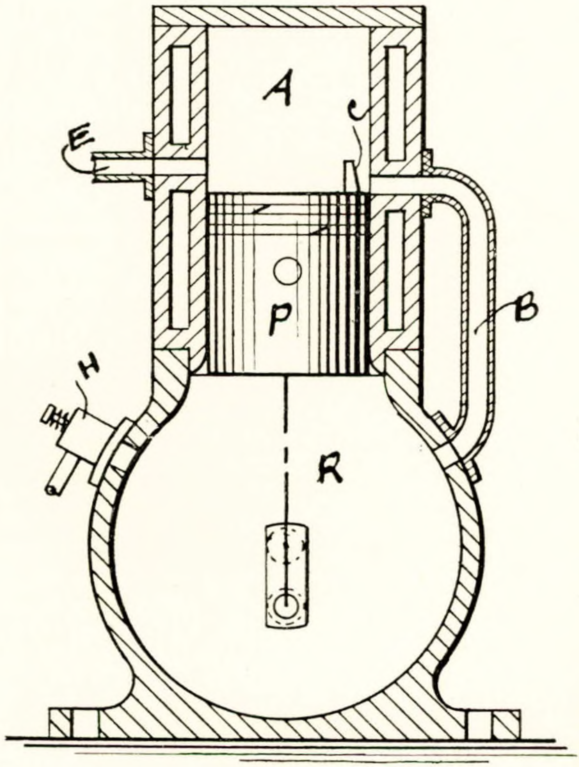


FIG. 3.

when explosion takes place in *A*, this air and gas are forced up the by-pass *B* into the working cylinder, and deflected to the top by the baffle plate *C*. *E* is the exhaust port at the bottom of the stroke. The trouble in both these types of two-stroke engines is that high speed is out of the question, because the new charge of air and gas is forced into a cylinder full of hot gas—at atmospheric pressure, it is true, but still red hot, and as you will see in the latter type there is nothing to prevent the flame which is in the cylinder at the bottom of the stroke flashing right back into the crank case. Another defect of this type is that when the bearings in which the crank shaft works are worn there is a leakage of the charge through the same, and there is not sufficient pressure in the crank case to drive the gas into the working cylinder apart from the fuel loss. This defect is more glaring when more than one cylinder is used, as it is difficult to get at the centre bearings when the cylinders are cast together. Thus in actual practice this means that a two-stroke motor of this type gives its maximum power at about 300 or 400 revolutions a minute, and owing to the large amount of exhaust gas left in the cylinder, the explosions are very weak, which means that power for power compared with a four-stroke motor they are very heavy engines, but, given a perfect two-stroke motor—that is one which would run at a high speed without the above-mentioned defects—it will develop double the power at the same speeds and with half the weight, and have as varied a range of speed as the four-stroke. There are special advantages in a perfect two-stroke motor which makes it pre-eminent for marine work; the first being that, as the engine is single acting, the thrust is always in one direction, so that no matter how worn the crank brasses may be, there is no knock at high speeds. In a four-stroke motor the brasses are always needing to be taken up, as there is a reversal of thrust similar to a double-acting steam engine. The second advantage is that as there is no mechanism for operating the valves, the only moving parts being the piston, connecting rod and crank, the crank shaft can run in either direction so that a multiple cylinder engine can be reversed in the same manner as a steam engine. Having spent a number of years in marine and gas engineering work, I was struck with the engineering and commercial possibilities of the two-stroke engine, and went into the question why it was not more generally used, and if there were faults, whether they could not be overcome by mechanical skill, in these days of accurate machine tools.

It is evident that the reason the Clerk type of engine was "knocked out" by the Otto engine, was that a complicated arrangement of slide valves, as used then, besides two cylinders, two pistons, connecting rods and cranks, entailed a much higher price for an engine of the same horse power, and there was always the risk of a backfire breaking the crank shaft or doing other damage. On the other hand its steady running, through having more frequent impulses, was a desirable feature, but this could always be obtained in a four-stroke motor by a heavy flywheel.

In motor-cars or for marine work this flywheel has to be carried, and its size and weight are greatly curtailed, besides considerable vibration is set up by having light flywheels, which, as weight is limited, is a necessity, so the impulses have had to be increased by adding more cylinders, and it has been decided by automobile engineers that the least number possible, to get an even turning movement on the crank shaft, is six cylinders of the four-stroke type, which after all is only like three single-acting steam cylinders. An extract from a speech by Mr. S. F. Edge at the Automobile Club on February 7, 1907, fully bears out my remarks on this point and shows the pressing need for a perfect two-stroke motor.

Mr. Edge said : " All engineering is a question of compromise. The main thing is to get a combination which, whilst having the fewest number of defects, is most suitable for the particular object desired. In connexion with the evolution of the Napier six-cylinder engine, the one idea has been to make the most suitable powerful motor for a motor-car. We have taken as the governing factors : First, that weight must at all costs be kept down ; secondly, that horse-power is required over 30 h.p. ; thirdly, tyres are, in the upkeep, the most expensive portion of a motor-car, and to reduce wear and tear on them is of importance. We might add to this list many other items, but these are the most important, and our endeavour has been to compromise one detail with another until the result was as perfect as could be.

" As motoring has proceeded, the demand for large horse-power has increased, and it is quite reasonable that it should. With this demand, engines became less commercial and unsuitable as power was added to in a four-cylinder engine. We all agree at present as to the importance of the Otto cycle being retained. This is one of the fundamental difficulties that, so far, we have all been unable to eliminate, and it should be borne in mind that Dr. Otto, when he evolved his famous cycle, did it deliberately to put the working of the gas engine on a correctly definite chemical basis. Many experiments in gas engines had been carried out before Otto's time, but he was the first to appreciate the importance of a definite exhaust phase, and of getting rid of the exhaust gases, if a commercial and economical engine were to be produced without extraneous aids to scavenging. What was true in Otto's time, as far as this is concerned, is true to-day. *We are, therefore, labouring under the difficulty of having an engine in practically all motor-cars that wastes three parts of its time—as far as each individual cylinder is concerned. This is a fearful handicap for automobile engineers, and the result was that, first, two cylinders were employed, then three, then four, and now six. As the number of cylinders was added to, so the difficulty decreased.*

"The early engineers got over this trouble by adding to the weight of their flywheels, but as power and the size of cylinders increased, the amount of compression to be overcome and the difficulties of keeping the engine running smoothly increased also. Flywheels have other drawbacks than that of mere weight, when it is considered what happens to the tyres every time a large flywheel is suddenly brought to rest (by the careless letting in of the clutch, for instance), and the gears, chains and tyres will be duly sympathized with.

"Many have jeered at the making of the six-cylinder, and said it was merely a question of adding two cylinders to the four. It was more than this. *It was a serious effort to overcome the inherent defect of the Otto cycle without the drawback and obvious defect of a big flywheel.*"

Two-stroke motors of the American type with single cylinder, are, however, not so costly to build as the Clerk type, so I chose this type to experiment upon and to improve. By studying various patents and becoming familiar with what had been done for the last thirty years in England, France, Germany and the United States, my experiments with various types of two-stroke engines demonstrated their many faults.

Slow speed means weight and high speed means power for little weight, so before a two-stroke motor could seriously compete with the four-stroke, this weight had to be cut down by increasing the speed and the efficiency of the engine, which meant clearing out all the hot exhaust gases so that high compression could be used, as high compression in a gas engine means economy, and high compression, like high speed, was not a feature of the American two-stroke engine using the crank case as a pump, owing to pre-ignition before the piston reached the top of its stroke, due to the large amount of hot exhaust left in the cylinder. (In fact, as far as power went, some previous forms of two-stroke engines have been very little better than hot air expansion engines.) This could be remedied by sending a charge of pure air unmixed with gas through the cylinder first, before the entrance of the gas, to drive out the exhaust and prevent the new charge meeting the exhaust; this principle, of course, had been exploited by many before me, but I had to do this, in order to ensure a commercial success, without using any separate pumps for gas or air scavenging to run up the cost and without any complications in the way of mechanical valves, always bearing in mind that the engine had to be sold at a considerable profit, while its price to the purchaser had to be less than the four-stroke engine at present on the market.

The following descriptions and diagrams will give the evolution of the Duplex two-stroke engine, as well as a description of some additions and improvements which we will probably adopt for large powered marine work.

Description of Working of Figures 4, 5, 6, 7.

