CONVERTIBLE COMBUSTION ENGINES.

BY ALAN E. L. CHORLTON, *Member*, OF LINCOLN.

The advance in the use of the Internal-Combustion Engine for all duties becomes yearly more marked, and in the last decade, particularly the latter five years, it has been almost phenomenal, as exemplified by engines of the higher compression type, using fuel oil. In the United Kingdom, where it would seem coal must always be the basis fuel, the popularity of the oil-combustion engine must naturally be restricted, except for special duties and conditions called into being, perhaps by fashion, or the alarm caused by the interruption of the coal supply, due to artificial conditions, such as strikes. At the same time, the conveniences in the use of oil are so noteworthy that they are bound to claim serious consideration in almost all cases, even where coal is the basis fuel.

It is not the object of this Paper to advance the claims of either the gas- or the oil-engine, but rather to direct attention to the possibilities of a convertible engine designed to use advantageously both gas and oil. In surveying the problem in general, one might at first sight say that the combustion engine most ready to work on differing fuels would be of the self-ignition type, with a cycle approximating to that of constant pressure, in which the heat of
[THE I.MECH.E.]

compression is always sufficient to ignite the incoming fuel, whether solid, liquid, or gaseous, and the only change necessary in going from liquid to solid would be in the fuel-injection device. In practice, however, owing to the difficulty with solid fuel injection, such a type would not prove workable, and even when the fuel is first gasified the results do not justify the complication. Thus this type, whilst highly successful on oil, must suffer a radical conversion to use coal. The problem of designing an engine is better met, especially on the grounds of simplicity and suitability for everyday use, by trying to combine known types for gas and oil in which good results are obtained at the present, and which, in general principles, show the same characteristics.

Many of the types of engines in everyday use will therefore be considered, as well as other methods presenting advantageous possibilities. In the normal engines for both gas and oil, the chief difference lies in the degree of compression. Thus the compression of a modern gas-engine using coal as its basis fuel may vary from 90 lb. per square inch, when using coke-oven gas, to 150 lb. per square inch for producer-gas (and even higher if waste gases are used from blast-furnaces, etc.). Whilst for the liquid fuel engine, using crude or residual oils, the compression pressure may exceed 500 lb. per square inch, as in the case of a Diesel engine using tar-oil, but may be considerably less if the temperature of ignition is obtained by uncooled surfaces, or auxiliary or pocket firing used.

As there is no fundamental difference in engines for gaseous or liquid fuels, except in their conventional cycles, it follows that any schemes of convertibility must provide means whereby the requisite compressions can be readily obtained, but as between 500 and 150 lb. there is a great gap, the tendency is for practical reasons to combine the lower compression oil-engine and the higher compression gas-engine, and thus deal with a smaller compression pressure range. The problem is mainly a mechanical one, in and around this change of compression, and a combination from a judicious selection of well-known types which have proved successful with their various fuels. Though the convertibility may be affected somewhat by the cycle—that is, whether two or four—it may be taken generally that the

FIG. 1.—*Diagram of Ordinary Motor-Car Engine*
using various fuels.

SECTION THROUGH AA.

FIG. 2.

Diagram of Convertible Engine
for small powers,
using gas or liquid fuel.

degree of compression is the governing factor. The desirable characteristics of the convertible engine are:—Simplicity and reliability; economy should be high for each fuel; first cost as little as possible above that of the standard engine for each fuel; easy convertibility; as near as possible the same power developed for each fuel.

The consideration of the subject may be more clearly undertaken by dividing the types of engines in use into three groups, with further subdivisions, due to peculiarities of design:—

- (1) Engines of low compression and low power.
- (2) Engines of high compression and higher power.
- (3) Engines of medium compression and higher power.

Group 1.—As an example of the first group, we may take the ordinary motor-car engine, Fig. 1, having a compression up to 90 lb. per square inch, and which, with slight modifications, will run on:—

- (a) Petrol or benzole.
- (b) Good paraffin with an exhaust heated carburettor.
- (c) Town gas.
- (d) Producer-gas made from coal or waste combustible materials.

It is designed for and works best on petrol; fairly well, however, but not so economically, on town gas; it requires very good paraffin; and is not efficient at the low compression with producer-gas.

To go further and extend the range of fuels, to use a commoner paraffin or a good brand of crude oil, means must be provided whereby more heat is available for the ignition and combustion of the oil, and this can be conveniently done by the addition of an unjacketed portion to the cylinder end, when the engine becomes of the hot-bulb type. A change of parts for such an engine does not present any difficulties, and these can be readily made to give with any adjustments of compression necessary for the producer-gas with the greater heat required for ignition and combustion of the oil. The gas fittings are provided with electric ignition, also suitable when petrol is used, whilst the paraffin and good crude oil would be self-ignited by the hot bulb, Fig. 2 illustrates the practical

application of these modifications. The engine illustrated was lately built with success to work on all usually available fuels, for small powers, and such a type can be changed by unskilled labour (maybe a farm hand) from a gas-engine working with a wood or coal producer, to an oil-engine using a good brand of Russian crude oil, the governor requiring no adjustment for the full range of fuels.

