INSTITUTE OF MARINE ENGINEERS

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President—SIR JOHN GUNN.

Local President (*B. C. Centre*)—LORD TREDEGAR.

Volume XV.

ONE HUNDRED AND FOURTEENTH PAPER

(OF TRANSACTIONS).

MARINE PETROL ENGINES

AND

MOTOR LAUNCHES.

BY

ORLANDO SUMNER, R.N.R. (MEMBER).

READ AT

THE LONDON INSTITUTION, FINSBURY CIRCUS, E.C.,

On MONDAY, JANUARY 11*th*, 1904.

CHAIRMAN: MR. W. C. ROBERTS (CHAIRMAN OF COUNCIL).

ADJOURNED DISCUSSION,

AT

58 ROMFORD ROAD, STRATFORD,

MONDAY, FEBRUARY 15*th*, 1904.

CHAIRMAN: MR. W. McLAREN (VICE-PRESIDENT);

AND

MONDAY, APRIL 11*th*, 1904.

CHAIRMAN: MR. D. HULME (MEMBER OF COUNCIL).

PREFACE.

58 Romford Road,
Stratford, E.
January 25th, 1904.

A meeting of the Institute of Marine Engineers was held on Monday evening, January 11th, at the London Institution, Finsbury Circus, E.C., when a paper was read by Mr. O. Sumner (Member) on "Marine Petrol Engines and Motor Launches." The chair was occupied by Mr. W. C. Roberts (Chairman of Council).

The discussion was adjourned till Monday, February 15th, at the Institute Premises, on which occasion Mr. Sumner hoped to be present with a small motor, that the details might be made more clear by references to the actual parts of the machine.

JAS. ADAMSON,
Secretary.

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THE marine petrol engine is, to all practical purposes, a self-contained gas engine. This has been made possible in the types of engine under discussion by the discovery that petrol, which is a distillation from petroleum at about 150° F., by being diffused among a proportionate volume of air forms a gas of highly explosive power when ignited, which power is greatly increased if the gas be brought under compression at the time of ignition. They all operate with a trunk piston, on the top of which the compressed gas is exploded. The specific gravity of petrol ranges from ·68 to ·72, that is to say, the weight of petrol is from 6·8 lb. to 7·2 lb. per gallon. The lower the specific gravity, the more rapidly will the petrol volatilise, and the quicker will be prepared the charge of gas. Hence it is obvious that the specific gravity of its fuel is everything to the working of the petrol-oil gas engine, and that small fraction, the second decimal of it, is of considerable importance. The contention by many motor constructors that their engines will operate *equally well* with any density of petrol is, on the face of it, absurd, and the claim made by some that their engines will develop the same power on either petrol or alcohol is a long way from being substantiated when their engines are submitted to a break test with the two fuels. As a steam engine is designed to operate under steam power, not hydraulic, so must an internal combustion engine be designed according to its specified fuel if the best results are to be obtained from it. The petrol which flows from the tank containing it to the engine must be rapidly formed into gas, when it enters the engine proper, and this takes place through the agency of the vaporizer, to which the petrol is led. This vaporizer is screwed into a hand-hole plate on one side of the crank case. The function of this vaporizer is to atomise the petrol into a correct amount of air.

On our engines the quantity of petrol admitted into the vaporizer is regulated by a screwed taper-pointed spindle, called a needle-valve. One end of this vaporizer is screwed into the hand-hole plate on one side of the crank case, and open to the latter; the outer end of the vaporizer is open to the atmosphere. The free passage between the two for the air is opened and closed by a mitred valve, which is actuated automatically by the piston displacement. Surrounding this valve is a one-way shell-cock for throttling the quantity of gas without interfering with the proportion of its mixture, which throttling gives a wide range of speed control. Into the seat of this vaporizer-valve runs a very small hole, direct from the needle-valve, and this hole is so placed that the petrol flowing from it enters the vaporizer proper in such a manner that the whole of the air, which is being drawn into the crank case at high velocity, owing to the piston displacement on its upstroke, must pass over the orifice of this hole, sweeping with it the small quantity of petrol, and atomising it on its passage. While this is the action which occurs during the upstroke of the piston, it is obvious that the downstroke of the piston must immediately close the vaporizer-valve, which valve not only closes to the air, but at the same time shuts off the petrol by covering the orifice which is on its seating, and its closing is quickened and the rattle of the valve prevented by its being provided with a weak compression spring.

Atmospheric conditions affect the vaporization of the petrol, and the mixture of petrol and air of to-day, with an atmospheric temperature of, say, 40° F., will not be the mixture suitable for to-morrow with a temperature of, say, 80° F. On a cold damp day the petrol will vaporize more slowly than on a warm, dry day, so to get the same power, slightly more petrol is required when the atmosphere is somewhat moist. It is only necessary to slightly open or close the needle-valve regulating the petrol to obtain the requisite adjustment, as the air-valve has invariably a set-lift.

Again, proportionately more petrol will be required if the engine is to run at, say, 300 revolutions instead of, say, 500 revolutions, because at the higher piston speed it is not possible for the whole of the volume displaced by the piston to be filled completely, owing to the indrawn air being restricted by its passage through the vaporizer. In such a case, then, the quantity of petrol required will be less. At the lower piston speed the wire-drawing effect of the vaporizer will evidently be less, and the quantity of air drawn in proportionately greater, hence in this case the correct proportion of mixture can only be maintained by admitting slightly more petrol. The adjustment quoted is of course not worth bothering about excepting in the case where it is required to run the engine for a considerable length of time at either the higher or the lower speed. To facilitate rapid vaporization of the petrol—which in itself is a form of refrigerating process—provision is made that the air drawn into the vaporizer shall be previously dried, and slightly warmed, if required, by taking it from a shell surrounding the muffler or the exhaust pipe. Such provision is handy in case of damp weather, but it has the effect of thinning the air, and practice shows that the cooler the air the richer the gas produced with the same quantity of petrol. At this stage I should like to make clear that a lead pipe, or copper, or brass, but not iron, should always be used for the conveyance of petrol from the tank to the vaporizer. Motor journals invariably state the advantage lies in the ease of bending it and sweating on unions, but there is another and imperative reason. We installed an engine in a large launch some months ago, and the trial run was highly satisfactory. Some time later we were informed that the engine was hard to start and acted sluggishly. As we had had this engine running a full nine hours' day in the shop before it left our works, and I had run the trial trip myself, I was convinced that the defect was certainly not in the engine. As it was the first complaint received, I went and made a personal examination. Everything seemed, and was, mechanically perfect. The petrol in the tank was all right, but the petrol entering the vaporizer was all wrong. The lead pipe which we always put in, had, owing to the carelessness of the launch-driver, been closed up in several places, and, on his own responsibility, the man had replaced it with a length of iron piping. The disintegration of the iron by the petrol resulted in the latter entering the vaporizer with a brandy colour, instead of being colourless. When this iron pipe was replaced by a lead one there was no further difficulty.

There are two types of marine petrol engines, known as the 2-cycle and the 4-cycle. The former has an impulse per revolution and the latter an impulse every second revolution. I trust that I shall be pardoned for the interpolation at this point that as the British Motor Power Co. are manufacturers of both 2- and 4-cycle engines, I can discuss freely from an unbiased standpoint the merits and demerits of the two types.

In the 2-cycle engine the crank case is air-tight, and the upstroke of the piston draws a vaporized charge into this crank case. When the piston descends the vaporizer valve is shut,and the (indrawn) gas consequently slightly compressed to about 5 or 6 lb. pressure. A little before the piston is at the end of the downward stroke its top edge uncovers the admission port in the cylinder wall, which port communicates by a coring made in the cylinder casting, with the crank case, thus allowing the slightly compressed gas in the latter to flow into the cylinder. The charge strikes a deflector or baffle plate, which is cast on, and is a part of the piston, deflecting the gas upwards. The object of this baffle plate is two-fold ; it prevents the gas from flowing across the face of the piston,and through the exhaust port, which is situated opposite to the induction port, but somewhat higher up ; secondly, by deflecting the gas upwards towards the combustion chamber, it prevents as far as possible in this type of engine its intermingling with the burnt gases from the previous impulse.

The term combustion chamber in internal combustion engines refers to that space above the piston where the actual combustion takes place, and the terms combustion chamber or combustion space, and compression chamber or compression space, are synonymous. The charge is ignited immediately before the piston reaches its top centre, and the impulse given is sufficient to drive the piston to the end of its stroke and to bring it to the top again by means of the momentum of a somewhat heavy fly-wheel. When the piston has travelled about three-quarters of its downward stroke, it uncovers the exhaust port, and slightly lower down the admission port, which latter is or should be full open when the piston is at the bottom centre. Generally speaking the best results are obtained when these ports are so situated that the exhaust port is full open the instant the admission port begins to open.

Simple, reliable and effective though the 2-cycle engine may be for any practical use, it has theoretical imperfections not found in the 4-cycle. It has not a complete exhaust or scavenging stroke, and a certain residue of the burnt gases from the previous impulse must be left in the cylinder, when the top edge of the piston has closed the exhaust port. Hence, the explosive value of the fresh charge of gas must be somewhat neutralised; and further, it has not the advantage of a full compression stroke, which actual compression theoretically will be three-quarters of its stroke, as the piston must evidently rise one-quarter of its stroke before it has closed the exhaust port.

The 2-cycle engine, simple as it looks, is a far more difficult engine to design than the 4-cycle, owing to the fact that its two strokes must provide for the various functions for which in the 4-cycle engine four strokes are provided; for instance, nearly three-quarters of the downward stroke will be impulse, nearly one-quarter of it will be exhaust, and one-eighth admission. On the up-stroke one-eighth of it will be open to admission, at the same time nearly one-quarter of it will be open to the exhaust, the remainder will be compression, in addition to which functions, throughout the whole of the upstroke the piston displacement must draw a full charge of gas into the crank case. The fractions of the stroke enumerated are approximate but may be taken as proportionately correct.

In the 4-cycle engine, which is but a petrol adaptation of the well-known "Otto" principle, the engine performs two revolutions or four strokes between each impulse, each stroke being devoted to the carrying out of its one individual function. It is not a valveless engine, like the 2-cycle, and, instead of having its induction and eduction ports cast in the cylinder wall or liner, its admission and exhaust ports are situated in or communicating with the combustion chamber; which ports are automatically opened and shut by mechanically actuated valves worked from the shaft by suitable cams and reduced gearing devices. In the first downward stroke the inlet valve is opened, enabling the piston to draw in a full charge of gas for the full length of its stroke, and the instant the piston arrives at the end of this stroke the inlet valve is shut. On the second stroke this gas is compressed for the full length of the stroke, both valves remaining shut. The instant the piston is ready for the second downward, that is to say, the third, stroke, the compressed gas is ignited and the impulse given, and this, assisted by the momentum of the fly-wheel, is sufficient to carry the engine through four strokes, or two revolutions. Both valves remain shut during the impulse and expansion of the gas on this third stroke until, when about nine-tenths of the stroke has been completed, the exhaust valve opens and remains open during the whole of the upward stroke, during which fourth stroke the piston pushes out or scavenges the burnt gases. This 4-cycle engine is then unquestionably the more theoretically perfect type of engine, for in it we have one complete induction stroke, one complete compression stroke, one complete impulse stroke, and one complete exhaust, or scavenging, stroke, as it is usually termed. The exhaust valve is timed to open slightly before the piston reaches the end of its impulse stroke, in order to overcome what would otherwise be too great a back pressure, which will be increased by the restricted area through which the exhaust gases must pass out to the atmosphere, and in very high speed engines it is found necessary to have this valve open even earlier.

The impulse must take place immediately the piston in any form of engine is ready for its downward impulse stroke. By this I mean that it is at that point when complete combustion must take place, and should complete combustion take place before the piston gets on its top centre, loss of power must follow, due to the retarding effect consequently produced. But the speed of these engines is so great that as the ignition of the gas immediately surrounding the spark is not simultaneous with, but slightly earlier than, the gas of the furthest part from it, evidently, as the speed of the engine increases, the actual ignition must take place before the piston reaches the end of the up stroke. The variation of power obtained by timing the ignition to take place earlier or later forms a prime factor in the regulation of speed control. In some very high speed engines the ignition takes place as early as half a stroke before the top centre.

Of the engines to which I have referred, each have their distinctive merits and demerits. It is not correct, as stated by manufacturers, that the 2-cycle engine will develop twice the H.P. of a 4-cycle of similar dimensions. At first sight it would appear that such must be the case, as the 2-cycle, of course, receives twice the number of impulses of the 4-cycle, but such reasoning makes no allowance for the defects of the incomplete exhaust in the 2-cycle engines to which I have alluded. With engines of similar dimensions and speed I have only been able to get 60 per cent. more power on the 2-cycle. It is only in the 4-cycle engine that we can possibly obtain the fullest kinetic value out of the fuel, but it will strike marine engineers that the heavy blow at the moment of impulse which must impart such energy to the comparatively very heavy fly-wheel as will carry it for three more strokes with no perceptible reduction in speed, entails heavy wear and tear, and the fact that this is allowed for by giving all parts subject to the shock additional length and diameter, while mitigating, does not remove the objection.