The first trouble to be overcome in trying to improve the crank case two-stroke engine was to stop the ignition of the incoming charge by the hot exhaust and the backfiring into the crank case and carburettor. This was done by fixing a non-return valve *F* (Fig. 4) opening from the atmosphere on the transfer pipe *B*, so that on the upstroke of the piston it would suck gas through the valve *H* into the crank case, and air down the pipe *B* through the check valve *F*. On the upstroke the mixture in the crank case would be forced up the pipe *B*, but it could not enter the cylinder *A* until the air contained in the pipe *B* entered first, and if there was any flame still left in the cylinder this air would prevent it meeting the inflammable mixture following. This worked exactly as intended, and I increased the speed of a two-stroke engine of this type from 350 revolutions per minute to 800 without a silencer, but on fixing a silencer on the exhaust *E*, I found there was so much back pressure that although it would run (without a load) at high speeds, it was very little better for power than the ordinary two-stroke engine, the explosions being very weak, although a nice silent vibrationless engine, as there was very little mean pressure. This is easily explained. The pressure in the crank case is never more than 5 to 6 lb. to the square inch, and the pressure of the exhaust at least 20 lb., which pressure of course is in the silencer, although it is rapidly falling, so the incoming charge at 5 or 6 lb. pressure had to

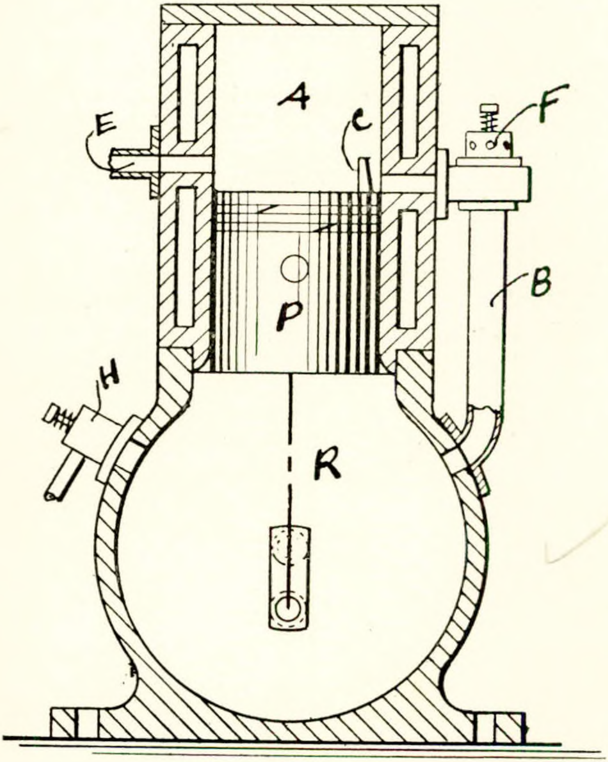


FIG. 4.

push out the dead exhaust gas left in the cylinder at atmospheric pressure against the pressure in the silencer. Some silencers are better than others. This trouble led to the designing of the engine described in Fig. 5, where a differential piston forms a vacuum pump at *D* to suck out the dead exhaust gas when the piston uncovers the auxiliary exhaust port *EE*. The cycle was as follows :—

On the upstroke, gas was drawn into the crank case *R* through the valve *H*, and air down the pipe *B* through the valve *F*. On

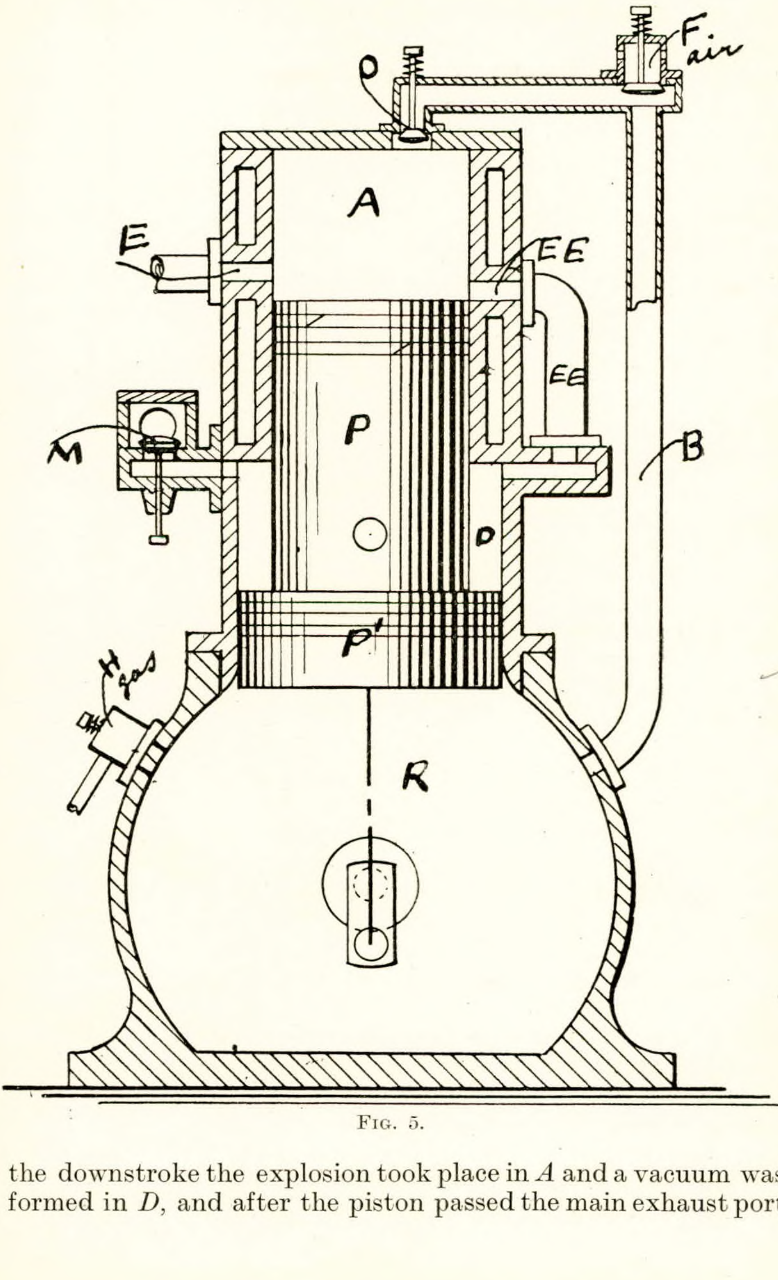


FIG. 5.

the downstroke the explosion took place in *A* and a vacuum was formed in *D*, and after the piston passed the main exhaust port

E, the exhaust gas under its own pressure passed through the same to the silencer. Immediately after, the auxiliary exhaust port *EE* is uncovered, and the dead gas in the cylinder *A* rushes to fill the vacuum in *D*. The contents of *A* are now, of course, below atmosphere, and the gas in the pipe *B* and crank case *R* considerably above atmosphere ; and this difference in pressure opens the valve *O*, and first air, which was drawn in through the valve *F*, enters the cylinder and prevents any back-fire through contact with the hot exhaust in the vacuum pump *D*, and then gas, which charge is compressed and fired in the usual way. On the next upstroke the cycle is repeated, and the contents of *D* pumped out through the non-return valve *M*. The trouble with this engine was that the bottom part of the piston being twice the area of the top portion, the pressure in the crank case was excessive, as I had double the volume required, consequently there was leakage through the bearings very quickly, and waste of power for no purpose. Also the vacuum pump got too hot for easy lubrication and required water cooling. To obviate these new defects seemed like piling up complication, and I called a halt and conceived the idea of arranging two cylinders side by side and connecting the bottom part of the piston of one to the working cylinder of the other, which would permit of air scavenging and also do away with the crank case as a pump. Engines made on this principle of mine have been inspected by numerous engineers, and have been very successful, running at speeds as high as 1,500 to 2,000 revs. per minute, and it makes a simple, reliable and light engine for motor-car work. The working of this engine is best described by the engineer who inspected it on behalf of one of the leading motor journals.

"One of the most interesting exhibits at Olympia was the Duplex two-stroke engine. In it a wonderfully simple expedient has sufficed to remove backfiring, which has been the bugbear of all previous investigators in this direction. Before describing the actual improvements that have been made, it will be well to preface a few observations on the causes that have hitherto led to failure in high-speed two-stroke engines. It is common knowledge that in the ordinary motor of this type the exhaust escapes from the cylinder through ports uncovered by the piston near the bottom of each downward or working stroke. There is no sweeping action as there is in the four-stroke cycle or Daimler engine, where the piston moves right up the cylinder to clear off all the products of combustion. It follows that the cylinder must retain a complete volume of exhaust gas at atmospheric pressure until the mixture for the next power stroke enters under a slight compression through a port, uncovered also by

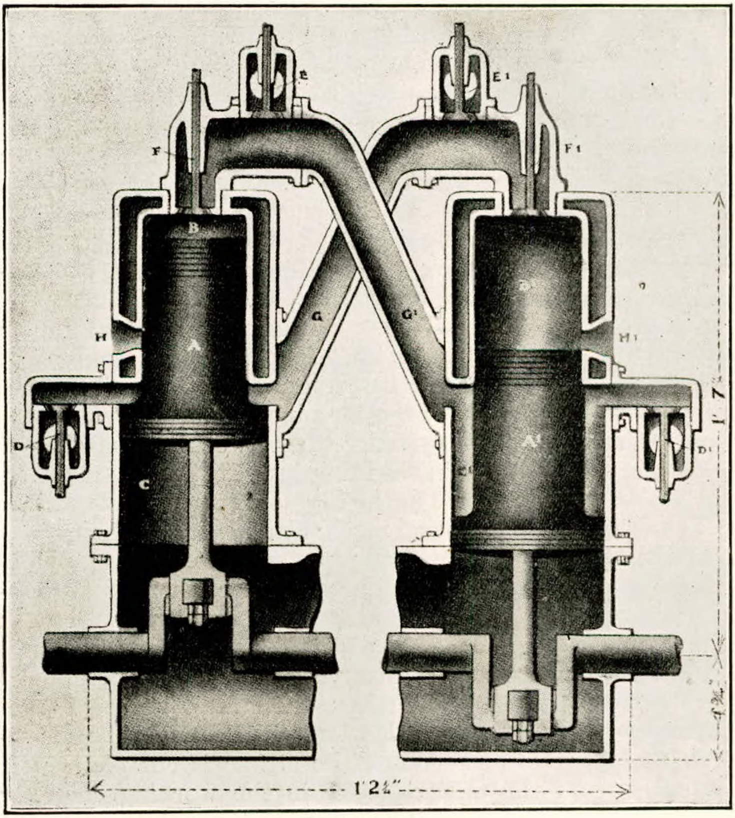


Fig. 6.

