RECENT IMPROVEMENTS IN THE INTERNAL-COMBUSTION ENGINE.¹

III.

WE have now to consider the way in which the recent great practical improvements in the design and operation of gas engines and gas-producing plant have come about, and how they are connected with the theoretical considerations referred to in the previous articles.

Despite the multitudinous ways in which the internal-combustion engine is employed, there is a general assortment into three main groups, which may be described thus:—

(a) Large gas engines for gas blowing, for the generation of electric power or other power purposes, the size being usually more than 1000 horse-power.

(b) Smaller gas or oil engines used for workshop driving, in sizes up to about 500 horse-power.

(c) Petrol engines for road transport, for marine work, and for aeroplanes, the sizes being usually less than 100 horse-power.

With class (a) are associated pressure gas producers, frequently worked with by-product recovery plant, and schemes for the utilisation of the waste gases of coke ovens and blast furnaces. The gas engines in class (b) usually derive their gas from suction gas producers, which are practically always of smaller size than the 500-horse-power unit, though attempts are now being made to work with the larger units suitable to marine work. H.M.S. *Rattler* is one of the very first instances of the application of the suction gas producer to marine purposes, and it has been remarkably successful. Looming in the distance is the prospect of using suction gas producers and gas engines in smaller units for road transport, but the difficulty of finding space on the present type of motor-car for the whole of the plant is a great one. On the other hand, the considerable economy in fuel to which this development would lead is an inducement to proceed with the endeavour to overcome these difficulties.

By far the most numerous class of internal-combustion engine is that of class (c), which includes the thousands of motor-cars and cycles now in use in all civilised countries. The fuel used is not invariably petrol, as successful attempts have been made to run on alcohol, benzol, and the heavier elements in the paraffin series. Ordinary commercial paraffin has recently been used with extraordinary success, particularly in tropical countries, and it is even reported from Uganda that the combination there of altitude with high temperature enables paraffin to be used as a fuel in small engines without any change in the usual petrol carburettor as used in this country.

Improvements in Class (a).

The chief direct practical improvements in this class are the better proportioning of parts, so as to avoid cracking by unequal heating, and the better general design of the fly-wheel effect in conjunction with such an arrangement of cylinders as to produce a more even turning moment, and therefore less cyclic irregularity. The former is evidenced by the greater trustworthiness to-day of the big engine, and the latter is abundantly illustrated by the following extract from Messrs. Andrews and Porter's recent paper² before the Institution of Electrical Engineers:—

"The large gas engines at the Bruckhauser, Homecomb and Heinitz installations visited by English engineers in August last are all provided with fly-wheels to maintain a cyclic irregularity within 1/250. The two former are single tandem engines, and the latter twin tandem, but no appreciable difference in the parallel running was noticeable."

The information derived from recent experimental work on piston and wall-temperatures will probably lead to still further improvements in the mechanical design of details, as once the conditions of the heat flow are known a proper proportioning and subdivision of parts is rendered possible. The recent improved trustworthiness of operation is shared

equally by the two-cycle engines (such as the Oechelhauser, Koerting, and others) and the four-cycle engines, and it is very difficult to say that either type is gaining ground at the expense of the other. By-product recovery work is becoming better understood, although there is always the difficulty that the by-products, when produced, have to be sold, and one has therefore to take into account the effect upon the market price should a largely increased output result from the extended use of such plant. The utilisation in gas engines of the waste gases of coke ovens and blast furnaces is now very usual. This is especially so in Germany and Belgium, where a great deal of work has been done in this direction; in the United States there has been a rapid increase in the adoption of this process, whilst in this country matters have moved appreciably, although, owing to the low cost of fuel in England, there is not the same economic pressure to make the change. On Tyneside an excellent plan is in operation, whereby engines running on waste gases are made to generate electric power, which is then supplied to, and paid for by, the central electric generating station. By this method of pooling the current, which, of course, cannot be economically stored, but has to be used as fast as it is produced, the complicated questions as to its utilisation are avoided.

A notable recent improvement in the ignition of gas engines of all sizes is the adoption of the electric system with either low-tension or high-tension currents. On the whole it seems likely that, as with motor-cars, the latter will in the end become the most used, though at present the low-tension system with moving contacts inside the cylinder seems to be the most popular.

Improvements in Class (b).