Gas engines on land are almost universally 4-cycle, and have but little wear and tear, but while this system is the same for both land and sea its method of application cannot be the same, and for several reasons. Consider such a 4-cycle land gas engine of, say, 8 H.P. on the brake, and a launch engine of similar power. In the land engine there is no necessity for the drawing in and vaporizing of an oil mixture; but it gets its gas under pressure. Its speed will be about 200 revolutions per minute, stroke about 15 in., and its fly-wheel about 54 in. in diameter; its weight will be about 25 cwt. In the marine petrol engine the stroke will be about 7 in., speed about 350 revolutions, fly-wheel about 20 in. in diameter, and its weight will be about 5 cwt. The very fact that the land engine weighs about five times more than that of the petrol launch engine is conclusive evidence that the latter cannot have the same life as the former. The large diameter of fly-wheel and the greater length of stroke possible on the land engine is entirely out of place in a launch, unless we wish to make it dangerously top heavy. The line of shafting must be kept as low as possible, and I know of more than one well-known make of 4-cycle marine paraffin engine with such a stroke and fly-wheel that they are positively dangerous in any ordinary launch in anything of a sea. The object of the fly-wheel is to preserve the steady running of the engine, and it is obvious that the greater its radius beyond that of the crank, the more efficient it must be, but to keep the shaft centre as low as possible, we must have a comparatively very heavy fly-wheel of but small diameter.

The 4-cycle engine, unquestionably, is the engine for large craft. The 2-cycle engine is suitable for any class of launch up to about fifty feet, although we are building 2-cycle engines which will give 50 H.P. on the brake.

The ignorance of many eminent motorists of the principles governing mechanics is, from the practical engineer's point of view, positively amazing. A gentleman considered by the Press a leading light in motor work, lately deprecated our manufacture of 2-cycle engines for marine work owing to their piston speed being limited to less than one-half of that of the 4-cycle engine, and was loud in his praises of the motor-car manufacturers who are running their 4-cycle launch engines at a speed of 2,000 revolutions per minute. I might state, in parenthesis, that the speed of the 2-cycle engine is limited, owing to its imperfect exhaust. Marine engineers have little use for an engine in any kind of craft afloat which will run itself to pieces after a year's hard driving, and the majority of us have had more trouble than we care to think about to make good the wear and tear and rattle on some of our auxiliary engines working at less than one quarter the speed quoted.

With ordinary care we would readily guarantee the life of both our 2-cycle and 4-cycle engines to be ten times that of such high speed monstrosities, and this for more than speed reasons. A steam engine has the oblique pressure from its piston—due and proportionate to the radius of its crank and length of its connecting rod—taken up by the cross head shoe on the guide-bar, and any wear or tear may be met by lining up. But in a gas engine we have neither shoe nor guide-bar, and the impulse is only on one end of the piston, which latter must consequently be of the trunk form, dispensing with piston-rod shoe and guide. Therefore that side of the piston and cylinder wall which is opposite to the direction of rotation must act as the shoe and guide respectively. And this is a form of wear and tear which must be reduced by reduced piston speed, and it must be remembered that in these engines such wear and tear can only be made good by boring out the cylinder and putting in a new piston complete. I recently had a large and very powerful motor car sent to our works, and I was given *carte blanche* by the owner as to what method I used, so long as I could overcome the objectionably loud barking of the exhaust without materially reducing the speed. This car, which was not then two years old, was built by a firm who are greatly pushing their high speed racing launches, and as their launch engines are simply their car engines, I am sorry for the purchaser of those launches, unless he be satisfied with a racing machine, and but two or three seasons use out of it. I stripped the engine out of this car, and proposed to do the work by introducing another silencer, and overcoming the increased back pressure consequently given by boring out the cylinders and putting in new pistons complete. The engine was light, well finished off (what there was of it), worked positively, and was all that could be desired in its running. Gauges off the cylinders showed them to have become oval, and my desire to bore these cylinders out only to the extent of the radius of the fullest worn part was frustrated by my finding that, had I done so, the cylinder walls would in some places have been only three-sixteenths of an inch thick. Now I do not want to make the incorrect inference that the cylinders had worn down to such an extent as this, but to make clear that in the original design the crazy demand for lightness had necessitated such a reduction of weight that to meet it even the cylinder walls were only given a sufficient thickness to stand at the utmost two or three years hard work, and that no consideration whatever had been given to the corrosion which is bound to take place in all water-jacketed gas engines on the outer surface of the cylinder liner. This corrosion, entirely unallowed for either through ignorance or intent, simply meant new cylinders, and while such a form of expensive up-keep may do with motor cars it is out of place and a possible danger on marine work.

Racing launches—as they are built at present, being of absolutely no commercial benefit—I do not propose to discuss.

Marine petrol engines are far from perfect and cannot be compared with steam for easy starting, reversing and slowing down, but they answer excellently for classes of work where a steam engine with its attendant boiler is entirely out of place. They are not self starters, because before an impulse sufficient to carry the engine over its centres can be obtained a charge of gas must have been drawn into the cylinder and compressed there. Their minimum speed is comparatively high, as they get an impulse but every second or fourth stroke, in addition to which the vaporization of the petrol is complete only when it is atomised by being diffused in the vaporizer with air under high velocity, which air velocity of course in both 2-cycle and 4-cycle engines is dependent upon the speed of the piston displacement. It is not a reversing engine, because it receives its power on one side of the piston only. In small 2-cycle engines the engine may be reversed by advancing the time of ignition to such an extent as to give a "back-fire," and thus reverse the direction of rotation, but such an operation, even by the most expert, is more or less a matter of luck, and puts a nasty torsional jar on the crank shaft which is aggravated by the heavy fly-wheel.

It is for these reasons, perhaps I should say defects—for although certain manufacturers make some pretty tall claims for their engines, these still exist, and have not hitherto been overcome, these defects are—in an apologetic fashion—somewhat compensated by introducing in the better class engines a reversing clutch, which will allow of the engine running continuously and in one direction of rotation. This clutch is devised to allow of the engine running either free from the propeller shafting, or to transmit to the latter ahead or astern motion, as desired, by means of the controlling lever actuating the clutch. When this lever stands vertical and in mid position the engine runs free from the propeller shaft; when moved forward, it is in go-ahead position, and the engine and propeller shafts are rigidly locked together by a cone-shaped clutch; when moved aft so as to give astern motion, the connection between the engine and propeller shafts takes place through a set of geared wheels in the clutch, which are so devised that the direction of rotation of the propeller shaft is reversed to that of the engine shaft. The advantage of such an arrangement is that a solid three or four bladed propeller may be used. With the smaller engines, and larger ones, too, of the cheaper class, it is customary to use a reversing propeller having two blades, and the reversing is obtained by changing the obliquity of the blades. In such an arrangement the shafting is continuous from the crank shaft right through to the propeller boss. This boss is slotted out for the reception of the base of the blades, which are provided with extension lugs and pins having a hollow sleeve shaft attached to them, which shaft or tube surrounds the propeller shaft and is carried through the stern tube and gland to the reversing lever, which latter controls the angularity of the blades through the agency of the sleeve shaft or tubing.

There are with both types of propellers the inevitable pros and cons which may be enumerated upon. The reversing propeller, of course, is evidently, from the simplicity of its construction, the cheaper, being but one-quarter the price of the reversing clutch, and it has two distinct advantages not possessed by a reversing clutch and solid screw. Firstly, while the minimum speed of the engine is always a comparatively high one—judged from the standard of steam—it allows of the pitch being instantly brought from full to its finest, thus giving a range of speed to the boat of from full to dead slow. Secondly, the changing of the obliquity of the blades from the so-called "neutral" position to the full ahead or full astern is gradual, an advantage more fully understood by discussing a certain disadvantage of the clutch and solid screw referred to later. There is really no such thing as "neutral" position for the reversing propeller, which, being of but two blades, has their otherwise excessive lengths for a required area restricted and reduced by compensating for that amount by the extra width at the tips. Hence the whole blade area is not of one true helicoidal surface, and the launch at "neutral" position will invariably forge ahead or swing around. It gives less speed, its boss offers more resistance to the water, and it gives objectionable vibration, especially at slow speed and when the launch is light. The reversing clutch and solid three-bladed propeller is the best type, undoubtedly, for speed. Its disadvantage is limited range of speed regulation, for the lowest speed of the propeller obviously is limited to the minimum speed of the engine, and it is sometimes desirable in a gale of wind to have the propeller reduced to a lower speed than it is safe to slow the engine down to without the risk of her stopping, and in my opinion, this, with one exception, is the only case—and very rarely do such occur—that the reversing propeller is unquestionably preferable to the solid one. The exception referred to may be illustrated by explaining an experience I had lately. We had a triple-cylinder engine of 15 H.P., and while out with it, experimenting with propellers, unfortunately had the ignition gear on one engine disabled by a boat hook. We had no propellers aboard, and the one we had on was of such a pitch that it pulled the two remaining engines down to what was practically their minimum speed. Then we immediately grounded on a sand bank, and had I not at once stopped the engines they would have been pulled up. We were so situated that it was impossible to get home for spare gear, and while the launch was dry on the bank we had to chip about 6 in. off the tip of each blade. This, of course, I must make clear, was only occasioned by having on at the time a propeller of far too coarse a pitch for the power and speed of those engines, but the explanation will demonstrate the advisability of remembering that with a marine petrol engine having a solid propeller there is emphatically a limit to the reduction of piston speed, and that a higher engine speed and finer pitched propeller is desirable for breakdown as well as for speed-of-hull reasons.

Water cooling in any form of gas or oil-gas engine is necessitated by the fact that for a fraction of time following the moment of ignition, the whole of the surface in the cylinder above and including the piston top is subjected to flame, the temperature of which is so great that no lubricant extant can compensate for the extreme dryness consequently produced; hence the universal use of water cooling.

Every engine has a practical efficiency greatly below that of its theoretical, due to numerous causes. The internal combustion engine has practically an efficiency of some 100 per cent. greater than the steam engine, occasioned chiefly by the latter's unavoidably tortuous path from the setting free of the kinetic energy in the coal to the point of actual delivery of that energy on the piston, other causes being mechanical ones more or less incidental to all types of reciprocating engines. The hydro-carbon engine —so-called from the principal components contained in and utilised from its fuel—is, however, essentially a kinetic engine, in which the greater power will be found in the engine having the greatest temperature in the combustion chamber at that moment when maximum pressure is delivered to the piston, other conditions, of course, remaining the same. A great proportion of this heat is absorbed by the cylinder walls and cylinder cover, being conducted through same, and diffused into the circulating water, which carries it away. From this it will be seen that while water jacketing is imperative, its usage is a destroying factor of great moment, considerably reducing the kinetic energy actually developed above the piston.

It is obvious, then, that the less the quantity of circulating water—or perhaps I should say the higher its temperature—the better, and the limit to the temperature is only reached when it is found that the temperature permissible for the perfect lubrication of the piston has reached its maximum limit. Lubrication for internal combustion engines cannot be dispensed with, owing to the presence of flame therein, although it may comparatively be less in a paraffin engine, owing to the latter's fuel generally being injected into the cylinder in the form of a spray, which allows of a film of paraffin coating the cylinder walls and thus assisting lubrication. But in a petrol engine the conditions are dissimilar, as its fuel enters the cylinder in the form of a gas of exceptional dryness—I might be allowed to define it as a gas of astringent dryness.

Lubricating oil should be of the best quality and given in the least quantity. Inferior oil leaves a carbonised residue which may in time gum up and considerably reduce the exhaust area, if not removed. Too much cylinder oil may occasion incomplete combustion, due to a portion of the smoke evolved remaining in the cylinder, owing to incomplete scavenging, and intermingling with the incoming gas; especially does this refer to the 2-cycle engine. Too much cylinder oil may also occasion miss-firing by getting between the ignitor points and short-circuiting them. The novice, however, should begin by allowing plenty of lubrication, and cut its quantity down to the lowest limit as his increased experience dictates. When the piston is in the lathe a couple of oil grooves should be cut around it, which will be found quite sufficient to carry the lubricant around the cylinder wall, and the lubricator should be so situated that it will deliver its oil between these two grooves.

Compression.—In the early stages of gas engine construction, the value of bringing the charge of gas to a state of super-atmospheric pressure at the moment of its ignition—by means of which greater power may be obtained for a given quantity of fuel—was not understood. They were built on the fundamental principle that one cubic foot of coal gas would expand into 10 cubic feet of flame at atmospheric pressure, and their enormous consumption of gas—in some instances as much as 100 cubic ft. per H.P. per hour—would speedily have quashed the industry, had not the advantage of firing the gas when under a state of compression been discovered.

This compression is obtained by a reduction of clearance space in the cylinder, which clearance has been gradually reduced until now some engines have their gas compressed to about 80 lb. per square inch, and their consumption has been cut down to about 15 cubic ft. per H.P. per hour. The amount of compression is limited to about 90 lb. per square inch, for as the temperature rises according to the increase of compression, spontaneous combustion may take place if the pressure quoted is exceeded, and premature ignition be the result. The maximum pressure obtained is directly proportionate to the amount of compression, and for all practical purposes may be said to be four times that of the compression. It follows, then, that any loss of compression entails great loss of power, so piston rings and joints—and on 4-cycle engines the valves also—must be kept tight.

Ignition.—Electric ignition is universal, and in all better class engines is obtained from an accumulator, or a magneto, which latter is practically a small bipolar, horseshoe-type dynamo, driven off the crank-shaft or fly-wheel.

As at least an elementary knowledge of electricity is desirable for anyone wishing to become a successful operator of petrol engines, I would like to make clear, in as plain a manner as possible, the principles governing electric ignition, as this is the only difficulty to be met after purchasing an engine of first-class make, and it is only by understanding the principles that we can solve the problem presented in practice.

I will assume that it is understood that—whether the current be derived from an accumulator by chemical agency or from a magneto-dynamo by the collection and commutation of its magnetic flux—the electricity produced is exactly the same, and is always a direct or continuous current, not an alternating one. I very much regret—at this point—that the limit of time debars me from describing graphically and fully the multifarious phenomena contained in this most fascinating subject.