the piston, but lower in the cylinder than the exhaust port. At high speeds the back pressure of the silencer retarded the burnt gases sufficiently to ignite the incoming charge of fresh mixture, and at the lower speeds, when backfiring did not occur, some of the mixture was lost by escaping through the exhaust port, the only precaution taken to minimize this waste being the bolting of a baffle plate on the piston head near the inlet port. In order to run a two-stroke motor smoothly it was necessary to keep the speed below 600 or 700 r.p.m., which resulted in a heavy and bulky engine. There was also the disadvantage that the speed could not be controlled easily, owing to the low compression that must necessarily be employed, and that the vibration was very marked owing to the large mass of the reciprocating parts. In some designs the crank case was used as a pump to force the mixture into the working cylinder—since the gas inlet occurs at the bottom of a stroke, it is compression, not suction, that must be employed to introduce the mixture—and either the stuffing boxes, required on the main bearings to keep the crank chamber tight, caused the shaft to run hot, or, in their absence, leakage took place as soon as wear commenced. In the Motor Engine and Manufacturing Co.'s Duplex engine *the cylinders have two diameters*, and the pistons are enlarged at their lower ends to fit the walls of the bigger chambers. It is into these lower annular chambers that the mixture is first inspired, and from them that it is pumped at about 10 lb. initial pressure into the working cylinders above. Transfer pipes connect across from the lower chamber of one cylinder to the working chamber of the other, in order to obtain the pumping effect at the required moment. It will be noticed in the diagram (which is not drawn to scale, nor to show the actual mechanical design of the motor) that at the highest point in each pipe, and as close as possible to the inlet valve of each working cylinder, there is an air-snifting valve. The operations that take place are as follows: On the downward stroke of, say, piston A, the mixture valve (D) opens automatically to draw in a very rich mixture from the carburettor, and, at the same time, the snifter valve (E^1) on the transfer pipe (G) communicating with the annular chamber (C) admits pure air. When the stroke is completed the burnt gases from the power stroke in the working chamber (B^1) of the other cylinder will be escaping through the exhaust port. Soon after the upward stroke of the piston (A^1) has commenced, the inlet valve (F^1) will open, allowing first the pure air which fills the transfer pipe to rush through the cylinder (B^1), and sweep out the remaining exhaust gases through the port (H^1), and then admitting the mixture which filled the actual pump (C). It will be recognized that only pure air can escape from the cylinder, the exhaust port (H^1) being closed by the time the mixture has entered. There is thus no waste of fuel, and there can be no backfiring at high speeds since the burnt gases have been scavenged away. This is not merely a theoretical supposition, but an actual fact, which we can confirm, because we have seen the motor running at 2,000 revs. per minute. Having achieved this result with a high compression—about 90 lb.—the inventor has produced an engine that possesses manifold advantages over the ordinary automobile type. For instance, since the number of power strokes in each cylinder are doubled, a Duplex engine, with cylinders of the same bore and effective stroke as an ordinary automobile motor, will develop double the power. In other words, the weight per horse-power is halved at least, without reckoning the saving made by abolishing many of the parts essential in a four-stroke cycle engine. To obtain the same power only half the number of cylinders are required, and owing to the more even turning moment and the slightly reduced effect of the inertia of the reciprocating parts, there will not be quite so much vibration as with the larger number of cylinders of the present-day car engine. It is worthy of notice that the three-cylinder Duplex should give greater flexibility and less vibration than the so generally adopted ordinary six-cylinder, with the great benefit of a shorter bonnet, and thereby reduced wheelbase. Owing to the necessity for arranging an easy escape to the exhaust, the engine runs very silently. And last, but certainly not least, as far as the average motorist is concerned, there are no camshafts or half-time wheels. There are but two plain check valves, and one automatic spring valve for cylinder."

The trouble of the back pressure set up by the silencer has been solved in the duplex engine in a very simple manner by providing an auxiliary exhaust port to open a little later to the air, as a vacuum is only a difference in pressure, and if the pressure of the incoming charge is in excess of that in the cylinder and there is a free exhaust (apart from the main exhaust to a silencer), it must be displaced by the incoming charge without back pressure, and such is the case in my duplex engine.

In Fig. 7 is shown a single-cylinder type of engine specially designed for marine work to use paraffin, but instead of the crank case the charge of gas is drawn underneath the hollow piston *P* into the space *R* through a non-return valve *H* and air down the pipe *B* through the valve *F*. On the down stroke, explosion takes place in *A*, and the main exhaust goes out of *E* to the silencer, and the remaining exhaust in the cylinder is pushed out through the auxiliary exhaust *EE*

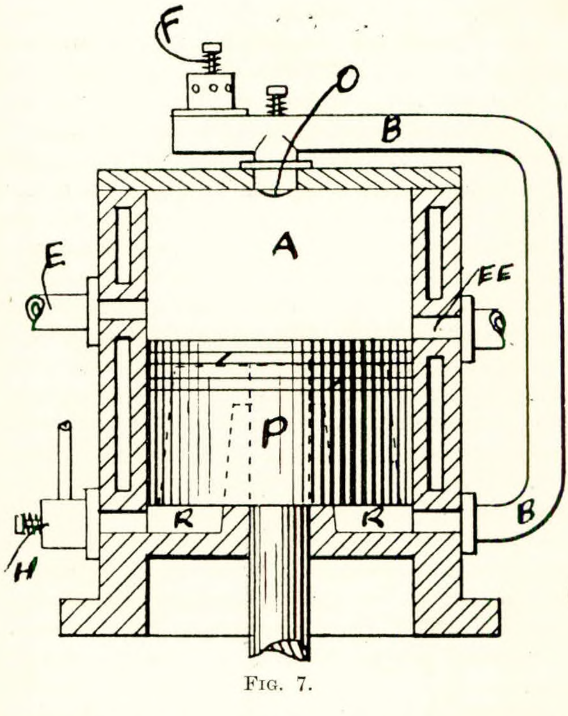


FIG. 7.

by the pressure of the incoming charge, always preceded by the scavenging air. For using paraffin the by-pass *B* is cast in the cylinder between the water jacket, so that the oil spray comes into contact with the hot wall of the cylinder and is never allowed to condense after being drawn and vaporized through the valve *H*, which is surrounded by hot exhaust drawn from *E*. Any of the pumps so necessary on a ship may be worked off the crosshead of this engine. The remaining details of this engine are well understood by marine men, and there is practically nothing to go wrong and few repairs beyond taking up wear ; but as there is an absence of moving parts outside the cylinder, the wear would be no more than with a steam engine, whose long life is proverbial and a source of envy to gas engine builders of the four-stroke type with their numerous moving parts.

Some may remark that I have not simplified the two-stroke engine, but have added two more valves where there was only one, and in some two-stroke engines no valves at all. My object has been simplicity combined with efficiency and cheap cost of production, and if efficiency is required valves are necessary and add very little to the cost of production, as the cost of the three valves on each cylinder is only as many shillings, and if there should be any demand from the public for an engine without valves my firm will make one with air scavenging and all the improvements mentioned in this paper.

One of the chief troubles in large size stationary gas engines of 1,000 horse power and over, is that in order to keep the pistons cool, they, as well as the cylinders, have to be water cooled, and for this there is rather a complicated piece of swivel-jointing work, the piston being always on the move. The method proposed in this paper, which from various experiments promises well, would get over this difficulty of high temperatures without wasting the heat. People who ought to know better informed me that it could not work, but could not say why, and as I had experimented and they had not, I kept on with my work (or rather hobby, as it was all money going out), more especially as the same people had said a high-speed two-stroke engine was out of the question without extraordinary complications, and as for gas turbines, that was perpetual motion madness. Within five years of those remarks being made, I have obtained a high-speed two-stroke engine with only three moving parts per cylinder, viz., piston, connecting rod and crank ; I have tried the internal water cooling, but not on a large scale ; most curious of all, at St. Denis in Paris there is a gas turbine running at 4,000 revs. a minute, giving 800 h.p., in which the sole secret of its working is the internal water spray injection. This type of turbine will not at present compete in the industrial market as it is of the continuous combustion type just as the first reciprocating gas engines were, the gas always burning, and is not at all economical for commercial work; but the point I want to call attention to is that without the internal water injection it could not run at all on account of the high temperature, and without internal water injection neither will the large marine gas engine of 10,000 horse power.

In Fig. 8 you will notice a section of the air valve used, but there is also shown a needle valve (*X*) and water pipe (*W*), so that water may be fed to the seating of the valve *F* at the discretion of the operator, and sucked in with the air in a fine spray, which is an extra precaution for large-sized engines, not so much to prevent the incoming charge being ignited by the hot exhaust, as the air alone, not being inflammable, prevents that, but to prevent ignition on the up stroke when paraffin is used, as on account of the high compression, paraffin spray or gas is liable to ignite on its own account without waiting for the electric spark to fire it, and in order to keep down the temperature of the air and gas being compressed, I

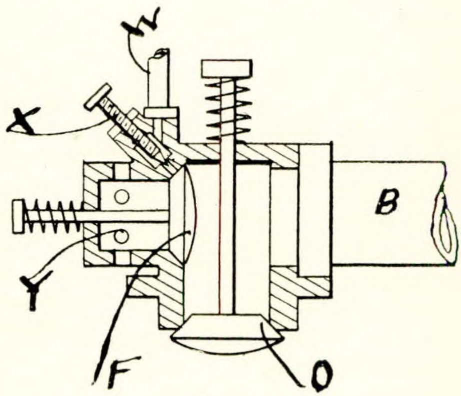


FIG. 8.

use water in this way, the water of course can be turned on or off by a tap. In addition to the prevention of pre-ignition, however, the water has the chemical effect, when paraffin or any hydrocarbons are used in excess, of greatly assisting in their perfect combustion. I will explain the chemical action which I believe takes place, and, what is more, will prove my theory, which anyhow works out in practice, as we are not the only oil engine makers using water, but I doubt if any have thought out what really takes place—apart from the point they use water for, that is, to prevent pre-ignition.