In both this class and class (a) it is noticeable that the engines designed on the Continent are more complicated in appearance than those designed here. The British desire for simplicity doubtless is, at the root, a good one. One of its most noticeable illustrations in modern life is the steam railway locomotive. As applied to the gas engine, this desire takes effect in the much simpler method of governing. The usual English plan is to govern on the "hit-and-miss" principle, that is to say, when the engine runs up to too fast a speed the cylinder for one or more cycles will get no charge of gas at all, or else (which comes to the same thing) the ignition will be cut off and no explosion take place (this, though a very simple means of governing, is wasteful in fuel). The average Continental design provides for the throttling (as in a steam engine or by varying the lift of the inlet valves) of the entering charge, so as to cause a less intense explosion. This tends towards a steadier speed, but on the other hand leads to a constant lowering of the compression ratio, and therefore to a diminished thermal efficiency and an increased rate of fuel consumption.¹ In England the difficulty of speed fluctuation, to which the adoption of the hit-and-miss principle leads, is met by increased fly-wheel effect or by dividing the power between a number of cylinders, but several well-known English makers are now governing by throttling the mixture.

The standard of achieved thermal efficiency is continually rising, although the amount of the improvement is the less easy to state on account of the very optimistic way in which certain experimental readings seem to have been taken. Much depends upon the ratio of compression, and many attempts have been made to permit of a high compression pressure without pre-ignition. This has been successfully attempted in several ways, viz. by the method of water injection, so lowering the compression temperature corresponding to a given pressure, or else by the method of supercompression, which consists of causing the in-coming charge to be at a pressure of from 5 lb. to 10 lb. above the atmosphere, so that here also a higher pressure corresponds to a lower temperature, and sometimes by the method of decreasing the proportion of hydrogen present, and so raising the temperature at which the mixture would be liable to pre-ignition. In the usual form of suction producer, the proportion of hydrogen pre-

¹ Continued from p. 202.

² "The Use of Large Gas Engines for Generating Electric Power." Read before the Institution of Electrical Engineers, 1909.

sent is usually about 20 per cent., and a method of lowering the amount which has been employed recently is to admit exhaust gases into the producer in place of the usual water supply. The CO_2 then takes the place of H_2O as an energy absorber, and the chemical composition of the resulting gas is so greatly affected that the hydrogen sinks to less than 1 per cent. Another recent improvement in the suction gas producer is the regulation of the water admitted, so that the composition of the gas may be the same, no matter whether the "draw" of the engine is vigorous or slight. Without some such device the gas tends to become "wet" at the lower loads, and the producer to "go dead." To avoid this, the water supply to the producer has to be cut off, or greatly reduced, in proportion as the governor is cutting out working strokes in the engine.

Improvements in Class (c).

These are exceedingly numerous. The most recent decided change has been the adoption of the sleeve type of valve in the Daimler engine. Despite apparent drawbacks from the theoretical point of view, it has lately undergone an extremely severe test under the officials of the Royal Automobile Club, and has emerged victorious. It is understood that a number of other manufacturers are now considering the adoption of the slide type of valve.

Another innovation is the use of air pressure to force the fuel up from low-lying tanks to the carburettor. This is claimed to be an improvement on the exhaust pressure feed, as being less likely to choke. As regards heavy oil engines, the chief improvement to be noticed is the widespread use of water injection, which is even more useful here than in a gas engine on account of the very low pre-ignition point of mixtures of oil vapour and air.

Attempts have continually been made to produce an engine working on the two-cycle principle, and there would seem to be no reason why engines of this kind should not be as practically successful as any built to operate on the four-cycle principle. One would expect that in this way a lighter engine could be built, and lightness is a great asset, particularly in the most recent use to which the internal-combustion engine has been put, viz. *aéroplane* work. Wonderfully light engines have already been made for this purpose. The 50 horse-power engine on the *aéroplane Silver Dart* weighs only 220 lb. without oil and water, or 4.4 lb. per horse-power. The 50 horse-power "Wolseley" V-type eight-cylinder engine, built for *aéroplane* work, is reported to weigh only 340 lb., or 6.8 lb. per horse-power, although the engine is fitted with a water-cooling system. The somewhat similar 80 horse-power engine fitted to Mr. Moore Brabazon's *aéroplane* is reported to weigh only 366 lb., or 4.6 lb. per horse-power; this is also a water-cooled engine. The possibilities of the different types of engine have lately been summarised in the technical Press¹ as follows:—