There are two types of electric ignition, known as the high tension "jump-spark," and the low tension mechanical "make-and-break." The former is used on motor car engines, the latter generally for marine engines. Although the object of both is the same—to produce a spark between two points in the cylinder and so ignite the gas—they differ entirely in principle and method of application. To produce a flow of electric current, an electric circuit must be closed upon itself. Not so with the "jump-spark" system, for it always works on open circuit, as there is a fixed air gap between its two platinum points on the spark-plug, the points being generally one-thirty-second of an inch apart. It is devised, however, that the voltage should be raised to such a high tension through the agency of an induction coil, that it will leap the gap between the points—of course inevitably in the form of a tiny jet of flame—and thus ignite the gas.

The "jump-spark" plug is screwed into the cylinder cover, and has at its lower extremity two platinum points projecting into the cylinder. This plug is built up of two parts, one inside the other, each carrying one of the platinum wires, and the central part is insulated from the outer shell of the plug by a bushing of mica or vulcanite. To the central part is attached the high tension wire leading from the induction, or as it is commonly called the "spark-coil," the function of which is to transform the comparatively low voltage, high amperage, of the primary current into a secondary current of very high voltage and proportionately low amperage. This is a part of the electrical equipment necessitated by the fact that the ordinary voltage of an accumulator or magneto is absolutely insufficient to jump the air-gap. In the induction coil, the primary wires from the source of electricity are connected by terminals with the primary wire in the coil, which latter is insulated and is wound tightly around a bundle of soft iron wires. Now, when current flows through this primary circuit, powerful electro-magnetism is produced similar to that in the field magnet of a dynamo. If, now, a secondary coil consisting of a great number of turns of very fine insulated copper wire be wound on the top of the primary coil, the electro-magnetism causes, by the law of induction, a current to be induced in the secondary circuit of very greatly increased voltage. It appears strange that such an action can occur when none of the wires touch each other—all being insulated—but it must be remembered that while it is possible to insulate a flow of electricity so as to prevent leakage and short circuits, there is no known material which is not easily penetrated by those mysterious lines of force termed magnetic flux, and it is this magnetic flux—the product of the electro-magnetism—which penetrates the secondary coil of wire and induces an exceptionally high voltage therein. The circuit is closed for a very short period to produce the "jump-spark," generally by an attachment so devised and situated that it is actuated by a projection extending from the boss on the inside of the fly-wheel, which is arranged to engage with it once per revolution in the 2-cycle, and once per second revolution in the 4-cycle engine.

There is a popular fallacy that a spark coil "increases the power" of the accumulator or magneto, but this cannot be so, as the Watt energy delivered from the coil must perforce be less than that which it has received, owing to the resistance offered by the windings in the coil itself. It increases the voltage, but it is entirely at the expense of a corresponding decrease in the amperage.

Low tension "break-spark" system.—This is an application of the fundamental principle that when any electric current carrying current is quickly broken a spark will follow for a short distance between the points of the break. An insulated plug is screwed into the cylinder cover, as in the former case, but this plug has but one point. It is simply a brass shell containing in its centre, and insulated by mica bushing from it, a mild steel spindle, to the top of which is attached the positive wire. This spindle has at its lower extremity, which projects some distance into the combustion chamber, a heavy platinum rivet set into it. Through the side of the cylinder, and a little below the line of the insulated plug end, the ignitor block is carried, having a steel rocking spindle running through it, which spindle has a short arm at right angles to it, and at that end which projects into the cylinder. The end of this arm also carries a heavy platinum rivet, which is so situated that when the rocking spindle is slightly turned its platinum contact point engages with that of the insulated plug, thus closing the circuit and causing current to flow. At a desired point of the stroke the two points are separated quickly—the quicker the better the spark or flame—made possible by a spring trip device which is an integral portion of the trip-rod, operated by an eccentric off the crank shaft. The adjustment for regulating the time of the ignition consists of a device operated by a screw which causes the trip in the rod—consequently the separation of the ignitor points—to take place at any time desired, and in our engines this screw and one more regulating the gas supply are the only two necessary to turn to speed up or slow down the engine, whether it be a single or a multiple cylinder engine. The principle of this mechanism is practically universal on all low tension engines, and any variations in the methods of its application are simply introduced to suit the ideas of different manufacturers.

Comparing the two systems of ignition, we find the "jump-spark" to be the most desirable, as its usage dispenses entirely with the mechanism necessarily employed on the mechanical "make-and-break" system. It is the only type suitable for speeds over 800 revolutions per minute. This, at least, is my experience, as we have found that the mechanical "make-and-break" with low tension is not quick enough, and beyond that speed mechanical difficulties are met with, owing to the present system of tripping the springs. The "jump-spark" however, is too unreliable for marine use, excepting in the hands of one experienced in its trickiness and conversant with the conveyance of high tension electricity without loss. The trouble with it is that other paths or shunts may be formed on the high tension circuit which offer less resistance to the flow of the current than the resistance offered by the air-gap between the spark points, and whenever this occurs the engine will miss fire. A small film of soot or oil getting between the points, a frequent occurrence, enormously increases the gap resistance, also occasioning miss-firing. To take a very crude illustrative form of getting at the voltage required to bridge an air-gap of $\frac{1}{32}$ in., not scientifically correct but approximately sufficient at this stage to demonstrate my point, 20,000 volts is the pressure required to jump an air-gap of 1-in., then $\frac{20000}{32}$ gives 625 volts as necessary to jump our $\frac{1}{32}$ in gap. But this is with an atmospheric pressure between the points of but 14.7 lbs. per sq. in., and the spark is required to bridge an air-gap under compression of five or six atmospheres, further increasing the resistance greatly, and requiring higher voltage to overcome it. This high voltage, while giving a nasty sting if the naked high tension circuit be touched, is not harmful, owing to the amperage being practically nil.

This miss-firing may be compared in effect to that on a steam engine, in which the valve is playing the occasional prank of keeping the steam ports shut for two, four, or more strokes, and if a single cylinder engine is used, a couple of miss-fires may stop it, owing to the brake effect of the water on the propeller. This is somewhat mitigated by employing wo or more cylinders.

The "jump-spark" is successfully used on motor cars, owing to the fact that when miss-firing takes place, the momentum of the car helps to carry the engine round, even though it be miss-firing badly.

On a single cylinder marine oil-gas engine, the greater portion of the actual energy developed, occasions an alternating system of storage and discharge of that energy into and from the metal contained in the periphery of the fly-wheel—which fly-wheel should be as light as possible consistent with steady running. Whatever energy is developed at the time of impulse which is in excess of that energy necessary for the maintenance of even running throughout the impulse stroke only, is taken up in the fly-wheel in the form of a centrifugal force, and the fly-wheel must be so proportioned that it will deliver back into the shaft all that surplus energy before it receives a further charge from the next impulse.

I spent several months experimenting last year in a futile endeavour to bring out a single cylinder engine with a "jump-spark" ignition, which would be absolutely reliable in the hands of anybody. It is no use saying it cannot be done, because it is, for I am acquainted with a large firm in the United States who have built and sold more marine petrol engines than England has ever seen altogether, and all on the "jump-spark" system. On one occasion when out with one of these experimental ignition engines, although I was using the very best of insulated high tension wire with rubber coverings over it, lapped each terminal and shellacked it to keep out moisture, I had a somewhat uncomfortable experience in a stiff breeze and moderate sea. By some means or other the spray soaked through the high tension wire, occasionally permitting the current to run all over the engine in preference to jumping the spark gap. In spite of the launch being flung about by the high sea, the engine itself worked beautifully and noiselessly, as it had no springs, levers, or trip-rods, and its exhaust was below water-line, but the miss-firing occasioned me no little uneasiness.

Here I would like to digress for a moment. I have had a fair share of experience afloat in all sorts of craft and weather, and I unhesitatingly say that a modern high grade motor launch can live safely in a sea which would swamp or turn turtle a steam launch of similar size, owing to the latter's heavy boiler and wash of water in it raising its centre of gravity considerably higher than that of the motor launch, with its squat, compact little engine. The motor launch rolls more, but it does it quicker, which is exactly the action wanted in a short, choppy sea. The shipping authorities of England are just now realising that there is not a single instance of work done by a steam launch which cannot be done better and more economically by a motor launch, and should any member of our Institute be desirous of having a practical demonstration of what can be done with a high grade cruising motor launch in a high sea I shall be most pleased if he will let me take him a trip, as my firm have nearly always at least one afloat.

To America is unquestionably due the successful development of marine internal combustion engines, and it is significant that the most successful manufacturers of these engines in the States are not motor car constructors, but marine engineers. This may be somewhat unexpected news, but I have knowledge of what I state, for I have visited the works of nearly every manufacturer of these engines in Germany, Belgium, France, Canada, and the United States. Now I frankly admit that the object of the extended tour referred to was solely to obtain information, but only in the United States did I find marine petrol engines which any marine engineer would consider worth his while—and his reputation —to be associated with, and we attribute the success of the "British Marine" engines to the fact that they are built up of the best points of the best engines I came across and handled in the States.

It would be interesting to know how the other few genuine English manufacturers obtained their ideas. The members of this Institute lead the world in the application of marine steam power, nevertheless we can learn much from America with respect to the application of marine internal combustion engines. I do not now refer to the marine petrol rubbish dumped into England by America and sold here—in some instances—under names other than those they bear in the States, but rather to such firms as those on the Great Lakes, who have engined the United States life-boats. These engines *will stand* stripping and examination, and every possible provision is made for adjustment occasioned by the inevitable wear and tear, and the manufacturers of these engines have built up their great trade, not by flashy catalogues and shoddy engines, but by the material and workmanship in the engines themselves.

A side-light may be thrown upon the present state of affairs in England concerning the small motor-launch industry by the following—which is *not* copyright. A London yacht agency was desirous of retaining the London representation of the "British Marine" engines. It is their intention, —so they say—to put on the market a first-class 27 ft. cruising launch, equipped with an engine not less than 7 H.P., with all fittings complete, ready for commission, for the sum of £150. When we dismissed the subject by saying that our engines were neither of the material nor workmanship of the type they were so charitably anxious to confer upon the ignorant public, they informed us that they could handle plenty of foreign engines, and also get hold of one or two *very good* (!) English makes, of a price low enough to make their intention possible. They were not launch builders, as we at first understood. Now here comes the rub: they were to have 15 per cent. on our engine, 15 per cent. on the launch hull and equipment, and those combined prices were to be low enough to sell at £150—after making their sale commission in addition! Query, Where were the motor and the launch builders to come in?

The amount and extent of juggling with their customers by some London motor agents would make even a company promoter blush. Just one instance out of dozens met with from time to time. A party inquired of certain London agents for an engine. Catalogues were sent, and a private letter with the intimation that in his "special" case—why, goodness only knows!—they would allow him a discount of 22½ per cent., but they trusted he would not make the concession known, as it was a favour only to himself (!), and the price quoted was to include absolutely everything, all delivered within a week. He took the bait—and the engine. It came in driblets, and some of it hasn't come yet, I understand, although that was several months ago. His letters of inquiry re absence of parts were answered with surprise—they would communicate with their "works." Still no completion of his order, so he had the deficient parts supplied elsewhere. After but a few weeks' handling he found that to tighten his crank-pin bolts necessitated the whole engine being cast adrift and turned upside down to get at them. That settled him, and it is being replaced with a "British Marine."

There are different ways of advertising. Ours is unique, I think, for we keep on view in our works for the benefit of clients—and ourselves—all the engines of other makes, which for various reasons have been replaced by ours.

Power.—The rating for power is generally based on that obtained by a brake test—always so on our engines. Motor-cars invariably have their H.P. over-rated. In a motor journal recently I saw it stated that the 33,000 ft. lbs. standard was but a phrase for H.P., and open to question. Well the phrase of expression may be, but if the standard of 33,000 ft. lbs. be universally used, what is the ground for the quibbling? Many are puzzled why a car, capable of doing 35 miles per hour, of, say, 20 H.P., has such a struggling, panting effort to mount a hill which a boy could negotiate in half the time. It is because their H.P. is calculated when at their required maximum speed, and the speed naturally being greatly reduced when hill-climbing greatly reduces the power, which is not fully compensated by any system of gearing.

There is no hill climbing worth considering on water, and what there is may be said to be taken up by the increased slip.

Strange as it may seem, marine petrol engines invariably have their H.P. underrated, a trick of the trade introduced by the American engines sold here, and faithfully followed by some English makers, until I firmly believe it is safe to say that the present system of catalogued H.P. constitutes a huge farce. A certain so called 1½ H.P. motor I recently had under the brake gave 2 H.P. full. Of course, it would burn the 2 H.P. allowance of petrol, but what a fine advertisement when pitted against an engine which is actually 1½ H.P. in a boat of equal size! There is nothing wrong in such proceedings, except it be in fooling the non-engineering owner that his 1½ H.P. (so-called), is speedier than Mr. So-and-So's 2 H.P. (actual). Only since I have been in my present business have I realised the amazing gullibility of the non-engineering public, who have obtained from motor journals an amateurish knowledge sufficient to render them like putty in the hands of a smart, blustering motor agent.

An indicator diagram off a petrol engine is not so reliable as one from a steam engine, owing to its pressure being delivered more in the form of a heavy blow and to the further deleterious effect of the high temperature causing the spring after awhile to vary in its reading as much as 10 per cent. These temperature deflections are modified by testing the spring under the conditions of temperature under which it is intended to work, and making allowance for the same, but the data arrived at will—in a marine petrol engine at any rate—be somewhat misleading, unless the temperature of combustion is ascertained and allowed for also. The very best of springs and special indicators give conditions satisfactory enough to determine if the design may be improved, but as it is so easy to apply, and so absolutely correct in its result, the brake test is the one which should be insisted upon, as it is the actual power in the crank shaft, being the indicated power less that absorbed by friction and by mechanical loss in converting a reciprocating motion into a rotary one.