At first sight some would think that the charge would not fire at all, but the actual fact is that water present in the air assists in the combustion. The approximate temperatures in the cylinder of a gas or oil engine are as follows :—

With a compression of 90 lb. to the sq. in. before ignition, the explosion temperature is over 2,000 degrees F., and the exhaust temperature over 800 degrees F.

Now, as water cannot exist as water at a temperature above 212 degrees, it will be seen that when sprayed into the hot cylinder of a gas engine it is turned into vapour or gas, which we know as steam, and as a vapour, its elements, viz., hydrogen and oxygen, are quite ready to take up with any substance or gas for which it has an affinity, and I have come to the conclusion that hydrogen has a strong affinity for carbon, as well as oxygen, in proof of which these three elements in various proportions are more numerous than anything else in this world, hydrogen and oxygen in the shape of water, and other hydrocarbon groups as coal, oil, sugar and nearly all our foods. It also seems to account for the fact that carbonic acid gas is soluble in water, that is, water will absorb this gas, and it will not so absorb any other gas or air, a knowledge which is turned to account by mineral water and bottled beer manufacturers. As you know, the products of combustion in a gas or oil engine consist mainly of carbonic acid gas. Now if water, that is to say, hydrogen and oxygen, are sprayed into this with heat present sufficient to turn the water into a gas, the hydrogen will combine with the carbon present in the carbonic acid gas, forming a hydrocarbon which will burn in the presence of the oxygen left out of the combination; oxygen, as you know, does not burn, it only supports combustion. As practical engineers, you want proof of this. I will give it "right here," as our American friends say, by a little experiment. In a Bunsen gas burner, air and gas are burning almost under the identical conditions which take place in a gas engine. The blue flame is an explosive one, and the product of combustion is carbonic acid gas. If I were to spray paraffin oil, which is a hydrocarbon, into this burner, it would turn the blue flame into a yellow one. I have here an ordinary scent spray, but instead of scent it has plain water drawn from the tap in it. Into this blue flame I will spray the water, when probably to your surprise instead of partially quenching the blue flame the water spray burns with a yellow flame, the same as if paraffin had been injected. Something of the same kind goes on when the smith puts water on his forge fire for a good heat; although he does not know it, he is after a hydro-oxygen flame, the hottest known to science. Bearing this experiment in mind, it will be seen that by internal water cooling, a gas-engine cylinder can be kept down to the temperature of a high-pressure steam engine, so that in the near future, for marine work, where there is plenty of water available, large gas engines of the two-stroke type are likely to be serious competitors of the steam engine, more especially as it is quite possible to build an alternate gas and steam engine, in other words, a steam engine without the boiler, working on a cycle somewhat as follows (*see* Fig. 9) :—

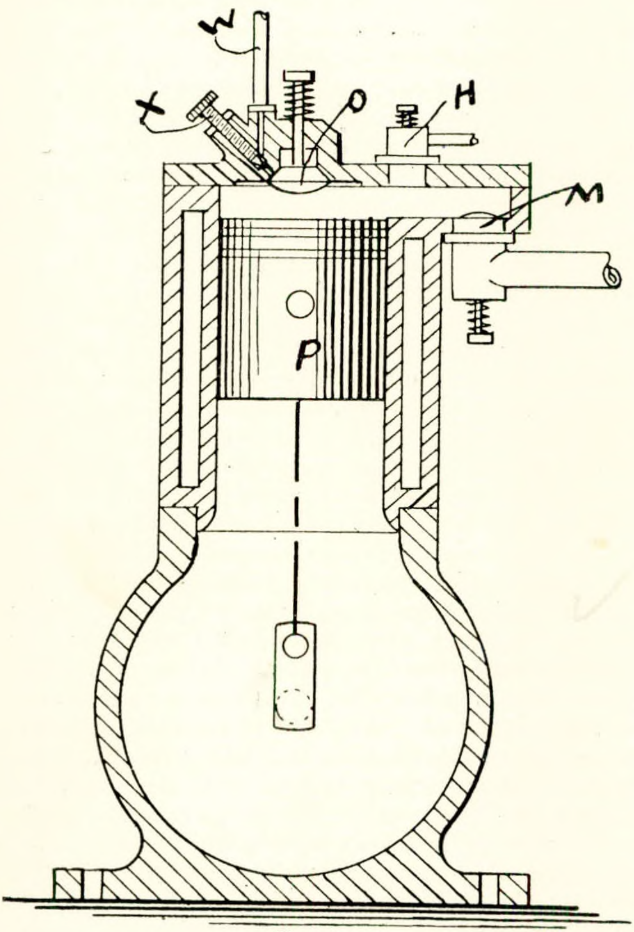


Fig. 9.

The first down stroke is a power stroke under the explosion of air and gas drawn or forced in through valve *H*, but at the end of this power stroke, instead of releasing the exhaust to take away the heat with it, re-compress it, and at the beginning of the next down stroke inject water spray through the valve *O*, which will be turned into steam in the same way as in a flash boiler, as the temperature in the cylinder will be between 800 and 1,000 degrees F. The second down stroke of the piston would thus be a power stroke under steam pressure, and by the time the bottom was reached all the heat and pressure would be taken out of the exhaust gas and distributed in useful work on the crank shaft, at the same time keeping the cylinder and piston at normal temperatures. At the end of the steam stroke the exhaust port or valve *M* would be opened, and the dead steam forced out by the pressure of the new explosive charge entering, which can come into contact with the exhaust gas without fear of being fired. A double-acting gas engine of this type could easily be made to work in large powers without fear of excessive temperatures interfering with the stuffing gland, the space between the stuffing box and the cross-head guide being used as an air and gas pump alternately, supplying each end of the cylinder. The actual engine my firm is making for experimental purposes and which has given every satisfaction is single acting, with a duplex type of piston.

Of course one point where steam scores over the gas engine is that steam can start against a load, and steam can be carried to any part of the ship to work winches, cranes, capstans, etc., and as the large marine gas engine would have to be started by some external means, my idea of the best way to do this would be to have a dynamo-motor on the same shaft acting as a flywheel, so that by running current through it from accumulators on board, kept charged by the same machine when running as a dynamo, it would act as a motor and start the gas engine, the engine, when started, would of course drive the dynamo, as well as the propeller shaft, and current from this dynamo could be used for lighting the ship and for operating the cranes, winches, etc. I think this method preferable to the use of compressed air, as the efficiency would be greater, and there are more uses to which the current can be put. The electric current would be produced by excess power of the engine driving the dynamo when not required for propelling the ship, as an automatic regulator would run the machine either as a dynamo or motor when required, the same as is now used on some types of motor-cars instead of change-speed gearing, the motor bolstering up the engine when more power is required, and storing up its excess power by means of accumulators when not required.

DISCUSSION

On Monday, March 4, 1907.

Chairman : Mr. Kelly has brought something new before us in his design of the internal combustion engine described in the paper, which is the third we have had on the subject; he will be pleased to answer any questions any gentleman would like to ask, and if any one wishes to take part in the discussion which this paper ought to draw out, I hope they will get up without waiting to be called upon.

Mr. Gander (Associate) : I should like to ask the speed of the engine illustrated by figure 7 ?

Mr. Kelly : It is designed to run at 600 revolutions per minute.

Mr. Gander : You say, referring to this engine, "any of the pumps so necessary on a ship may be worked off the crosshead of this engine" ; would they be worked direct ?

Mr. Kelly : Such could be worked direct ; a good many high-speed steam engines run at that speed with pumps fitted.

Mr. GANDER: But are the pumps running at 600? Is not that rather a high speed?

Mr. KELLY: Yes, the pumps are running at 600; there is no trouble in working a pump at 600; in fact, all marine internal combustion engines with direct acting pumps work at high speed, that is, worked by an eccentric on the shaft. It is single acting, so you do not get any knocking with it. Of course, the speed of a marine engine is subject to the propeller; it may be designed to run at 600, but if the propeller is not designed according to the lines of the boat the engine cannot do it.

Mr. W. PULLEN (Member): I think the last speaker is quite right with regard to the pumps. We have had some experience with these, and the tendency is all against direct-connected pumps for this speed; they knock to pieces very quickly and the independent pump is much more satisfactory.

Mr. KELLY: They can be geared down to give the best results.