Type of engine	Weight per brake horse- power lb.	Weight of 50-brake horse- power engine lb.
Four-cylinder vertical ...	8	400
Eight-,, diagonal ...	6	300
Diagonal, with several cylinders grouped on one crank pin	4	200
Rotary ...	3	150

From this it appears that engines amply light enough for *aéroplane* work have already been built, and there is not much scope left for any improvement in this direction for which the two-cycle engine would be useful, although there is still room for general improvement by the avoidance of the use in the engine parts of all heavy materials of low mechanical strength. On the other hand, the lighter the engine the better, as it means the possibility of adding additional accessories that make for constancy of operation, such as duplicate ignition, ample water-cooling arrangements, &c. The *aéroplane* appears to offer little chance of an "altitude stop" to permit of the engine being adjusted, and constancy of operation is therefore the one essential thing so far as the motor is concerned.

Carburettors are continually being improved, but the ideal one, which will give a constant mixture at all speeds

and all loads in all weather conditions, has yet to be invented. The high-water mark as regards fuel economy that has so far been reached is the performance of the White and Poppe carburettor in the 1907 Royal Automobile Club trials of commercial vehicles. This carburettor was fitted to a Maudslay car, and showed the very high "figure of merit" of 62 gross ton miles per gallon of petrol, which is nearly twice as good as was obtained from the average car of that time. In the last two years the average has, however, risen appreciably. This, with an assumed road resistance of 50 lb. per ton, would correspond to an efficiency of power transmission between the carburettor and the road wheels of no less than 15 per cent. What the road resistance really was is not known, but now, without doubt, such road resistances ought to be accurately measured and the results applied.

Conclusion.

With such a rapidly moving industry as that of the internal-combustion engine, prophesy is even more unsafe than it usually is. Writers have been bold enough to look forward to solid explosives being employed, but there one is faced with the difficulty of selecting any form of solid explosive that would have an entirely gaseous exhaust. When the gas turbine has taken practical shape, this consideration may be of less importance. Indeed, the combination of a solid explosive with a gas turbine promises this advantage, that the difficulty of the initial compression would thereby be removed. On the other hand, if we may judge by analogy with the steam turbine, provided that it were possible to keep the exhaust pressure sufficiently low, a high initial pressure would not be essential to economy. Whatever may be the outcome of the present experiments with gas turbines, or of gas producers, suitable for marine purposes on the one hand or to road transport on the other, one may be certain that the days of the external-combustion engine, the steam engine, are numbered, and that the engineers of the near future will not be satisfied with any less degree of efficiency than that which the internal-combustion engine will afford. One seems to see in the world of engineering the working of a continuous process leading to the supersession of those ideas, which, though old and tried friends, are found to produce less efficient results than those obtainable by more scientific methods. There is no reason that the writer can see to doubt the continued operation of this process during the present rivalry between the steam engine and the internal-combustion engine.

H. E. WIMPERIS.

OSMOTIC PHENOMENA AND THEIR MODERN PHYSICAL INTERPRETATION.¹

OSMOTIC pressure is a phenomenon of such importance in the theory of solutions, and in the interpretation of all vital processes, and so much valuable work has recently been directed to its elucidation, that, although it is a somewhat thorny and difficult subject, no apology is needed for any serious attempt, however inadequate, at its explanation.

One of the earliest recorded experiments on osmotic pressure is that of the Abbé Nollet, who found that a bladder containing alcohol, when immersed in water, absorbed water so greedily as in many cases to burst the bladder. The experiment illustrates in an imperfect manner the fundamental property of all animal and vegetable membranes of allowing some substances to pass through them by osmosis more easily than others. In many cases such membranes, while freely permeable to water, are practically impermeable to certain substances in solution, and play the part of sieves in directing and controlling diffusion. It will readily be understood that results of the greatest importance to biology have been obtained by studying this property of *semipermeability*, as it is called, but the application of natural membranes to the physical study of the subject is necessarily limited on account of the difficulty of obtaining sufficiently large and perfect membranes capable of withstanding any considerable pressure.

¹ Discourse delivered at the Royal Institution on Friday, February 26, by Prof. H. L. Callendar, F.R.S.

¹ *Engineering*, April 16.