As brake horse power is possibly a term not freely understood by some marine engineers, I will take the liberty of explaining it. It is a test in which the actual power delivered by the engine at a given speed is absorbed by a brake around the fly-wheel and registered. The system adopted by us is as follows. One round turn of a canvas strap—a rope will do—is placed around the fly-wheel, one end of which is secured to a spring balance and the other end to a scale pan intended to carry the weights. The spring balance is suspended higher than the fly-wheel and at a point perpendicular to the side of it. If the strap then be carried from the spring balance straight down until it touches the side of the wheel and is then led underneath it, and around over the top and back to the same side, and be kept stretched by weights hanging from its lower end—which weights will hang in line with the spring balance above it—there will be a brake around the whole of the periphery of the wheel, which will reduce the speed by the addition of the weights in the pan, at the same time absorbing the power. This absorption of power is the actual power which will be delivered by the engine to its crank shaft when any load is on it which will pull the number of revolutions down the number of revolutions tabulated at the time of the test.

The spring balance and the weights must be on that side of the wheel which will occasion the direction of rotation to have the tendency to *lift* the weights—that is, on a right handed engine, the port side, and on a left handed engine, the starboard side.

The engine is started up, given its full gas, ignition given a "lead," or timed to fire at earliest possible so as to get highest speed, while in the meantime the weights in the pan are increased or decreased as the case may be, until the speedometer shows the desired speed. A water circulation is run on the wheel to obviate the burning of the strap by friction. Readings are then taken from the speedometer, the spring balance, and the actual weight in the pan, and substituted in the following formula which will give the required B.H.P.

$$\text{B.H.P.} = \frac{(W_a - W_b) \times N \times C}{33{,}000}$$

Where W_a = Weight in scale pan, to which must be added weight of pan itself, weight of strap (excepting that supported from the balance), and weight of any guide blocks which may be holding on the strap.

W_b = Weight indicated on spring balance.

N = Revolutions per minute.

C = Circumference of wheel or drum upon which the brake is acting.

Rotary Petrol Engines.—We have for a few months been engaged with experiments on a somewhat extensive scale on behalf of a client, for the production of a rotary motor. An engine I have designed on behalf of this client, upon a form embracing his principles, is now rapidly approaching completion. As, however, an actual trial run and test has not yet been made, and the work, until after that stage, is confidential, I am debarred from explaining what is unquestionably a most ingenious idea. Whether it will justify that idea by developing more power on at least the same, or less, consumption, trials only can demonstrate, but if the Committee will accept of them, I will at a later date forward photographs of this engine in sections and complete to the Institute, accompanied by a detailed report of the trial. If, perhaps, say next session, I am privileged to give a more advanced paper than this very elementary one upon this almost new subject, of oil-gas, or, I should say, internal combustion engines, as the subject applies to the Members of this Institute, I will base such paper upon the technique governing the principles of design for both heavy and light oil engines—that is to say, both paraffin and petrol engines—and the difficulties with which manufacturers are confronted in their desire to carry out practically those theoretical ideas which are scientifically correct, the chief of which difficulties are :

1st. Incomplete scavenging of the exhaust gases.
2nd. System of ignition.
3rd. Mechanical loss inherent to reciprocating engines.

The first, despite many inventions and patents, still exists, as at present every charge of compressed gas which is ignited, instead of being pure, has intermingled with it a quantity of burnt gases from the previous impulse—which quantity must be equal to the entire clearance or compression volume and proportionate to the pressure at the moment the exhaust valve closes.

2nd.—Time will introduce a system of ignition preferable and more reliable than the electric "jump-spark" or "make-and-break."

3rd.—The remedy for this defect introduces the question of rotary motors, that is, motors in which the piston is in disc form, shrunk on the shaft and rotating with it, thereby dispensing with connecting-rod and crank. They are as desirable as the Parsons turbine, but inventors—who are the greatest cranks imaginable—do not seem to grasp the fact—which is self-evident from a close study and comparison of gas and steam engine diagrams—that the one is an explosive agent, and the other essentially an expansive one. Rotary motors will certainly come to the fore within the next few years, but in my opinion they will never completely oust the reciprocating engine, because in it the *explosive* agent exerts its power on a direct drive, whereas in the rotary the converging of that same agent into a circular drive entails a greater loss of power than the crank effort in a reciprocating engine. That the rotary motor will reduce weight for a given power I do not believe, for while it dispenses with certain gear it demands other details far more delicate in action and adjustment.

The CHAIRMAN was sorry that the paper was not yet printed. However, it would be in the Institute for distribution in time for members to read it before the adjourned discussion took place. Mr. Sumner had also arranged for a model to be delivered for demonstration that evening, but, unfortunately, that model had not arrived. It would, however, be sent on to the Institute, where it could be seen before the discussion took place. They were much indebted to Mr. Sumner for his very interesting paper on marine petrol motor launches. Those motors seemed to be coming to the front, and were evidently going to stay. The subject was one well worth their attention, to study their action as far as possible. He was surprised to hear that the Americans were ahead of them in regard to petrol engines and motor launches; it was a pity, and he did not see why they should be. They would have to find out the reason, and try to get ahead of them sooner or later. They had very little time to spare that evening, but he was sure that Mr. Sumner would be pleased to answer any questions that the members might like to put as far as time would permit.

Mr. W. GARDNER (Member), who opened the

discussion, said he had not often had the pleasure of attending the meetings of the Institute, of which he was a member, although he was afraid a very nominal member. It was not always convenient for people who lived in Surrey to go down to Stratford, but he was quite certain their meetings at the London Institution always "drew" him, and he had been present at all the meetings held at that place. He had listened with much interest to Mr. Sumner's very able paper, which began at the beginning of the subject, and led them right up to the present day practice. It might please Mr. Sumner to know that the practice of his firm was practically that put forward in the paper. He had been specially interested in the latter part of the paper, wherein the author had referred to his experiments in regard to a rotary petrol engine, because his firm was also engaged on a similar experiment, and, like the author, at the present moment they dared not tell what those experiments were. They were, however, very hopeful that in less than the time indicated a successful rotary petrol engine would be evolved. The rotary engine had a great number of advantages in regard to weight for power given, and the wear and tear also seemed to be much less than with the ordinary reciprocating petrol engine. He would like to thank Mr. Sumner for coming all the way from Preston to give them so very enjoyable a lecture.

Mr. B. A. RAWARTH (Visitor) asked if Mr. Sumner could give them some idea of what was the mean pressure in the cylinders of those petrol engines. Some little time ago motor engines were constructed for the North Eastern Railway Co., for running motor cars on a small branch line; the dimensions of the cylinders were given at the time. They required to be of 100 horse power, and in order to give the power the mean pressure needed to be 120 lb. per square inch. Those motors did not fulfil their function, and they were taken out of the cars. Quite recently other engines had been tried. He had worked out the mean pressure for the horse-power, and it came out at 80 lb. per square inch. So far as motor cars were concerned it was often difficult to understand how the horse-power could be got out of the cylinder at all. In the reliability trials made last autumn by the Automobile Club the judges worked out the horse-power from the action of the engines in going up hill. They took the rise, and time occupied in negotiating it, together with the weight of car, and so settled the horse-power. Some of the 12 horse-power cars were written down to less than 5 horse-power. Only a few of the cars were over 6 and 6½ horse-power. Possibly Mr. Sumner would be able to tell them what was a fair mean pressure to get out of the cylinder in petrol engines working under reasonably favourable conditions.

Mr. A. E. Ash (Visitor) said that whilst he had at one time been a marine engineer, he was now also engaged to a certain extent on motor-car work. The workmanship about those engines was a very different matter to steam practice. With regard to the old steam winches, they all knew that a good deal of rough work went into them, and yet they would run round all right, and efficiently do the work required, and at the same time stand exceedingly rough usage. The construction of the petrol engine was, however, a very different matter. Speaking to marine engineers, he would like to convey the idea that the ten thousandth part of an inch was a measurement which it was very right to aim at in motor work, and, if they could get it, it came very near perfection. For instance, a cylinder one thousandth part of an inch oval or taper would never give real satisfaction, and yet a thousandth part of an inch was not perceptible with the hand calipers. He thought Mr. Sumner would bear him out in these remarks.

Mr. Sumner said the last speaker was unquestionably correct so far as car work was concerned, but the same accuracy was not carried out in marine work, so far as he was able to say. It was desirable to cut down the weight of car engines as low as possible, but there was no such desirability in marine work. If they had a 25-ft. launch fitted with a 4-cycle car engine of 8 horse-power, they would have to add about 12 to 15 cwt. of ballast. Hence, the majority of builders of marine petrol engines put the weight into the engine. The Napier people, who originally put car engines into launches, were now modifying their practice entirely to suit the really rougher requirements of the launch work, which did not entail such lightness of weight. With regard to the question of mean pressure, a great deal depended upon the type of engine, whether 2 or 4 cycle. The only one of which he had any data with him at that moment was a 4-cycle engine, and that engine had a mean pressure of 80 lb. throughout the stroke. That was with the compression of 80 rising to, approximately, 320 as the maximum pressure, and that again varied according to the length of stroke. With the 2-cycle engine some people insisted on greater pressure and less diameter, whilst other manufacturers had larger diameter and less compression, thus getting greater piston area. Naturally, the results were not the same. It was rather a hard question to deal with, and he would like to forward on some diagrams, from which they could draw their own conclusions. It was rather a technical point to go into at this stage, and one was liable to convey ideas wide of the mark. To thoroughly explain this action of gas in a gas engine so as to render it as clear as that of steam in a steam engine it would first be essential to explain the laws of Joule, Boyle, Charles, and Regnault on gas, and to delineate what gas-engine experts term "Carnot's cycle of operations," substantiating same by both independent and personal data, for which he was not fully prepared. The engines, however, to which Mr. Raworth refers, are 4-cycle, and in these—in fact, in numerous cases now—100 lb. per square inch is an accepted mean pressure by no means uncommon or abnormal, when the high maximum pressure and short stroke of modern oil motors are taken into account. While such a mean pressure may occasion a pressure of over 50 lb. per square inch at the point of release to the exhaust, such an apparent excessive loss is but the inevitable resultant of the high speed, high compression, short stroke style of motor which is proved to have the highest economy in consumption of fuel.

Mr. W. H. FLOOD (Member) in proposing a very hearty vote of thanks to Mr. Sumner for his paper, said it gave him great pleasure to be called upon on that occasion. The paper that had been read that evening, like many other papers that had recently been given, was one that should lend itself to a lengthy discussion. Petrol motors, he thought, were practically in their infancy, more especially for marine work, and he, like many other members present that night, felt a little bit at a loss for sufficient matter wherewith to open up the discussion on account of the usual copy of the paper not being in circulation. That, he thought, would explain why the subject had not been more fully discussed. Few of them, he thought, knew sufficient of the subject to go any further with the discussion at the present stage. He would be very pleased to look the subject up further, if it would be convenient for the discussion to be postponed, and on looking around amongst the members he was of opinion there were many gentlemen present who would be only too anxious to go a little further into the matter.

The vote of thanks was cordially voted to Mr. Sumner.

The Chairman announced that the discussion would be adjourned until Monday, February 15th, instead of Monday, February 22nd, as originally intended, to suit the convenience of Mr. Sumner.

A vote of thanks to the Chairman concluded the proceedings.

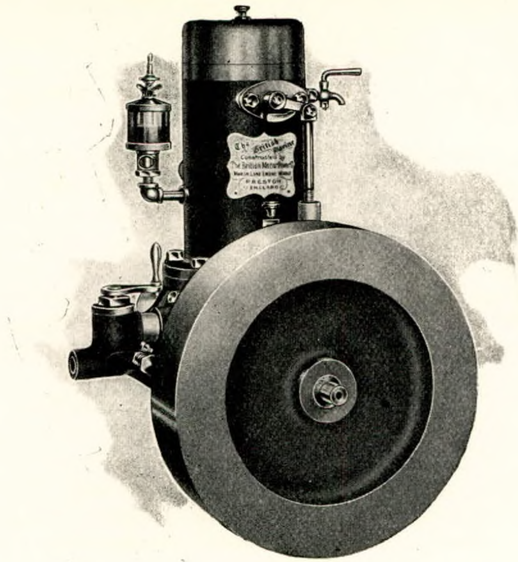

FIG. 1.

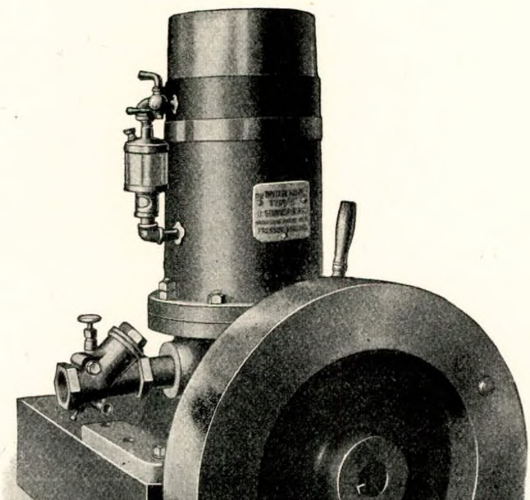

FIG. 2.