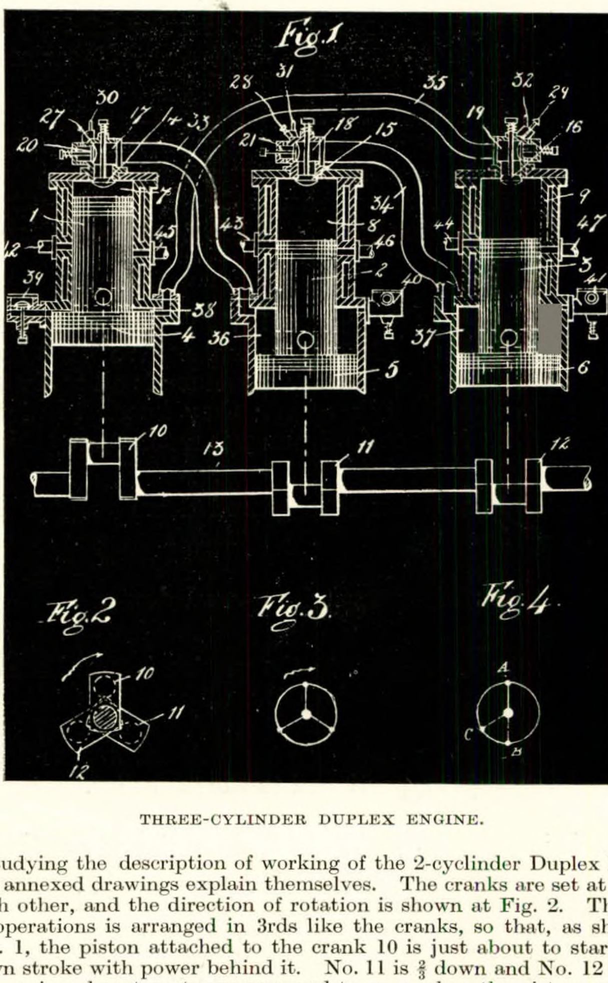
Mr. PULLEN: They must be geared down.

Mr. KELLY: Of course, in the marine internal combustion engine the pump has to be driven from the shaft by some means, as there is no other power. A good many use chain wheels and sprockets and gear them down, but, as I said, the speed of course is proportioned to the propeller.

Mr. G. A. PULLEN (Member): I would like to ask the author, referring to the paragraph where he says "It is worthy of notice that the three-cylinder duplex should give greater flexibility and less vibration than the so generally adopted six-cylinder with the greater benefit of a shorter bonnet and thereby reduced wheelbase," I should like to know how that three-cylinder engine of the duplex type acts.

Mr. KELLY: Of course, that is part of the quotation from one of the motor journals, and they are not my own words.

I will explain the action by a sketch on the blackboard. (Detailed sketch supplied later as below.)



THREE-CYLINDER DUPLEX ENGINE.

After studying the description of working of the 2-cyclinder Duplex Engine, the annexed drawings explain themselves. The cranks are set at 120° to each other, and the direction of rotation is shown at Fig. 2. The cycle of operations is arranged in 3rds like the cranks, so that, as shown in Fig. 1, the piston attached to the crank 10 is just about to start on its down stroke with power behind it. No. 11 is $\frac{2}{3}$ down and No. 12 is $\frac{1}{3}$ up. The main exhaust ports are arranged to open when the piston supplying the charge is $\frac{1}{3}$ up, so that the pump piston just finishes its stroke as the exhaust port is closed. Fig. 3 shows the cycle in the working cylinder, from 1 to 2 being expansion or power, from 2 to 3 being exhaust and incoming of scavenging air and new charge, and from 3 to 1 being compression of charge in working cylinders to $\frac{1}{4}$th their previous volume, the ratio between all phases, or time taken to perform them, being the same as in a 4-stroke engine. This explains the mystery of the Duplex Engine, and is the solution of the problem of how to make a high-speed two-stroke engine. It will be noted that the working piston pumps out $\frac{1}{3}$ of the exhaust gases in addition to displacement by incoming charge.

Mr. PULLEN : Thank you, I see.

Mr. KELLY : In actual practice it requires a mechanical valve because the automatic valve will not open on the upstroke; so the engine does not get the full charge.

Mr. PULLEN : Have you built the three-cylinder engines ?

Mr. KELLY : Yes, we have built a three-cylinder engine, but the two-cylinder beat it in the results; the latter takes a pull of 240 lb. on a 15″ flywheel at 850, with the former we just get 30 H.P. out of it at 1,000. Of course a four-cylinder is better, because a three-cylinder engine has always an unbalanced crank, while with a four-cylinder there is a balanced crank and balanced impulses. We make the four-cylinder type for high speeds in preference, and only make the three-cylinder engine if specially ordered, in which case we put mechanical valves on and weights on the crank shaft to balance.

Mr. TIMPSON (Member) : Could Mr. Kelly tell us what is the consumption of paraffin ?

Mr. KELLY : I have not tested with paraffin, but the consumption of petrol is about ·85 of a pint per B.H.P., in other words, about 20 B.H.P. with a consumption of 17 pints.

Mr. TIMPSON : And what arrangement have you for starting ?

Mr. KELLY : The duplex starts with a half-turn of the crank.

Mr. TIMPSON : Have you had any test taken in commercial running ?

Mr. KELLY : For marine work, no. The trials have been more or less experimental.

Mr. TIMPSON: Regarding the point mentioned in the last paragraph in connexion with having a dynamo-motor on the shaft in preference to the use of compressed air, I do not know that there is much to be gained by it. Compressed air, of course, can be used for more than starting. It has been used for driving the winch and capstan without trouble.

Mr. KELLY: I think most marine engineers will agree with me that you do not get the efficiency from compressed air that you do from electricity. Then again, of course on board ship you must have light, and if you get the dynamo fixed up you can use it for lighting the ship as well.

Mr. TIMPSON: In engines of which I have had experience there is no trouble in compressed air starting.

Mr. KELLY: In actual practice?

Mr. TIMPSON: In actual practice. We fitted arrangements for starting a motor with compressed air, a 60 B.H.P. motor. In one instance the boat was stopped without means of starting the engine, for want of an auxiliary air compressor, and when this was fitted there was no trouble. With the motor that I referred to we have had five weeks' steady running, and the owners have stated no fault. The consumption is only a barrel of oil per week. That is with a two-cycle engine, yet it has been stated without truth that the two-cycle engine had failed. The consumption works out at ·2 of a pint per B.H.P. on the 60 H.P. engine.

Mr. KELLY: Of course your compression is very high, 200 lb. is it not?

Mr. TIMPSON: Yes, 200 lb.

Mr. KELLY: I quite agree that it is absurd to say that the two-cycle engine is a failure; in my opinion it is bound to supersede the four-cycle; the reduction in weight alone is a great advantage.

Mr. TIMPSON: Generally speaking the simpler you can make your engine the better, because of the class of men who are usually employed to look after them, very often men who know nothing about engines. I might add that I can fully bear out what Mr. Kelly said about the water cooling. At first, running at a high speed, we had some difficulty with hot bearings, but we mixed water with the oil in the crank-case and there was no detriment whatever to explosive mixture drawing air from the crank case.

Mr. Kelly : You add 20 per cent. to the power of your engine by spraying water into the cylinder.

Mr. J. Lang (Member) : What about the reversing of the engine ? It will be rather troublesome I should think.

Mr. Kelly : You would require a commutator at each end of the shaft and switch over alternately ; there is no trouble whatever in reversing, the principal difficulty is in giving the engine a start ; you must get an impulse from some outside source.

Mr. J. H. Redman (Assoc. member) : With regard to the dynamo, would it not be necessary to have a clutch to disconnect ?

Mr. Kelly : Yes, that would be necessary.

Mr. Wm. Earnshaw (Assoc. Member) : Could Mr. Kelly tell us the amount of water required for the injector, and if there is any means of regulating the same ?

Mr. Kelly : There is a needle valve which controls the water in exactly the same way as it controls the petrol and carburettor, and which is figured and marked so as to give the right injection of water into the engine. It is an alternate gas and steam engine. There is a governor arrangement which ensures that if no gas enters there is no water.

Mr. Earnshaw : About how much water is used ?

Mr. Kelly : For every H.P., one-eighth of a pint, one-eighth of the oil consumption.

Mr. Earnshaw : While the engine is running have you any means of telling if it is getting the right amount ?

Mr. Kelly : The needle valve will tell that.

Mr. Earnshaw : Can you alter it ?

Mr. Kelly : Yes, you can alter it; a needle valve is easily altered just the same as the carburettor is altered. You can flood the engine with oil, or just get the right mixture. Of course, you will hardly get too much water, because there will only be sucked in just sufficient water to vaporize it.

Mr. Lawrie (Member) : The mass of detail given in the paper is too much for one to digest all at once, especially when one can only claim a very limited knowledge of the subject. I was going to ask one or two questions about this marine oil engine, but Mr. Timpson's questions brought out the points that I wished explained and I do not think I have any remarks to make on the paper; I should just like, however, to refer to an incident. I happened to see a motor-car in difficulties and the driver spent some time in finding out the cause and in putting things right. A lady who was driving past, stopped her motor-car and got out. She saw what was the matter at once, and in about two minutes, after the hints she gave him, the driver got things put right and away he went and everybody was happy again. After what I have read and heard to-night I will always take off my hat to that young lady.

Mr. J. Clark (Companion) : Like some of those who have spoken already, I know next to nothing about oil engines, but one can always ask questions. I suppose that these engines illustrated here are water jacketed ?

Mr. Kelly : Yes, water jackets are general.

Mr. Clark : Is there any precaution taken to prevent deposit from the water ? We know that London water is very hard and when it is heated up it leaves a deposit, which retards the transference of heat. In the case of narrow spaces there would be a danger of them becoming blocked by this deposit.

Mr. Kelly : In the water jacket there is always circulation going on.

Mr. Clark : Yes, but in spite of that in high temperatures you get the deposit.

Mr. Kelly : Well, if the water boils there may be a deposit.

Mr. Clark : But without it getting to that temperature.

Mr. Kelly : They run motor-cars for months, and there is very little deposit, but the usual precaution to prevent deposit of this kind is to add a little caustic soda. Of course, it is nothing like a boiler, the water never boils, if it does you are asking for trouble.

Mr. J. G. Robertson (Member) : A question was raised in connexion with the proposed arrangement for a dynamo-motor, I take it that this refers to a large engine. (Mr. Kelly : Yes. Now we know the arrangements necessary for turning a dynamo into a motor, especially in reversing the engines, and I do not know whether any special reason is given for this being advised as a good method, but it does not appear to be so on the surface. I should also like to ask Mr. Kelly how the efficiency of his two-cylinder engine compares with other engines, say of the four-stroke type.

Mr. Kelly : The ordinary petrol engine consumes one pint per B.H.P., of course taking the normal compression of 80 lb. ; the consumption is always proportionate to the compression used before ignition, but if you have the normal pressure you are safe in assuming one pint per B.H.P. The ordinary two-stroke engine has been known to consume from 2 pints to 3½ pints per B.H.P., mainly because there is only a baffle plate (American type of two-stroke engine shown in figure 3) its object is to divert the charge to the top of the cylinder. What actually happens is that the charge goes over the baffle plate to the exhaust port E, and you cannot use the high compression which is the chief factor in economy owing to the large amount of exhaust gas left in the cylinder.

Mr. G. Shearer (Member) : I am afraid this paper is a little too much for me to grasp at a glance. I was late in coming in, and in addition I must say that Mr. Kelly read rather too quickly for me. I will require to look this paper through again before I can say much about it, but I might ask Mr. Kelly, in connexion with this two-cylinder engine, figure 6, is it a reversible engine? (Mr. KELLY: Yes.) I thought I would bring this point forward; it was one of the points of discussion at the last meeting on the same subject.

Mr. KELLY: Yes, it is a reversible engine, there is nothing to prevent a crank running either to the right or left.

Mr. SHEARER: But in a two-cylinder engine where do you get your compression if you want to reverse?

Mr. KELLY: If you are going ahead and wish to go astern you just switch off your ignition till the engine slows down to about 150, then suddenly switch over, and immediately back-firing ensues, before the top of the stroke is reached, and you bring the ignition over. It is easy enough to reverse, the hard part is to start them against a load; only a steam engine can do that.

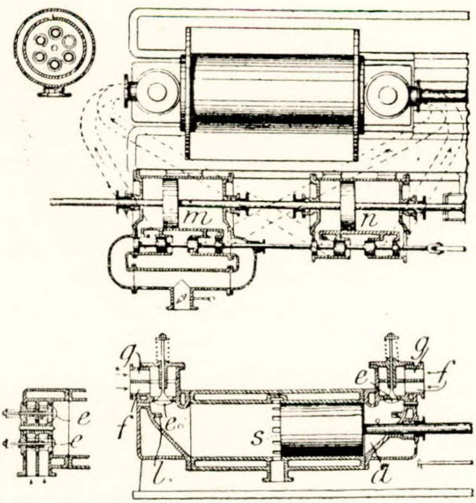
Mr. SHEARER: You say you have difficulty in starting. What is your method of starting?

Mr. KELLY: In all internal combustion engines you must start with a turn of the crank, that is the difficulty. The usual method is with a half turn of the crank. It is a question of starting without external means; that is where a steam engine has the advantage; but looking at it from a commercial point of view, does the gas engine or the steam engine cost most to make per H.P. and upkeep?

Mr. P. SMITH (Member): As a Marine Engineer, I am not ashamed to admit that I have not been educated up to this class of engine. After a little business I recently undertook with regard to a motor-car I came to the conclusion that it was a box of mystery to me and, therefore, I had to call in an expert, but I really believe that the expert did not know much more than I knew myself about it. I have been disgusted to see the motor-buses flying about the streets, with the fearful noise and the abominable smell, especially in the summer time. That is the internal combustion engine. On the other hand, I have stood and looked at a steam propelled 'bus in the city, silent, beautiful, no smell, and the steam exhaust, exhausting I presume through a condenser, hardly perceptible. The paper we have heard to-night is a very able one, and I wish I could have grasped it all, but I wish Mr. Kelly and his co-workers every success, because I am quite satisfied that these engines are capable of very great improvement.

Mr. E. W. Ross (Hon. Fin. Sec.) : I am afraid I am in the same unhappy position as the last speaker, but perhaps Mr. Kelly would kindly explain what he means by "cycles," and "two-stroke" and "four-stroke," also if there is such a thing as a double explosion, from both ends of the stroke, one up and one down ?

Mr. Kelly : Yes ; in fact the "Körting" engine, a German make, works on that cycle. I will explain it by sketches on the blackboard. (Detailed sketches supplied later as below.)



KÖRTING TWO-STROKE GAS ENGINE 500 TO 1,500 H.P., SPEED 80 TO 120 REVS. PER MINUTE.

The engine is double acting like a steam engine. The pumps are also double acting. The piston uncovers exhaust ports *s* at the end of each stroke. Air is then admitted from the pump *n* worked off the crosshead like a slide valve, and afterwards gas from the pump *m* enters. The air and gas enter by the same valve *e* from pipes *f* and *g* respectively, and as the outlet valve from the air pump opens before that of the gas pump, the air forces back the gas in the pipe *g* before the valve *e* is opened.

Mr. Kelly : I have endeavoured to get the same effect as this type of engine without the pumps and without the valves.

Mr. Ross : Does that engine exhaust into the atmosphere ?

Mr. Kelly : It exhausts into the atmosphere.

Mr. Timpson : There seems to be an impression that these internal combustion engines are more difficult to understand than the ordinary steam engine. I think there is a good deal more of the " box of mystery " about the latter than the former, and therefore the motor engineer has far less to learn. The troubles mostly occur with the mechanism. The " mystery boxes " when you come to study them, are much simpler engines than they seem, and much simpler than the steam engine.

Mr. Redman : Have you tried the suction gas ?

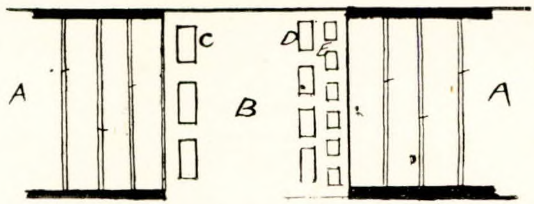
Mr. Kelly : No, if you have to get the suction gas producers, you might as well have the boilers and use a steam engine ; it is a moot point if there is any weight gained.

Mr. Redman : What is the smallest size you make ?

Mr. Kelly : $3\frac{1}{2}$ bore, which gives the two-cylinder about 12 H.P. That is the smallest size at present. They give 12 H.P. to 1,000 H.P. according to sizes.

Mr. Shearer : Could Mr. Kelly give us any information in connexion with the double-acting piston gas engine, that is the one-cylinder engine with the explosion in the centre ?

Mr. Kelly : Yes, that is the " Oechelhauser," another German type ; it and the " Körting " are practically the only perfect two-stroke engines for stationary work. I will give a sketch and description of it on the blackboard.



AA Pistons, *B* Explosion space, *C* Exhaust ports, *D* Air ports, *E* gas ports.

This engine is made in sizes up to 1,000 horse power. Explosion takes place in *B* and the pistons *AA* are driven apart, and the shock is taken off the foundation. *AA* each drive crossheads which are connected by swinging rods so as to run in unison. The air and gas are supplied by separate pumps in the same manner as the Körting engine. There are valves on the pumps, but no valves in the cylinder proper, which is a plain tube.

Mr. SHEARER : Could you give us any information as to the efficiency of that engine—the double-piston engine ?

Mr. KELLY : It has very good efficiency.

Mr. SHEARER : I should think the efficiency would be great because in all engines up to the present we have a dead end, the cylinder end, which is stationary, the action taking place only on the one piston, but when both pistons are at the centre you are getting the same amount of pressure on both. Of course, I am comparing it with the steam engine ; you get the advantage of the start there, but the expansion would take place much quicker, and I was just wondering what the efficiency of an engine of that kind would be in steam.

Mr. KELLY : What militates against it in actual practice is the complicated action. There are so many moving parts, and the friction is so great as well as costing a good deal to make per H.P.

Mr. SHEARER : Do you have the power on the two sides ?

Mr. KELLY : The explosion takes place between two pistons connected by swinging levers and rods.

Mr. SHEARER : On the one crank shaft ?

Mr. Kelly : Yes, you connect to the one crank shaft. Some make them with two crank shafts.

Mr. Shearer : Then what governs them—how do you govern an engine with two crank shafts ?

Mr. Kelly : These shafts are connected up by rods similar to the wheel of a locomotive.

Mr. Shearer : That comes to the same thing as having a double crank on one shaft and a return connecting rod.

Mr. Redman : One maker, I forget his name for the moment, manufactures an engine with a four-stroke cycle and working on the same crank shaft.

Mr. Kelly : Yes, there are engines made in America on that principle. Of course, you get steady running, but against this must be set the cost of production. The Arrol-Johnson in England and the Koch in Germany are examples.

Chairman : Is there any other gentleman would like to ask more questions or say anything on this paper, or do you feel inclined to continue this on another night ? The information put before us is valuable, and I think we ought to make the most of the opportunity of settling any questions that may arise in our minds on this subject. I myself cannot say much about it, but I think the ordinary oil motor 'bus is capable of improvement. I would like to ask Mr. Kelly whether it is true that these repeated breakdowns are due to the driver getting confused with the lubricating oil. If one asks what has gone wrong the answer is that there is nothing the matter with the engine, it is the lubricating oil, that is as far as we can get.

Mr. Kelly : Of course, as one gentleman has remarked about the steam 'bus, they are very nice to look at, but has he ever ridden on top of one of them ? The steam 'bus is not as great a commercial success as the petrol 'bus, otherwise there would be more of them made. If you could use coke or coal they would be all right, and fairly simple, but you have to come back to paraffin oil, and you get it. The fumes from the steam 'bus are worse than the petrol, you don't see them so much, but you get the effects. I have nothing against the steam engine, but when you have the boiler and coal furnace the upkeep is too much, as you must have two men, one for engine and one for firing. The steam engine is a model of simplicity, and the idea of a two-stroke engine is to reach the simplicity without the disadvantages of the oil burner and boiler.