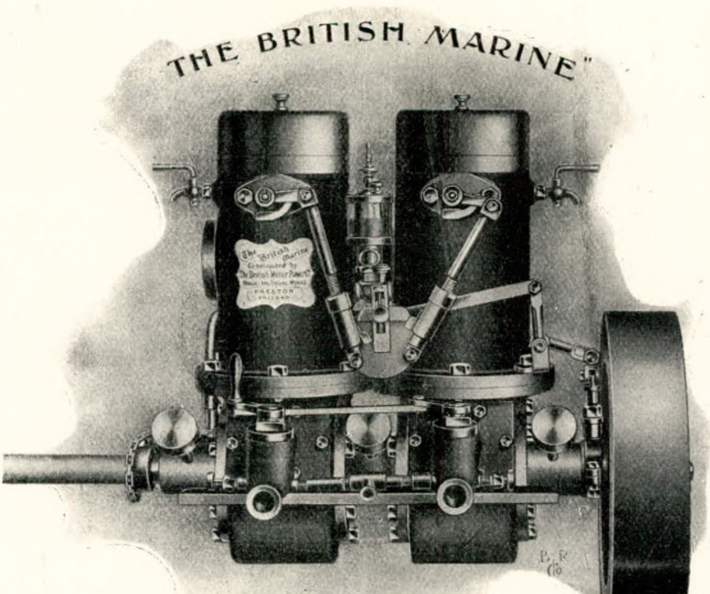

FIG. 3.

ADJOURNED DISCUSSION

AT

58 ROMFORD ROAD, STRATFORD,

ON

MONDAY, FEBRUARY 15th, 1904.

CHAIRMAN:

MR. W. McLAREN (VICE-PRESIDENT).

THE HON. SECRETARY: I regret that the author of the Paper is unable to be with us this evening, as set forth in the following letter:

"*February 11, 1904.*

"DEAR SIR,—Referring to your letter to Mr. Sumner, I may say that owing to an unexpected and unallowed-for pressure of work in view of the approaching season, Mr. Sumner will, I fear, greatly to his regret, be unable to be with you on Monday next.

"There is some misconception in regard to the engine, despatched for exhibition at the lecture, but delayed en route.

"A large number of engines are under construction, but no one of them can we guarantee the delivery of in time for the discussion. When the present pressure, however, is somewhat relaxed, Mr. Sumner authorises me to say that he will obtain the consent of his co-directors to the presentation to the Institute of one of the firm's marine petrol engines."

In the absence of Mr. Sumner, it was decided to still continue the discussion on the Paper.

Mr. G. SHEARER (Member) reopened the subject by describing by means of diagrams on the blackboard the mechanism of the Ovenell internal combustion turbine.

The CHAIRMAN then asked if there was any other gentleman present who would like to make any remarks on the subject. Mr. Shearer, he thought, had not taken quite the direct line of the author's paper, but a question had been asked at their last meeting on the subject with reference to turbines.

Mr. SHEARER said he had raised the point with a view to eliciting information on the subject, for the benefit of others as well as himself.

Mr. T. D. SANDERS (Visitor) then, by the aid of the blackboard, gave a description of the "King" petrol motor engine.

The principal features of this engine were that when the piston *A* (Fig. 4) moves upward, a charge of vaporised gasoline is drawn through the vaporiser inlet *B* (Fig. 5) into the crank chamber *C*. When the piston moves downward, as shown in Figs. 5 and 6, that vapour was compressed in the crank chamber *C*. As the piston *A* reached the lower end of its stroke, it brought the admission port *d* (Fig. 6), in the hollow piston, opposite the by-pass opening *eee* (Fig. 6) thus allowing the vapour or gas in the crank chamber to pass into the upper end of cylinder *G*, through the admission valve *f*, which was forced open. The upward stroke of the piston closed the valve *f* (Fig. 4), and the gas thus held in the chamber *G* was highly compressed by the piston moving up against it. This gas was then ignited by an electric spark in the ignition chamber *H*. The expansion caused by the ignition of this gas forced the piston downward. As the piston passed downward the exhaust port *K* was opened and the burned products of combustion were entirely exhausted from the cylinder, and the upward pressure on valve *f* was thereby relieved. The new vapour which had been compressed in the crank chamber by the downward stroke of the piston was again allowed to pass through the port *d* and chamber *eee* (Fig. 6), and thus, by its pressure, forces open the valve *f*, which allowed that new vapour to again enter the cylinder chamber *G*. The downward stroke of the piston

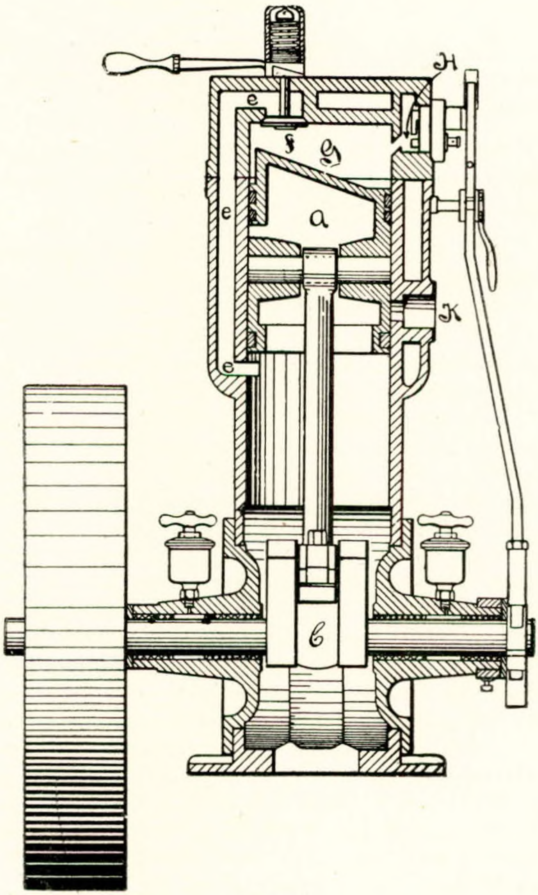

FIG. 4.

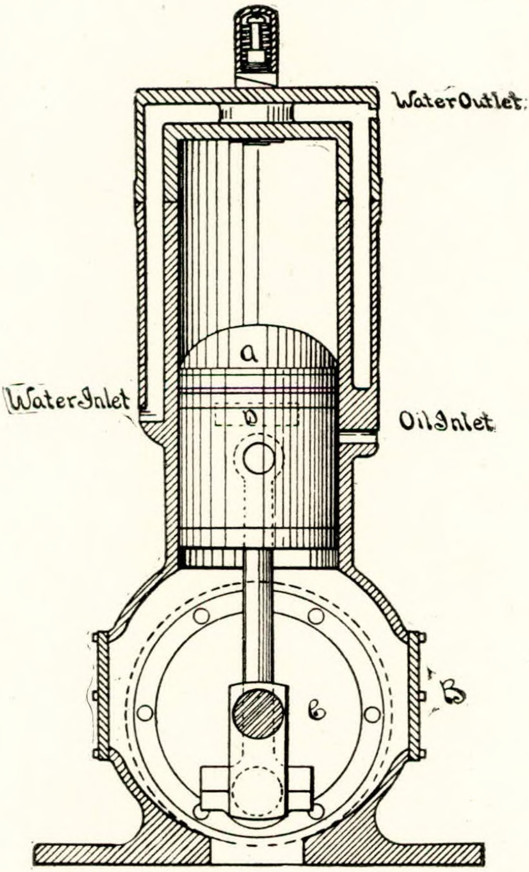

FIG. 5.

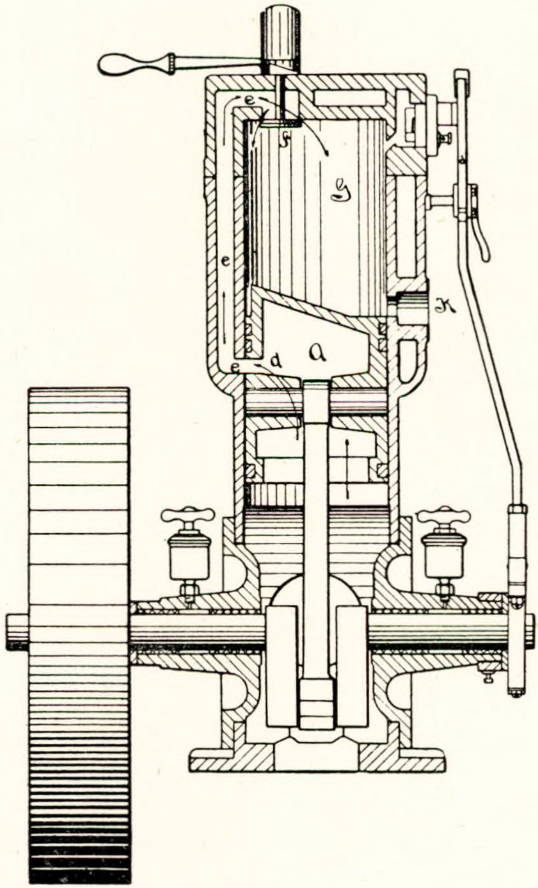

FIG. 6.

had given a momentum to the fly wheel, which drove the piston upward again. Thus the valve was closed, and once more the gas was compressed in the upper end of cylinder and a new charge of vapour was again drawn into the crank chamber.

Mr. D. HULME (Member of Council): These engines, I presume, are small.

Mr. SANDERS: The diameter is 3·5 in. for a 1½ H.P. engine. We make them up to 7 in. bore and 8 in. stroke.

Mr. HULME, continuing, said his experience of internal combustion engines had been that, in some cases, by leaving some of the exploded gases in the cylinder, they had a decided economy. Of course, it depended on the gas they were using. In gas engines, if they used the ordinary town gas, it was more economical to leave some of the exhaust in the cylinder. If however, they were making their own gas, and had a light and poorer gas, such as was known as producer gas, it was far better to clear it all out. In speaking of the economy of the two engines that had been described, it would be necessary to run them in competition in order to see which would do the greatest amount of work on the least consumption of fuel. With small engines of that class it would be somewhat difficult to run them for a very fine experiment unless they were run for a considerable time. He was certainly of opinion that when they were using rich gases which were made from petroleum it would be an economy to leave a little of the exhaust in the cylinder.

Mr. SANDERS: Why would you advocate leaving a little of the exhaust in the cylinder?

Mr. HULME, replying, said that they got no advantage from compressing all pure air. The power produced was due to the explosion.

Mr. SANDERS said it appeared to him that, as the fuel to be exploded had to produce a certain result, the purer it was the better. He had heard Mr. Hulme's point brought forward on more than one occasion, and he had consulted people with great experience of those engines, and they had told him that the cleaner the exhaust and the more thorough the scavenging of the cylinder, the better the results obtained.

Mr. HULME: I am speaking of large engines, and of taking indicator cards off those engines. I certainly agree that when using producer gas it is better to clear the whole of it out, but when rich gases are used I have found it an advantage to leave a little of the exhaust in. It adds to the temperature of the incoming gas, and expands it still further and increases the pressure.

Mr. SANDERS: It reduces the weight of the explosion.

Mr. HULME: You get greater value in the cylinder, due to the increase of temperature from the gas left in.

Mr. SANDERS: I do not think that would be a good point. It might induce premature combustion. If the compression is excessive, premature ignition might take place, and that, I think, would cause premature combustion.

Mr. HULME: You cannot get premature combustion under 600 degrees of temperature.

Mr. SANDERS: I know plenty of cases where it has occurred.

Mr. W. E. FARENDEN (Assoc. Member) said he was very sorry that the author of the paper was not present that evening, for there were several points that he would have liked to put to him. In the early part of his paper he referred to the specific gravity of petrol as ranging from ·68 to ·72. What would be the flash point of that petrol? In some engines he had found the petrol used had a specific gravity of from ·82 and upwards. A little further on, when speaking of an iron pipe that had been substituted for the original lead pipe, he had said "the petrol in the tank was all right, but the petrol entering the vaporiser was all wrong." Why not fit a copper pipe in preference to a lead one for conveying the petrol from the tank to the vaporiser? A lead pipe was more likely to get damaged unless it was well protected. The author had given the weight of the land engine as compared with the petrol launch engine, but he would like to know the weight of the petrol launch engine as compared with the steam launch engine. Also, how did the average life of the petrol launch engine compare with that of the steam launch engine? He quite agreed with the author as to running those small engines at too high revolutions, for unless the engines were well designed and had ample bearing surfaces their lifetime would not be so long as the slower running engines, and they would soon shake themselves to pieces. The motor boat should be safe, comfortable and durable, with machinery designed to run for years, with little trouble and expense. A breakdown in a boat was a far more serious affair than a failure on a road vehicle, as assistance could not be so readily obtained. The author had referred to the petrol engine as not being a reversing engine. Could not internal combustion engines be made reversible? It was done, he understood, with success by the three-cylinder Bertheau engine. Could the author tell them anything about that engine? It was claimed that it could be reversed instantaneously, and the speed varied as required.

Mr. SHEARER: Does that Bertheau engine reverse with its own mechanism or by gearing?

Mr. FARENDEN understood that it reversed instantaneously by its own mechanism. The Bertheau engine was made by Messrs. Thornycroft. Mr. Sumner had said he would like to give them a trip in one of his launches. He thought they would be very glad to accept his offer. Towards the end of his paper the author said "the brake test is the one which should always be insisted upon, as it is the actual power in the crank shaft." He quite agreed with the author regarding the horse-power developed by petrol motors, and that the brake horse-power should be insisted upon. Indicator diagrams could also be taken as a check, and to see if the design was satisfactory or could be improved upon. He thought there was a great saving in the weight of the motor, petrol, and all accessories, as compared with the steam launch engine, with its boiler and connections. He would be glad if the author would give them the weight of the motor, petrol, and all accessories for a 30 ft. launch, say for a speed of eight knots, and the approximate cost of same; also the consumption of oil, and cost per day to run a launch of that size. He had no doubt the Council of the Institute would be very pleased to accept the author's promise to forward plans and sections of the rotary petrol engine when the actual trial runs and tests had been completed, and they would look forward to having another paper from him on that valuable subject.