Chairman: Speaking for myself the title of the paper rather led me astray. I never dreamt for a moment that the subject was going to be on internal combustion engines until I came into the room, and I was rather priding myself on being able to say something on the subject of internal water cooling, but I had in view high-speed engines with the water cooling in the crank chamber. However, I might say that the firm I am connected with have been trying various steam motor wagons, also one petrol wagon, but we have not yet been able to get up the weight-carrying capacity. One, of 2½ tons capacity, gave excellent work as an experimental motor, it was all over London in about three hours, which was a matter of great importance and advantage to our firm, with an early market. The steam motor wagon will, we are quite satisfied, work out fairly cheaply and will supersede the horse wagon, in my opinion. I must add my quota to the expressions of pleasure in hearing Mr. Kelly read this paper to-night. From the information and experience obtained from these experiments I think the subject is deserving of another night's discussion. During the intervening time we may be able to get more information on the subject and question Mr. Kelly more fully. I may say for your edification, as regards papers being read here on Petrol Oil Motors, there was one read on April 11, 1904, by Mr. Orlando Sumner, R.N.R.; you may be able to gain something from that, also Mr. Timpson's read on December 3 last, and after another read through this paper by Mr. Kelly you ought to be quite prepared for him.

Mr. Timpson: I might say that comparing the cost of running an oil motor with other engines, the average of a number of week's running works out at 22*s.* per week for the oil motor and £6 per week for the coal engine.

CHAIRMAN : Like the rest of the members present I have very much enjoyed this paper, although I have been unable to add anything to the discussion. Mr. Kelly has been able to answer, and I believe answer correctly, every question asked him to-night. Not only the members present but the Institute as a whole is indebted to Mr. Kelly for this deeply interesting paper, and I would like to remind Mr. Kelly that the whole of the members will have an opportunity of reading it and the discussion. I would like to move that this discussion be adjourned to this day fortnight.

Mr. P. SMITH seconded.

Mr. MATHER : I have very much pleasure in proposing a hearty vote of thanks to Mr. Kelly for this valuable addition to our literature, and I think this paper, together with previous papers on the subject, shows that there is a considerable amount of attention directed to not only internal combustion engines, but also their application to marine purposes. On reading the paper through I notice there is one interesting paragraph that has not been referred to to-night, and it seems to offer what might be a solution of the problem of the future of internal combustion engines. In the latter part of his paper Mr. Kelly refers to an engine using alternately gas and steam in a single cylinder. I would like to ask if an engine of that type has been constructed ? (Mr. KELLY.—Yes.) In actual work ? (Mr. KELLY.—Yes.) Well, that point struck me as being one of the most important in the paper. I beg to propose a hearty vote of thanks to Mr. Kelly.

Mr. SHEARER seconded.

A vote of thanks to the Chairman closed the proceedings.

ADJOURNED DISCUSSION

On March 18, 1907.

CHAIRMAN: MR. F. COOPER, R.N.R.

CHAIRMAN : Mr. Kelly has very kindly consented to come here again this evening, and I hope you will be able to give him enough questions to keep him going now that he has come. Copies of the discussion which took place at the last meeting are on the chairs, and you will see from them what points have already been brought out in connexion with this subject. The meeting is now open for the discussion.

Mr. F. M. TIMPSON : Mr. Kelly has, I think, dealt pretty exhaustively with his subject, and I don't think it leaves very much for discussion. However, there is one point I would like to refer to which he mentions, in relation to the drip of water into the cylinder. Of course, that is not a new idea, I have found it used in several cases ; for instance, there is a launch running across the Medina river in the Isle of Wight, owned by Mr. J. S. White of Cowes, which has a similar arrange ment, and they are also made by Messrs. Gardner with this arrangement.

Mr. KELLY : That is quite right, but there are no makers who at present manufacture an alternate gas and steam engine. The water drip is not uncommon ; in fact, no stationary paraffin engine can run without the water drip.

Mr. TIMPSON : In relation to the remarks about high speeds, there seems to be a diversity of opinion on that point. To my mind the high speed engine is more inclined to waste ; there is a certain time in which the internal combustion must take place, and if you exceed that rate of combustion you must have a certain amount of waste.

Mr. KELLY : Well, at first, like the turbine, it was extremely difficult to get economy with high speeds, but the difficulties have been overcome and we are now able to get a speed of from 800 to 1,000 without trouble, and an engine of any bore at all at that speed is giving forth some power.

Mr. TIMPSON : But still a great many of the high-speed engines waste a lot of their oil.

Mr. Kelly : In that case I should say it is a question of proper mixture.

Mr. Timpson : But a great proportion of the exhausts are quite hot.

Mr. Kelly : Well, in a sense they should be.

Mr. Timpson : Would you call that perfect combustion ?

Mr. Kelly : Yes, I should say so, even in that case ; the test for combustion is to hold a piece of white paper over the exhaust, and if it isn't fouled, the combustion is reckoned to be perfect.

Mr. Timpson : But there must be an excessive amount of oil passing to the exhaust for the enormous heat that is very often generated.

Mr. Kelly : Not so, it depends upon the compression ; if the compression is 80 lb. the pressure at firing is about 300 lb. ; if the compression is 300 at firing it is about 500, and exhaust about 50 or 60. The temperature would be somewhere about 800°.

Mr. Timpson : We have engines running where you can put your hand over the exhaust, and that is at 120.

Mr. Kelly : In an exhaust after it goes through the silencer ? (Mr. Timpson.—Yes.) Well, that is how it is accounted for.

Mr. Timpson : I am of the opinion that where you have a very hot exhaust you are wasting your fuel, that is how it works out in actual practice. I know it is claimed that you get greater power for minimum weight in these high-speed engines, but in my opinion they are more for motor-cars than for marine work.

Mr. Kelly : For the high speed, yes ; but the question of high speed is always a question of weight, and the propeller must be designed to work with the engine ; any speed can be obtained if the propeller is increased in proportion to the weight.

Mr. TIMPSON: I quite agree in all that is said in the paper respecting the question of the two-cycle engine displacing the four-cycle. Of course there are great advantages in the former, both in the matter of space and weight, there is not the slightest doubt about that.

Mr. J. ANDERSON (Assoc. Mem.): I should just like to ask Mr. Kelly if there is any chance of the charge in his engine firing before the compression is complete, actually before the piston reaches the end of the stroke, as in this case it seems to me there is a possibility of the engine going wrong. Supposing a motor-car is going uphill, the charge might ignite too soon, and instead of running forward the engine might take a stroke back, in which case the car would probably stop on the hill and even be in danger of running downhill. I am sorry I have not had time to go into the paper thoroughly, but I put this question merely to get information.

Mr. KELLY: That was the difficulty with the ordinary two-cycle engine; there was a certain amount of exhaust gas left in the cylinder, and there was so much of this exhaust gas, and it was so hot, that there was always a serious danger of backfiring resulting, so the speed of previous types of two-cycle engines was limited to 300 or 400, with the liability on a hill of backfiring and the engine running down backwards. We had to overcome this difficulty, and that is the reason of the air scavenging; there won't be that backfiring if all the exhaust gases are cleared away. Actually the sparking is advanced, contact takes place five-eighths of an inch from the top.

Mr. ANDERSON: It is electrical ignition, I suppose. Does it run well?

Mr. KELLY: Yes, and it is a very regular-running engine.

Mr. ANDERSON: It seems to me to be an ideal engine for motor-car work, there is little gearing, no cam shafts, it has always a constant pressure on the crank shaft, so that there is no wear and tear on it, and it can be put into the hands of a more or less unskilled driver and still not run the risk of his making a mess of the engine. It is a most interesting subject, the two-stroke internal combustion engine, and I think builders generally have adopted the wrong methods for marine purposes, as I believe the majority of motor-car engines are far too light for this work. Hitherto motor-car builders have been under the impression that there was nothing in marine propulsion that they needed to know in addition to their experience with motor-cars, but the conditions are very different. The motor-car engine is a light one, while the marine engine needs to be fairly heavy and substantial, and I do not think that point has met with the attention it ought to have had. One of the reasons of the comparative failure of the internal combustion engine for marine purposes is that launches have been built by motor-car people only for racing purposes, trying to get a speed of 25 to 30 knots—" freak " engines I would call them, which are absolutely no use for commercial purposes, but this engine by Mr. Kelly seems to me to fulfil the conditions which are necessary for the average launch.

Mr. Kelly : The only reason I referred to the high speed in this engine was to show that when it gets a high speed it gets rid of the exhaust; with a slow speed there is no difficulty whatever in getting rid of an equal volume. But I referred to the high speed to show that there is not the trouble with the backfiring.

Mr. Anderson : With reference to the carburettor in this engine. Do you use the exhaust gases for vaporizing the petrol, or is it simply the air flowing over the petrol ?

Mr. Kelly : The air flowing over the petrol will vaporize it if there is a good vacuum. Very often a by-pass from the exhaust is fixed round the carburettor, but that is to prevent freezing, not for vaporizing.

Mr. J. H. Redman (Assoc. Mem.) : With regard to the point raised respecting the hot exhaust, I have found that on the exhaust pipe being removed it very easily happened that flame passed out of the exhaust valve. I might also say with regard to the freezing of the carburettor that I have seen ice nearly half an inch thick on the baffle plate inside the carburettor, when the by-pass was not coupled up. I would like to ask Mr. Kelly if he had any difficulty in choosing the strengths of the springs top and bottom to steady the inlet valves.

Mr. Kelly : No, we had no difficulty with that. There was on the first engine a little trouble in adjusting the size of the air valve to the size of the mixture valve ; of course there are no mechanical valves in this engine.

Mr. Redman : I was referring to the automatic valves to the carburettor, as I should think very little difference in the strength of the spring makes a lot of difference in the running of the engine. Do you make these engines up to 120 H.P. ?

Mr. Kelly : Not so large as that yet. We have made one four-cylinder which will give nearly 50 H.P.

Mr. Redman : At what speed ?

Mr. Kelly : It is designed for 1,000, and I presume it will run at that. It is only six-inch stroke, so that the piston speed is all right at any rate.

Mr. W. E. Farenden (Associate) : I should like to ask the author if he intends the two-stroke high-speed internal combustion engine to be used for marine purposes, as the very high rotative speed of the crank shaft, from 1,500 to 2,000 revolutions per minute, mentioned in the paper, might be reliable for motor-car work, but for marine purposes it is quite out of the question. Gas engines for propelling vessels must be built fairly heavy and capable of being perfectly controlled for starting, stopping, and reversing, and running at all speeds, and for large engines they must have direct drive and be reversible. They must also be quickly stopped and started again when required, either for ahead, or for going astern. I should like to know whether this engine will run when varying the speed from "full" to "dead slow" without stopping, and if it takes any appreciable time to start and stop this engine, also what is the brake horse power of the engine running at this high speed, and the consumption with gas plants of this type per brake horse power. The gas engine for marine purposes should be of the simplest kind, and for commercial purposes must be reliable.

Mr. KELLY : The brake horse power of the engine mentioned is 20 H.P. at 1,000. It was not intended for marine work ; for marine work the speed would be about 500 to 600 revolutions, with a variation from 100, but of course it depends upon the size of the propeller. There was no difficulty in reversing, but a clutch is necessary to start the engine free from load. With regard to the consumption, about one pint per brake horse power is required. That practically is about the consumption of internal combustion engines if running at the speed designed and everything is going right. My main object was to obtain an efficient two-cycle engine, so that at any speed the power of the internal combustion engine would be doubled. Of course I do not propose to run it at a high speed, but I may say that the length of the bearings is nearly four and a half times the diameter, which is a fair margin. Most car engines are about one to one and a half times, and this causes the trouble.

Mr. TIMPSON : What system of lubrication do you adopt ?

Mr. KELLY : We have used a drip and pressure from the exhaust or from the crank case.

Mr. TIMPSON : Not so much from the cylinder ?

Mr. KELLY : On to the cylinder, we have a splash in the crank case.

Mr. TIMPSON : Do you not have difficulty with the oil finding its way upwards ?

Mr. KELLY : No, we have vacuum valves on the crank case to keep the pressure down.

Mr. TIMPSON : Do you approve of the splash ?

Mr. KELLY : Yes, for the crank shaft and bearings.

Mr. REDMAN : I find that the consumption of petrol at 1*s*. per gallon works out at 1½*d*. per hour per brake horse power, and with paraffin at 6*d*. per gallon it is ¾*d*. per hour.

Mr. KELLY : Yes, that is quite right, the consumption per brake horse power is practically the same for all internal combustion engines. Of course you get better efficiency by using a higher compression, but in that case you want a much heavier engine.

Mr. Redman: Starting and stopping seem to give the most trouble.

Mr. Kelly: Yes, for all internal combustion engines used for marine work. The high speed is not so much for commercial running, it is more for torpedo work with a fine pitch that the speed is wanted.

Mr. Timpson: Do you approve of electrical ignition?

Mr. Kelly: I do for the two-stroke engine.

Mr. Timpson: I think that is where you are in for trouble. I have had a good deal of information from different launch drivers who use the electric ignition and they seem to have a great deal of difficulty with it, they are always in trouble.

Mr. Kelly: Well, if it is a question of the coil, that is the electrician's part of the work, we have to do with the engine.

Mr. Timpson: But you are going to put this engine into the hands of bargees, or people who have had no previous experience of an engine. If you are building an engine that any one can handle, you don't want to call in an electrician every time it gets out of order.

Mr. Kelly: There is no need to trouble an electrician provided he supplies you with a good coil in the first place.

Mr. Timpson: In actual practice that is an objection and many are confused with it.

Mr. Kelly: There is no difficulty with low-tension ignition.

Mr. Timpson: Generally speaking you find a certain amount of trouble with electric sparking.

Mr. Kelly: But I find more have difficulty with the hot tube method. With a stationary engine the hot tube is all right because there is often a big flywheel weighing about half a ton; it doesn't matter whether she fires in the right place or not, but put a hot tube on an ordinary motor-car and what is the result ?—firing all over the place, one cylinder breaking the power of the other. A two-stroke engine even with air scavenging is practically impossible with a hot tube. Take that engine of mine, the air goes in first, carrying off all the exhaust gases. When the gas comes in there is a nice hot tube waiting for the rich charge of gas, and the hot tube gets it.

Mr. Timpson : The best way is to have a system adopted which is neither the hot tube nor the coil.

Mr. Kelly : I know a fine two-stroke engine which practically broke the firm who built it simply because they would cling to the hot tube ignition, and I have no doubt some of those present know the firm I speak of too. They had a very good engine, but the hot tube spoiled it.

Mr. Timpson : That is so; we have no tube at all.

Mr. Kelly : No, but you need a very big flywheel.

Mr. Timpson : A flywheel is necessary for marine internal combustion engines. If the boat is running in a rough sea and a heavy gale of wind the engine is sure to race. I have seen an engine running under these conditions without a stop. But allowing for all that in these engines you want simplicity, and the more you can do without either tubes or sparking the better.

Mr. Kelly : Of course you have to start with the blow-lamp.

Mr. Timpson : You must generate heat in any case.

Mr. Kelly : And then of course there is the disadvantage of the big flywheel.

Mr. Timpson : They all require a flywheel.

Mr. Kelly : A four-cylinder engine of the two-stroke type should not.

Mr. TIMPSON : Is your two-stroke engine without a flywheel ?

Mr. KELLY : Only big enough to form a clutch.

Mr. TIMPSON : Still it is a flywheel.

Mr. KELLY : You can't call it a flywheel, it doesn't give any help to the engine, being only about 7 to 8 lb. weight.

Mr. TIMPSON : For what size of engine ?

Mr. KELLY : 50 horse-power. It is only a clutch, not a flywheel. In fact the engine doesn't want the flywheel. If you have a heavy flywheel you haven't much variation in speed, although you do get steady running, and then of course in marine work you always have the propeller.

Mr. TIMPSON : There is not much of the nature of a flywheel about a propeller.

Mr. KELLY : The propeller is always breaking the flywheel motion. The flywheel does not count so much in marine work as regards stopping and reversing. If you have a two-cylinder double-acting steam engine they don't want a flywheel, neither is one wanted with a four-cylinder single-acting engine of the two-stroke type.

Mr. TIMPSON : Even then they all carry a heavy flywheel, they are often fitted to steam vessels. All marine internal combustion engines need a heavy flywheel ; I don't know one that hasn't it.

Mr. KELLY : It is better to do away with the flywheel if you can do without it.

Mr. TIMPSON : Certainly, the more you can do without it the better, but I don't think you can do without it.

Mr. REDMAN : The matter of ignition is of the greatest importance, and I think there is an advantage in the electric ignition in being able to adjust and control it and not rely too much on automatic ignition, as a very little difference in the time of sparking makes a great difference in the running of the engine.

Mr. KELLY: That is true, the firing must take place at the psychological moment, which you can effect by means of the coil, with accumulators or magnetos.

Mr. REDMAN: I suppose you refer to the single coil, with high-tension distributor.

Mr. KELLY: We have been very lucky in getting hold of a coil for the four-cylinder engine which has only one trembler to it.

Mr. REDMAN: On the low-tension side? Mr. KELLY: Yes.

Mr. REDMAN: You have a contact breaker on the shaft, I suppose. Mr. KELLY: Yes.

Mr. REDMAN: With regard to pulling up I think the propeller would help the engine to pull up quickly. In the case of a 36 H.P. gas engine I know of, it took three minutes to pull up the heavy flywheel. Don't you consider the engine would start practically with no load at all, when driving a propeller?

Mr. KELLY: Quite right, with a propeller the load increases with the speed.

CHAIRMAN: We have to thank those that have taken part in the discussion, and perhaps Mr. Kelly is just as well pleased that the discussion has not been prolonged, as he wishes to get away by the 9.30 train. I think this has certainly been a very valuable paper. Personally I do not recollect a paper where the author has been so thoroughly conversant with his subject and so quick to pick up the drift of the questions. I have listened to many papers in this room and I am sure the variety of questions very often makes it difficult for the author to know exactly what is in the mind of the questioners, but Mr. Kelly has shown us how great a grasp he has of his subject by being able to see the points directly they were mentioned.

Mr. ANDERSON: I have much pleasure in proposing a hearty vote of thanks to Mr. Kelly for reading this paper.

Mr. Timpson: As Mr. Cooper has said, Mr. Kelly has a great knowledge of his subject and has been very ready in taking up all the points that were raised. We owe much to him for coming again to-night to reply to these questions, and I have therefore much pleasure in seconding this vote of thanks.

Mr. Kelly: I thank you very much for the reception you have given me on both occasions. I have studied the subject of two-stroke engines very fully, almost every kind, and shall be pleased at any other time to give you the benefit of my experience on them.

A vote of thanks was then accorded to the Chairman, and the proceedings closed.