Mr. C. PERKINS (Member): Is that a reference to a rotary piston engine or an engine of the turbine type?

The CHAIRMAN: On the turbine principle. Can Mr. Sanders enlighten us on some of the questions that have been put forward?

Mr. SANDERS would be pleased to do all he could to assist the discussion. He was a boat and launch builder, not an engineer; so he hoped they would not blame him if he put them somewhat off the track at times. He regretted he could not give them the flash point of petrol. He could tell them, however, that petrol was not so dangerous as many people supposed. It could only be ignited by an open flame—that was all he could say about it. The next point raised had reference to the number of revolutions per minute. Before his firm took up the 2-cycle engine, they tried to run, as an experiment, an English 4-cycle car engine, running at 1,800 to 2,000 revolutions per minute. The firm were not very keen about taking up the engine at the time. They fitted that particular engine into a boat, which they sold on advantageous terms, subject to trial. They put the boat into the water, but before running any length of time the high revolutions caused the boat to leak so badly that the engines were stopped. His firm generally used lead piping for conveying the petrol from the tank to the vaporiser. Copper was very good, but he thought it was more liable to fracture under vibration than lead. Lead, being more ductile, would take up vibration better. Lead was easily bent, not so easily fractured. All things considered, he thought lead would be found most satisfactory. With regard to the cost of running the engines, he thought it was generally accepted as a fact that petrol 2-cycle engines consumed about one pint of petrol per H.P. per hour, and if they took an engine whose maker said it only consumed half-a-pint per H.P. per hour, they would find that such 2 H.P. engine was really only a 1 H.P. engine. Petrol was to be obtained at 9d. per gallon, so an 8 H.P. engine would consume about one gallon per hour, costing 9d. at trade price. Other expenses were grease for bearings and lubricating oil for the cylinder; but these were not very expensive. They might say that an 8 H.P. engine could be run at a cost of 1s. in all per hour, if they could obtain the petrol on favourable terms.

The CHAIRMAN: Brake or indicated horse-power?

Mr. SANDERS: Brake.

Mr. HOWIE: It is practically the same approximately.

Mr. SANDERS said he thought the B.H.P. would be under the I.H.P., because there must be some loss on arriving at the propeller. With regard to the question of weight, he thought their $1\frac{1}{2}$ H.P. engine weighed about 130 lb., and their 3 H.P. engine about 230 lb. The 8 H.P. engine would weigh about 900 lb. He would like to say that so far as testing was concerned their engines were tested, and they were afterwards coupled up to the propeller, and were then worked with the propeller revolving in a large tank of water. This method of testing possessed obvious advantages. They could see that the engine would turn the propeller, whilst the engine itself was not allowed to race.

The CHAIRMAN: Is that tank of a uniform depth of water that the launch would be drawing.

Mr. SANDERS: No; it is just a very large tank.

Mr. PERKINS: It is the shaft that is passed through into the tank.

Mr. SANDERS: Yes. The shaft passes through a bulkhead fitted with stuffing boxes. Continuing, he said he would like to tell them of an interesting case concerning one of their engines at the present time. A gentleman who was a scientist was going to the West Indies to obtain specimens of animal and sea life at a depth of from 1,000 to 2,000 fathoms, and he had one of their $4\frac{1}{2}$ H.P. engines to drive a winch. The net was let down to 2,000 fathoms and then drawn up, and that engine reeled off the 2,000 fathoms from one reel to another in twenty minutes.

Mr. FARENDEN: Do you know anything of the Bertheau 3-cylinder engine?

Mr. SANDERS, replying, said he did not know anything of that particular engine, but with regard to petrol engines reversing, most 2-cycle engines could, and would, be reversed. Ports were placed in such a position that it did not matter which way the engine moved. Sometimes it would start one way and sometimes the other. Many manufacturers told them to start one way, for the screw propeller was screwed on to the shaft, and if they turned the wrong way it might unwind and fall off. If they wanted to reverse they were to switch off the ignition, just before the engine was stopped, and as it was coming up on the top centre they were to switch on the current and they could reverse the engine—that was, if they were used to it. He had seen it done, and had done it himself once in ten times. That was with a 2-cycle engine. The engines made by his firm did not reverse.

The CHAIRMAN: There is a fly-wheel in every case?

Mr. SANDERS: Yes; otherwise they could not possibly start the engine—they could not let the power in. That was made in the vaporiser, and brought into the engine by turning the fly-wheel over. It depended upon the operator whether they started quickly or not. With a good engine they could start with a turn to a turn and a half.

The CHAIRMAN: Would the propeller turn also, or be free?

Mr. SANDERS said the propeller was generally connected up and turned with the engines, but with reversible blade propellers, in order to ease the strain on the operator's arm in turning over the fly-wheel, it was usual to reduce the angle of the blades. When the engine started up the blades were ready either for ahead or astern, as the case might be.

Mr. PERKINS: What is the size of the lead pipe used to convey the petrol from the tank to the vaporiser?

Mr. SANDERS: About 3/8″ diam.

Mr. PERKINS: If that pipe were made of copper, with an expansion curve it should stand all vibration.

Mr. SANDERS said that would bring in the question of price. They had to turn those engines out as cheaply as possible. The diameter lessened considerably as it went to the vaporiser. At the point where the spirit entered the vaporiser the diameter was exceedingly small.

Mr. PERKINS: I do not think vibration would hurt a copper pipe if it were made with sufficient expansion curve.

Mr. SANDERS said it had been proved that lead answered every purpose, and was effective. He might add that he was having a boat built for himself; he hoped it would be completed in the course of two months, and he would be pleased to invite the members to come to a trial run at Burnham-on-Crouch.

The CHAIRMAN: I should think the lead is bound to sag until it goes to pieces.

Mr. SANDERS: The lead pipe is laid on the bottom of the boat.

The CHAIRMAN: If there is any beating and vibration I would put very little faith in lead piping.

Mr. SHEARER differed from Mr. Sanders very much. He could understand a plumber putting a lead pipe into a motor car or a launch, but for an engineer to do a thing of that kind was more than he could understand. Lead piping put into a vehicle of any kind, whether for water or land purposes, would not stand vibration. The vibration on any vehicle would sag down the lead piping. He did not care what size it might be, whether from a quarter of an inch to a foot in diameter, but a lead pipe of any length must be supported throughout its entire length, not here and there by brackets or hooks only. When supported on hooks it simply sagged down. Those who had any practical sea experience found that all their lead water pipes, unless they were properly supported, would sag down. He would never use a lead pipe himself, or allow anyone to put lead piping into any portion of a marine engine where it was possible to avoid it.

The vibration of the pipe would shake the joints loose. It was not even suitable for a motor car. He had never seen a reliable petrol engine yet. He was a great admirer of the petrol engine, and had no doubt that in the future it would be a success; but in its present stage the steam engine was much more reliable. Of course, the great advantage of the petrol engine was "the compact, squat little engine" in a launch, compared with the heavy boiler and the great quantity of water it required in a seaway. However, there was another boiler now—the flash boiler—the weight of which was a mere nothing compared with the ordinary boiler or the Belleville. He had often observed, when on the road, that a motor car would run beautifully when on level ground, but when it came to a hill the speed was reduced, and consequently the power was reduced, as the speed of the car kept up its power. So soon as the reduction took place it ended in a slow-down or stop. Once it stopped on the hill they would never start it again. They might get out and push. That was a case of a car stopping on a hill for want of power.

Mr. PERKINS: Are you referring to a steam or petrol car?

Mr. SHEARER said he referred to a petrol car. With the flash boiler there was no such trouble, as if the car stopped on a hill there was an increased pressure at once. It was the reverse with the petrol car. It was necessary to have a flash boiler because of its lightness, and that boiler was always reliable. They could run it at any speed; they could slow down, and they did not require any gear. It was a direct push. The steam engine on the car he considered the most reliable at present. He had seen a few thousands of cars on the road, and been running alongside of them, and that was his experience.

Mr. PERKINS: Regarding the stopping of these cars, is there any necessity to stop a petrol car on a hill?

Mr. SHEARER: They stopped for want of power.

Mr. PERKINS: You said that when they come to a hill the engine slows down. How would the steam engine come off on a hill?

Mr. SHEARER: Steam would increase its pressure by stopping, whereas the petrol engine loses.

Mr. PERKINS: I cannot see that point. Each car has its maximum power. If you take a hill that stops the car, well, you have reached your maximum power, and neither a steam nor petrol car can restart.

Mr. SHEARER: It cannot get beyond its pressure.

Mr. PERKINS: You are pitting the steam car against the petrol car. Take two cars of equal maximum power, and I say that the hill that will stop the one will stop the other.

Mr. SHEARER: In getting up a hill the petrol car is reducing power all the time, as she is slowing down if the car cannot take the hill.

Mr. PERKINS: Then you are putting the car beyond her maximum power; when you begin to reduce the speed you are going beyond that car's natural power. The same would stop a steam car, if you overtax it. It seems to me you are taking an unfair case against the petrol car.

Mr. SHEARER: I say that the petrol engine is not reliable. The ignition is the great trouble with all such cars. If any little hitch happens to the ignition whilst the car is mounting the hill the car stops, and cannot start again.

Mr. PERKINS: If anything goes wrong with the car she must stop. The argument was not dealing with breakdowns. So soon as you start slowing down the petrol car by putting too much work on it you have gone beyond its maximum power.

The CHAIRMAN: There is a point in the author's paper with regard to the difference between 300 revolutions and 500 revolutions. The efficiency is much better with the higher revolutions, and less petrol is used. With regard to the point put forward by Mr. Shearer as to the reduction gear on the petrol cars to gear the power, the engine is brought up slower and they do not get the efficiency.

Mr. SHEARER: The engine is going back on her efficiency as she slows down.

Mr. PERKINS: If you reduce the gear in ordinary power you need not reduce the engine speed—at least, you need not in most cars. You need not reduce your engine speed by reducing the gear. I can say one thing with absolute certainty, and that is that in changing the gear to a lower speed there is no question of reducing the speed of the engine. You can vary the speed of your engine in many cars up to 30 per cent. without advancing or retarding your ignition. You get the engine at full speed and at maximum power with your lowest gear. There is no question of reducing the speed of your engine unless you want to do so for some other purpose.

Mr. HOWIE: I agree with the last speaker. The gear is reduced just the same as a locomotive is reduced. The power is reduced, but the efficiency of the engine is not reduced, that is the designed efficiency. With regard to hill-climbing with the steam engine, when the engine takes the hill the boiler pressure is going up until it gets to the limit, that is, its maximum power, and yet it may stop for want of the necessary power.

Mr. SANDERS: Mr. Shearer brought up a point regarding the reliability of petrol engines. You must recollect that most people are not used to any sort of engine. I think Mr. Shearer would not put a dustman into a steamship and expect him to run the engines successfully. Most of the people who buy petrol engines have never seen an engine in their lives, and the fact that those engines have frequently run thousands of miles points to the conclusion that the petrol engines are exceedingly reliable. When anything does go wrong they begin to fool about with the vaporiser and spoil their mixture. As a general rule you will find that the engines are more reliable than those who own them.

Mr. PERKINS: That raises another point, as to cars being easily stopped on a hill. In most cases any trouble on that score is caused by an inexperienced driver, who does not change his gear soon enough. He wants to get as much speed as possible so that he can rush up the hill, and he leaves his high gear on too long, and before he has time to get his high gear out and put the low gear in the engine is becoming so reduced in speed that it is not able to go on. That is the driver's fault.

The CHAIRMAN said the petrol engine had to have so much momentum stored into it, as was done with the fly-wheel in the steam engine. Referring to a winch which was brought up all standing, when the winch was oiled, it started, yet steam was on that winch all the time.

Mr. SANDERS: I think there are several cars with multiple cylinders. When the car stops, a charge is retained in one of the cylinders, as the piston rings fit tightly. The charge is retained for a considerable time, so that you are able to start away without the organ-grinding business that has been referred to.

Mr. PERKINS: The lack of reliability does not apply to stationary petrol engines.

Mr. SHEARER: No, only to car or launch engines; not at all to land engines.

Mr. PERKINS: I know of one 2-B.H.P. engine that has been running two years, and I think the only thing that has been done has been to put in one new ignition tube. It has been doing pumping work for a deep well, with a gardener looking after it who simply keeps it clean.

Mr. SHEARER : Racing cars of high speed simply jar themselves to pieces, because there is not enough material in them.

Mr. PERKINS : Racing cars are not supposed to be heirlooms. They are only built to last one year.

Mr. SHEARER : I am convinced of the future of the petrol engine. I much prefer the steam engine with the flash boiler for the car, and I do not know whether you followed me in my remarks regarding the loss of power in the petrol engine on the hill. The petrol car engine is all right so long as you can keep the engine running at maximum speed, but if that speed is not maintained I say the power is diminishing all the time, and the consequence is that she will stop on a hill where a steam car, if she stopped, would have no difficulty in getting away again. I hold to the steam engine for the car up to the present time, of a type similar to that which I have described.

The CHAIRMAN said he was not prepared to take part in the discussion that evening. He had made a few notes, but would prefer to go over them again before speaking. They would have to continue the discussion at some future date when it would be convenient for Mr. Sumner to be present. The Institute would most cordially accept the engine he had offered. It would be very valuable to have ; and they must also thank Mr. Sanders for his offer. He thought the Recreation Committee might take up the matter of the suggested trip on the river. The next paper that would be read was on " Coal, from Seam to Shipment," and that paper would be read at Stratford on March 14.

The meeting closed with the usual vote of thanks to the Chairman.

DISCUSSION CONTINUED

AT

58 ROMFORD ROAD, STRATFORD,

ON

MONDAY, APRIL 11th, 1904.

CHAIRMAN:

MR. D. HULME (MEMBER OF COUNCIL).

The CHAIRMAN: I have much pleasure in calling on Mr. Sumner, who has come from Preston to reply to the discussion that has already taken place on this subject, and has brought a petrol engine with him to show the details.

Mr. SUMNER, responding, said that they all knew, and every marine engineer knew, that it was correct that copper was a far more suitable material for pipes than lead. Mr. Shearer, however, had objected to the use of lead pipes in motor launches, because he said they had to be held up and supported. But in motor launches the petrol pipe was laid along the garboard strake, and was supported right from the petrol tank to the vaporiser. He had never seen one yet that was supported by brackets.

Mr. A. M. SANDERS: I have never known of any case where the pipe is so supported. It is supported, as you suggest, either on the garboard strake or on the timbers of the boat.

Mr. SUMNER: It is just passed over the ribs; that is sufficient support. One objection to the use of a lead pipe was that if anyone put his foot on it it was more liable to be crushed in than a copper pipe. It was not necessary to put in a copper pipe in small launches, but in a large or a costly launch he would put in a copper pipe. For small craft lead answered perfectly well. The bore of the pipe was small, and it did not give any trouble, and he had had no trouble with lead pipes.

Mr. W. McLaren: I understand it is not a question of price. There is some other motive for the use of lead.

Mr. Sumner: Lead, copper, or brass could be used, or, indeed, any material that did not alter the specific gravity of the petrol. Neither lead, copper, nor brass affected the petrol in any way, whereas iron did; that was the point he wished to make clear. Brass he considered too brittle for the purpose. With regard to the vitiation of the gas, he would say that his opinion about getting rid of all the burnt gases had undergone a considerable change since last January. He would explain that when they came to examine the engine he had brought with him and saw the position of the parts. In January last he had stated that the best results were to be obtained by having the exhaust port full open the instant the admission port opened. In the engine he had with him the exhaust port opened about $\frac{1}{8}$ in. (or $\frac{3}{16}$ in. at most) before the admission port opened. The depth of exhaust port was $\frac{3}{4}$ in., and admission port $\frac{5}{8}$ in., and it *braked* exactly the same horse-power as the engine to which he had referred at the last meeting. The object was to bring the exploded charge as low down as possible, and so get the most value out of it. In the original type of engine he had, the admission port was $\frac{1}{2}$ in. in depth, and exhaust port about $\frac{9}{16}$ in. That would give, say, $4\frac{1}{4}$ in. $-$ $1\frac{1}{8}$ in., $3\frac{1}{8}$ in. as the actual length of the volume carried by the gas on its explosive stroke. But the engine they had before them carried down to nearly $\frac{1}{2}$ in. more, and that had not made any difference on the brake. The contention was that it ought to make it better, but he had found it had not interfered with the engine in the slightest degree. The next thing he intended to do was to try more compression, and endeavour to get better results. The idea was to retain the exploded gases as long as possible in the cylinder without interfering with the incoming charge. There must be absolutely no atmospheric pressure in the engine by about 4 in. of the stroke. There was only about 5 lb. pressure in the crank case, and it would not go into the cylinder if there were any appreciable pressure at all. So far as vitiation of the gas was concerned, it certainly did not seem to make as much difference as he had thought it would make. At the last discussion Mr. Hulme had said that he had had the same experience—viz., that the small quantity did not seem to make very much difference.

The CHAIRMAN: It is an advantage.

Mr. SUMNER: Suppose the whole of the charge were cleared out, it would have to be filled up again. The difference between the volumes before explosion and when the charge was exploded to atmospheric pressure was only 2 per cent. He hoped he made himself clear. Suppose there were a certain volume compressed in the cylinder head, it would be of a certain cubic capacity. When that volume was exploded and released to atmospheric pressure the volume at atmospheric pressure was only 2 per cent. greater than the volume before ignition. So, by whatever they retained of that in the cylinder head —if it did not make any difference at all to the actual working of the engine—they required that much less to be drawn in through the vaporiser and crank case.

The CHAIRMAN: That will certainly show an economy.

Mr. SUMNER: Exactly; it does increase the economy. That brought forward another point. In the early stage of those engines it was inferred that the gas was stratified, or did not mix properly, and that the internal part of the cylinder head should be so designed that it would collect and retain a part of the fresh incoming gas not contaminated at all with the burnt mixture, and so get a better explosive effect. On the cylinder cover of the engine before them they would see that a semicircular ring was cast round the cylinder cover, and an insulated plug to catch the incoming gas; but it had been found absolutely useless. The alteration made no difference; and that must be due to the fact that there was no such thing as stratification at the speed the engine ran. The gas must evidently be whirled into a satisfactory mixture, or it would not ignite. So now they were doing away entirely with the semicircular ring, as the less unnecessary gear they put on an engine of that type the better. He would be more than pleased if some of the members would pass a remark on the subject, or a question which would invite any further explanation, as it was possible he might be slipping over some points that were familiar to him, but which some of those present might like to have made clear.

In reply to Mr. Sanders that too great an increase in temperature was liable to cause premature combustion, it was found by running the engine without any piping on at all and using a weak mixture, they could so arrange the gas that occasionally nothing but a live flame would come out of the exhaust port, which would fire the next stroke. It did not then cause a back-fire at that temperature. The engine had a great deal of running to show that premature ignition could not take place without the presence of flame in the cylinder. A great deal depended on the compression, and they could not afford to do the same thing with a 4-cycle as with a 2-cycle engine for the reason that the compression in that 2-cycle engine was only about half of the compression of the 4-cycle engine, owing to what might be termed the faulty construction of the exhaust. The compression on the engine before them was about 40 or 45 lb., which would give 4 B.H.P.; but there was no reason why they should not have 80 lb. compression on a 4-cycle engine. Any more compression on the engine of that particular design, working at 500 revolutions, would occasion back-firing, or the incoming gas would ignite. He wished to make it clear that with a given temperature at the moment of exhaust, which was almost the same moment of ignition in the engine on view, there would not be the same temperature as in the 4-cycle engine. It had another stroke to go up, so that it was not a parallel case between the 2- and 4-cycle engines, working as they did on different principles. The only occasion in which there was any liability to firing was in the presence of flame; that was the only time that they were likely to get crank-case explosion. It was in the form of flame when the ignition port was open, in firing the gas in the crank case and choking the piston on the other side. Unless there was something of that sort going on, there was nothing at all of the effect of a crank-case explosion. The actual temperature was not altogether governed by the compression, yet at the same time it did affect the temperature. Supposing the gas had exploded at 40 lb. in the 2-cycle and at 80 lb. compression in the 4-cycle engine, the temperature in the 4-cycle type would not be *pro rata* to the 2-cycle engine. In other words, there would not be twice the temperature in the 4-cycle engine. There was very little difference in the temperature of the exploded gas.

Mr. T. D. SANDERS: But you are getting a far greater number of explosions.

Mr. SUMNER: And a complete clear exhaust stroke. In 2-cycle engines you cannot get a complete exhaust stroke. Assume that the upper edge of the exhaust port is 1″ from the bottom, then we have $3\frac{1}{2}$″ stroke, while it is only open for a little less than half a stroke, taking it on the down and coming up. In the 2-cycle engine the exhaust port is only open for barely half a stroke, whereas in the 4-cycle engine you may call it open for quite half a stroke. That is the difference. In the 4-cycle you get a great deal higher speed, but a more complete exhaust stroke, which you do not get in the 2-cycle engine. Practically three-quarters of the exploded charge is compressed again in the 2-cycle engine, whereas only the actual volume of clearance in the 4-cycle is retained with the new charge.

Mr. T. D. SANDERS : I should have thought the heat was generated from the explosion, and not from the exhaust.

Mr. SUMNER : Of course ; but the admission of the new gas takes place immediately the exhaust is completed in either type of engine, and in the 4-cycle the admission of gas is after the exhaust is closed—with a complete exhaust stroke, at least. Continuing, he said that with the 2-cycle engine the admission port to allow the fresh gas to come in was open a $\frac{1}{4}''$ after the exhaust port, and was as low down as it was possible for it to be put. There was some truth in the contention that a vitiated gas did affect the power, for they could only get, approximately, 60 per cent. more power out of the 4-cycle than they could out of the 2-cycle.

Mr. J. THOM (Member) : Do you get 60 per cent. more out of the 4-cycle at the same speed ?

Mr. SUMNER said that they did. Really they would expect to get twice the power.

Mr. THOM : You say that is impossible ?

Mr. SUMNER : Yes.

Mr. THOM : When the admixture was admitted and mixes with the other used-up gas it would not be so good an explosive mixture, nor would you expect to get the same result from the same quantity of petrol ?

Mr. SUMNER : That is why these engines are slightly more expensive in consumption than the 4-cycle, because you cannot get quite the same value out, owing to the amount of vitiated gas.

Mr. W. McLaren (Vice-President): That is a point upon which I am not quite clear. The exhaust port and the gas port are open both at the same time. Is there no loss from the admission port and into the exhaust port on that particular point of the travel of the piston? Also, how do they affect the compression? Do you not lose so much of that gas that you wish to compress in the cylinder?

Mr. Sumner: No. There is a baffle plate so fitted that it would deflect that gas up the side of the cylinder wall, and the two ports are diametrically cast opposite each other. Before it is possible for the gas to go up and return, the piston is up and shuts the exhaust edge of the port. The two ports are exactly opposite each other, but the exhaust edge is uncovered slightly before the admission edge. In the first engine that we built we had the bottom edge of the exhaust port in line with the top edge of the admission port, so that the exhaust port would be full open before the admission port was uncovered at all. We found it more beneficial to bring the exhaust port lower down and exhaust at a lower temperature, and retain the gases to further expand on the stroke. The reason the gas does not go right across the face of the piston is because of the deflecting baffle-plate which is cast on the piston top. This plate deflects the gas upwards a little. One reason why the 2-cycle engine will not work very slow is this: if the piston does not come up smartly, the major part of the gas will slip across to the exhaust port before the upper edge closes it. You can generally tell whether there is any petrol coming out by putting your face close up to the engine. If any petrol is coming out you can distinguish it by the smell and the stinging sensation of the eyes. We find it does not make any difference to bring this port down. That is my previous contention of having the exhaust full open before the admission port was open at all.

(Mr. Sumner here explained the details of the construction of the engine by means of a diagram on the blackboard.)

Mr. J. THOM (Member) then asked for some particulars as to the thickness of the cylinder walls.

Mr. SUMNER, replying, said that the actual liner of the engine he had with him was $\frac{1}{2}''$ or $\frac{7}{16}''$ thick, and there was a jacket of $\frac{3}{8}''$ and an outside material of $\frac{5}{16}''$.

Mr. THOM: Is there no difficulty in furring up?

Mr. SUMNER: No. There is one point to be observed in the majority of cases. With regard to car engines, you cannot run them the same as steam engines. They must be kept free from grit. If there is the slightest bit of grit about the ignition it interferes with its time.

Mr. T. D. SANDERS: When the new charge strikes against the baffle-plate it is deflected, and as the exhaust is taking the same power, as those streams move upwards they must strike against the waste products, and some of them must be driven out. Sometimes there is a flame; that, I think, shows that the petrol is giving out a charge which is being fired just outside the exhaust port. I should think there must be a very considerable waste with this method.

Mr. SUMNER: It would appear that there must be. With regard to the presence of flame at the point of exhaust, it is determined by the strength of the gas. If a proper explosive mixture is used there will be no flame. It only takes the one-hundredth part of a second for every explosion to take place and bring the flame to CO_2 and H_2O. If you have a correct mixture of gas there will be no flame there.

Mr. T. D. SANDERS: Cannot the flame be caused by a charge going right through the cylinder and coming on the walls of the exhaust, which are sometimes red-hot.

Mr. SUMNER : That cannot be. No piston would stand it. If you have an engine burning an excessively rich gas it takes the form of a combustible, and not an explosive, agent ; and the combustible being a slower burning flame than the explosive, may occasion in such an instance the existence of flame up to the moment the inlet port is uncovered by the piston, of course igniting the incoming gas prematurely. This also may be caused by a very weak or poor gas. The correction in the first case is, give less petrol ; in the second, open the petrol valve on the vaporiser a little more.

Mr. T. D. SANDERS : That does not explain the point. Do you explain the muffled explosion only by the charge getting through ?

Mr. SUMNER : Exactly.

Mr. T. D. SANDERS : According to your suggestion, that charge cannot ignite. Yet we all know that it does ignite.

Mr. SUMNER : It can only ignite by reason of the presence of flame. It cannot ignite because of heat in the muffler.

Mr. T. D. SANDERS : It would be the bad effect of the previous stroke.

Mr. SUMNER : Yes, or the previous stroke not firing at all. It is a case of missfiring.

Mr. T. D. SANDERS : That would be the case if a charge could get through the engine.

Mr. SUMNER : Exactly. It may be due to the fact that you have a bad mixture of gas. You could have exactly the same thing happening with a 4-cycle engine.

Continuing, he said he had known of a Crossley engine that fired in its exhaust. That particular engine was a 4-cycle one—one of the best in the market. There was no fault with the exhaust, but the exhaust valve was leaking, and the engine was not always firing, thus allowing a portion of the gas to get through into the exhaust box, and the following impulse was sufficient to ignite it.

The CHAIRMAN said his experience was that firing in the exhaust pipe was due more to variable mixtures of gas and air and not being able to regulate timing of ignition spark to suit every mixture. At the present time he was firing two inches before the end of the compression stroke, with producer gas and air of equal parts, with commercial gas one part and air twelve parts, dead on the back centre. If either of these mixtures were supplied, they could rely on the engines firing as regularly as the stroke came round; but if these mixtures were varied the engines would occasionally miss a fire, and scavenge the cylinder of the unfired charge, which charge would be fired in the exhaust pipe by the flame from the next fired charge. If the engine valves are perfectly tight and sound we can rely on them for a long period, but if heavily loaded there was a possibility of a varying charge, sometimes missing a fire and being fired in an heated exhaust pipe.

Mr. SUMNER said that if they were firing with rich gas it might occasion flame at the moment the exhaust opened, and slightly further on, and when the admission port opened, its presence would have the effect of firing that gas. The Crossley Company had been experimenting in that direction for some time, but he thought they had now given it up. Their idea was for a jet of air to be blown across the face of the piston at the completion of the scavenging stroke to blow out all the waste products. That plan, however, had made no difference with the efficiency of the Crossley engine. He had one of those engines, and it only consumed 13 to 14 cubic feet per hour, which was very economical, and any clearance out of the old charge would have tried the scavenging stroke. He noticed that at the last meeting Mr. Howie had made a remark to the effect that the

I.H.P. was practically the same as the B.H.P. He would say that there was a difference of from 10 to 15 per cent., at any rate, in gas engines. Approximately it might be called a difference of 12 per cent. It was rather surprising that a party of amateurs, viz., the Marine Motor Association, had got out the best formula for deciding the B.H.P. of those engines. That formula worked out correctly to one or two decimal points, which was very good, considering that the formula was practically a new one. For 2-cycle engines their formula was $\frac{A\ S\ N}{600}$. (A = area, S = stroke in feet, N = number of revolutions per minute· 600 is the constant for 2-cycle and 400 for 4-cycle engines.) If they applied that formula to the engine before them they would find that it worked out at 4¼ B.H.P. As a matter of fact, that engine, when they tried it that morning, swung at 4 H.P. with only three minutes of testing, and they might have got it up a shade more. He remembered the time when he would have been glad to have had one or two such formulæ to enable him to get the B.H.P. of an engine.

Mr. BALES: Six hundred is the constant?

Mr. SUMNER: Yes; and 400 is the constant for 4-cycle engines. Those numbers are taken from a number of practical tests with the best style of engines that they could get hold of. Anyone in charge of that class of engines would be acting wisely if he took a note of that formula, so that he could work out the B.H.P. of any engines when he wanted to do so.

Mr. JAS. ADAMSON: It would be interesting to know where the 600 came from, and whether it has not been worked back from actual tests of well-known and established engine-makers.

Mr. SUMNER: There is one technical objection to that formula, in that it takes no account of the actual compression. The formula makes no allowance for that, but, so far as we can make out, it has hit on the maximum initial pressure. Making those deductions from an engine that was run at as high a pressure as possible, I have, with a $2\frac{1}{2}$-H.P. engine, worked out the H.P. by the use of that formula to within ·25 of the B.H.P.; that shows the formula is based on the B.H.P. We ran the pressure too high in some cases, and had to take it off. We had a long spigot on the cylinder cover, and machined it off until we got the best results.

Mr. BALES: If you take the I.H.P. you must take the quantity of compression into consideration.

Mr. SUMNER: It does not depend altogether on the compression. The power depends on having a perfect gas at variable compressions.

Mr. BALES: You would get a better compression with good than with bad gas.

Mr. SUMNER: You would get a far more effective compression. In this formula I take it to be the maximum power that the engine would develop at its best.

Mr. BALES: The constant is based on the assumption that a perfect gas is being used?

Mr. SUMNER: I cannot positively say, but am inclined to agree with Mr. Adamson that these constants have been worked out backwards from data supplied by manufacturers, evidently from a knowledge that a certain diameter of cylinder, length of stroke, and revolutions per minute equals so many H.P., and *pro rata*. No experienced engineer with a knowledge of internal combustion engines would have compiled a formula for H.P. simply upon cylinder dimensions and speed, entirely ignoring that essentially prime factor of power in this class of engines, viz., compression.

Mr. SUMNER then proceeded to explain how to obtain the compression of an engine, illustrating his remarks by means of a diagram on the blackboard. He also supplied the following formula for obtaining the compression:

$$\text{Compression} = \frac{TCV \times AP}{CS},$$

where TCV = total compression volume, AP = atmospheric volume, and CS = compression space. Continuing, he said that for 2-cycle engines 170 lb. was the maximum initial pressure, whilst for 4-cycle engines 300 to 400 lb. was the pressure.

Mr. HULME: I take it, there being a pressure generated in the crank-chamber when the piston closes the ports.

Mr. SUMNER: That is purely an atmospheric pressure at the moment the piston closes the exhaust port. The exhaust port is a little later in being closed than the admission port. It is a fair thing to assume atmospheric pressure at closing the exhaust.

Mr. A. H. MATHER (Hon. Financial Secretary): Referring to the trial the engine had undergone that morning, did the alteration of the position of the port make any difference in the brake power? Also, did they have an opportunity of testing the consumption of oil? There should be an increased economy if the power remained the same.

The CHAIRMAN: There should be the same power, and not so much oil used.

Mr. SUMNER: The engine would have to be run for a considerable time to get reliable cost results, and these he had not tested, but simply the power relative to the alteration mentioned.

Mr. DAVID GREER (Member) said it appeared to him that the machine was a very sensitive one. Why was it necessary to talk of the difference in the material of the pipes leading into it?

Mr. SUMNER: Because I stated that an iron pipe should not be used. That was the only reason. The size did not make much difference. We had a ¼-in. diameter for a 10-H.P. engine.

Mr. GREER: You say there is a needle valve. That is another highly sensitive part that is very objectionable in the working of the machine.

Mr. SUMNER: We are altering the valve now, and I will explain the style we are making at the present time.

Mr. GREER: Is it not an advantage to have only two strokes instead of four strokes?

Mr. SUMNER: In the 4-cycle engine we should have admission and exhaust valves. We should not have them in the 2-cycle type.

Mr. GREER: What do you gain? Is it more economy? What is the object in preferring the 2-cycle to the 4-cycle engine?

Mr. SUMNER: Suppose you are going to work the machine at 800 revolutions. For marine work you know that your propeller must have some chance of getting a cut at the water. The 4-cycle car engines will give twice the number of revolutions. Referring to the case of a trawler where the engines could not be delivered in time, there was some thought of putting in a well-known paraffin engine, the "Gardiner," which was one of the best on the market. That engine was to take a boat off the bank at Kingston, and which had to be floated at high tide; but it was still on the bank, because the owner had referred the matter to some consulting engineers in Dublin, and those gentlemen told him that the idea of an engine running at 800 revolutions per minute to develop 10 H.P. for a trawler was ridiculous. The "Gardiner" engine could not run at anything less to develop 10 H.P.

Mr. GREER: Is this 2-cycle engine any more economical than the other?

Mr. SUMNER: It is slightly more expensive.

Mr. GREER: You give rates of speed for the engine, but it is not absolutely necessary for the engine to act directly on the propeller.

Mr. SUMNER: It is not advisable to have a second drive. Some of those engines are to be fitted into trawlers for deep-sea work. The benefit is that they work out at somewhere about 60 per cent. of the 4-cycle engine of the same speed.

Mr. BALES: What is the life of an engine running at 800 revolutions as compared with one at 300 revolutions, in constant work? There may be economy in the long run, and that may answer Mr. Greer's question.

Mr. SUMNER: *Pro rata*, it would be 2½ times as long. In this engine you must have your piston absolutely tight in the cylinder, or you lose compression, and your power is dependent on compression. A loss of compression means a great loss of power. Assuming that the compression has a drop of 5 lb., which amount is easily lost, that would mean, approximately, a reduction of initial pressure of 20 lb. In a steam engine you can take up any of your guide wear-and-tear, but in this engine the cylinders have to take it up. In the 4-cycle engine the higher piston speed must occasion greater surface wear; with slower speed you get over that difficulty.

Mr. W. McLAREN said, that so far as he could learn, the 2-cycle engine was the one for marine engineers, and not the 4-cycle, because they had to so increase the fly-wheel momentum to carry them over the scavenging strokes in the latter type, whereas in the 2-cycle engine that was not necessary. That was how it appealed to his mind. They had an explosion or impulse every second stroke, instead of every fourth stroke.

Mr. GREER: What are the revolutions of this engine compared with the revolutions of the turbine engine? What is the difference in speed?

Mr. SUMNER: The revolutions of the turbine engine are far greater than with this engine.

Mr. GREER: You object to the revolutions of the 4-cycle engine, and yet the turbine engine goes much quicker than that.

Mr. BALES: You have no connecting-rods with the turbine engine.

Mr. SUMNER: You are quite right, the line of my contention being that a reciprocating internal combustion engine with a maximum piston speed of about 425 ft. per minute, such as I advise and manufacture, has obviously a far greater length of life than one of the car type, which may have a piston speed five times greater—in many instances 2,000 ft. per minute. The objection to the 2-cycle engine is the drawing of gas into the crank case. Unless this gas needle valve is set to admit the exact quantity of gas, the speed of the piston displacement will only vaporise a certain quantity of gas, and there will be a fall into the crank case, and that will make the admixture a richer gas and delay ignition in the cylinder. It fires and ignites in the crank case. That is the sole objection I have found with the 2-cycle type. The difficulty was in designing a vaporiser that will allow perfect control, so that you do not get too much gas.

Mr. GREER: That is the objection for marine purposes. When racing the engine will run away.

Mr. SUMNER: There is not the slightest difficulty with regard to the engine running away. It depends on the piston displacement. The valve is actuated by the speed of the engine.

Mr. GREER : It will vaporise all the quicker if the engine runs away ; the vaporisation of the gas will take place all the quicker. Is that not one of the reasons why there is less trouble with the carbonisation of the the gas with the 4-cycle engine than with the 2-cycle engine ?

Mr. W. McLAREN : Does the pressure in the crank chamber affect the lubrication ?

Mr. SUMNER : Not in any way.

Mr. W. McLaren : I understand it is splash lubrication ?

Mr. SUMNER : No. The crank case is arranged to allow for a recess round the sweep of the crank, and there is a tube which goes right through the bottom at such an angle that it sweeps into this recess, and there is only a small quantity of oil there. The oil is sprayed all over the crank case. Whatever oil is not carried away in the exhaust drops right into the crank case, and will find its way into the recess. The objection to splash lubrication is this : if there is too much oil the whirling of it causes it to splash when the piston comes down, and a little may get whirled into the cylinder, and it is liable to get between the two ignition points, so insulating them, and occasionally you would miss fire.

The CHAIRMAN : With regard to piston fit, I recently saw in an article by one of our gas-engine makers that it is necessary to leave the piston $\frac{1}{8}$ in. small to allow for expansion.

Mr. SUMNER : They are ground to a perfect fit before they are put into the cylinder. We never have any trouble on account of jamming.

(At this stage of the proceedings Mr. Sumner took the engine to pieces, and explained in detail the various parts.)

On the motion of Mr. W. McLAREN, seconded by

Mr. THOM, a very hearty vote of thanks was accorded Mr. Sumner for his paper and for the trouble he had taken in bringing down the engine.

A vote of thanks to the Chairman for presiding brought the meeting to a close.

Mr. O. SUMNER's further reply: With reference to the remarks as to the vitiation of gas by failure to clear out burnt products from cylinder after each explosion, and dealing further with this, my latest and recent experience entirely refutes the advantages claimed by Mr. Sanders for the "King" engine, in which provision is made for getting rid of a somewhat greater portion of the exhaust gases by providing an inlet valve in the cylinder heads. In parenthesis, I might observe that any valve opening into an explosive chamber is not reliable unless mechanically operated from the crank shaft; also the continual pressure of flame necessitates them being constantly ground in. On our latest engines we are using a very high compression—possibly the highest in the world—on this type of engine. So high is this compression that it is an impossibility to start the engine by hand without opening the communication to the small relief cylinder situated on the top of the cylinder cover, which arrangement we have just protected. When starting up, the gas passes into this relief chamber, and the actual compression volume is, maximum compression volume plus relief chamber volume. This enables even our largest engines to be as easily turned over the centre as our smaller ones. After starting under these low compression low power conditions, simply shutting off this relief chamber instantly gives maximum compression and consequent maximum power. The speed of the engine is then regulated by a throttle-valve controlling the gas.

Now to the point of contention. Speed may be reduced by opening to relief chamber, giving larger compression volume, and this makes not the slightest difference to the regular and accurate running of the engine, despite the fact that owing to the peculiar formation of this chamber—somewhat of an inverted bottle shape—it is an absolute impossibility for this relief chamber ever to free itself of its burnt gases so long as the engine is running. Imagine the air vessel of a feed pump, on a modified and correctly designed scale, to be on this cylinder cover, and the position will be understood.

After over a year's almost constant experiments on the vexed question of a vitiated gas, these have emphatically demonstrated that it is false economy to clear it out of the cylinder any more than what may free itself to atmospheric pressure at the exhaust. Hence it is obvious—especially when one sees these latest engines of ours running—that any "complete scavenging" devices have certainly, to use the hackneyed expression of "Reed's," a "novelty which exceeds their usefulness."

During this summer we shall run some extended consumption trials at sea under the recently improved conditions referred to, after which I will forward report of same to the Institute.