A comparative commercial Table of the results obtained with this engine, is :—

—	Compression.	Max. Pressure.	M.E.P.	B.Th.U. per b.h.p. hour.
Paraffin oil .	55	210	58	14,500
Producer-gas	90	230	65	12,000

Fig. 2 shows the gas- or petrol-engine with electric ignition, also the oil-engine, a hot-bulb being added in the latter case and ignition obtained thereby.

This type of engine is not suitable for any but comparatively low powers, and the range of fuels does not include one heavier than good crude oil. Further, its economy on oil is not high. It is mainly described here as it contains the basic principles of a more suitable engine for large powers. Further modifications must therefore be made, in order that the fuels of poorer quality may be used, and this for any range of power. These conditions demand an engine having a considerably higher compression for the fuel and residue oils, and in the second group we have engines with high compression and higher power.

Group 2.—This group is represented by the Diesel engine, with a compression of over 500 lb. per square inch, when using tar-oils (unless an ignition oil is used). As the maximum compression for gas (in the normally used type of engine) does not exceed 150 lb. per square inch, it will be readily seen that there are considerable mechanical difficulties in building an engine in which both of these compressions can be obtained, with a reasonable amount of modification. Further, the Diesel engine has an expensive

high-pressure air-pump, which is unnecessary for the ordinary type of gas-engine.

Apart from the mechanical difficulties, the commercial possibilities of this type may be compared, the oil and gas sides being as follows for engines of the same cylinder dimensions :—

—	Compression.	Abnormal Max. Pressure.	M.E.P.	Approx. B.Th.U. per b.h.p. hour.
Oil-Engine	500	Over 1,000	100–110 lb.	8,000
Gas-Engine	150	600	80 lb.	8,500

These figures show how incompatible the two designs are, for they illustrate that the Diesel structure must be built twice as strongly for the very high maximum possible pressure, due to the fuel-valve sticking, etc. The higher M.E.P. used is some compensation for this extra cost and weight. The mean cylinder pressures reveal a still further disadvantage when the gas conversion is considered, for there is, besides this high first cost, a reduced power, owing to working at a lower M.E.P.—80 as against 100–110 lb. per square inch. A convertible engine on these lines does not seem a commercial possibility. The cost of the air-compressing part of the Diesel has not been considered, nor has the working of the gas-engine on the Diesel cycle, for this alternative, at any rate at the present date, is not a commercial proposition. (The net efficiency may be actually lower, due to the loss in the gas compression; and the risks of working greater.) Although it is of the utmost necessity that any lasting type of prime mover must have in these days as its essential feature economy in fuel, it is still not the only point, for reliability and simplicity must be equally considered. Whilst, therefore, recognizing the economy of the high compression self-ignition engine, we are compelled to look to one of the other types described as a more suitable combination for everyday use.

Group 3.—This group comprises engines with a moderate compression suitable for developing higher powers. The range of

the compression of these engines lies in between that of Groups 1 and 2, and usually is from 150 to 300 lb. The compression of 150 lb. is suitable for most forms of producer-gas, but it is not usually exceeded, for the reason that pre-ignition of the compressed charge is more prevalent in very high compression gas-engines. On the other hand, it is necessary for all compressions below self-ignition compression, as in the Diesel, to employ some auxiliary means to obtain the necessary height of temperature for the proper combustion of the residue oil. Normally, as in the second engine, Fig. 2 (page 157), the additional heat is obtained by an unjacketed surface or combustion bulb at the cylinder end. This temperature-raising device is employed, with other agents, to give the best effects, on the score of economy; for the lower compression, such as 150 lb., a satisfactorily running oil-engine is obtained; the economy, however, is not quite so high and the range of fuel not so fully extended.

The various devices employed in and around the question of temperature, compression, and convertibility of this group of engine, may be considered by subdividing it under the following heads:—

- (a) Engines working with a compression not exceeding 150 lb. both for oil and gas, and which may employ pocket-firing with or without air-injection for one, and electrical ignition for the other, or some combination, the smaller compression not involving material mechanical change of the parts.
- (b) Engines working with a higher compression for oil than gas, involving some modification of the combustion chamber by substitution of a part for oil as against a part for gas; otherwise maintaining the simplicity of both types.
- (c) Engines obtaining the necessary change from gas to oil by temperature control of the air charge, together with alteration of the valve settings.
- (d) Engines employing the super-compression of Dr. Dugald Clerk, to control effectively thereby the compression required for either fuel. (Final ignition temperature by other means.)

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Under subdivision (a) there is a large number of engines which are used only for oil, but which might, without material alteration, become effective in the use of gas, although the whole combination is not as efficient as the highest individual member. As an instance of this division, there is the two-cycle Bolinder engine, at present only used for oil, although originally used by Day for gas, Fig. 3. When made with a stepped-piston, as in Fig. 4, with uncooled cylinder-head substituted by a water-cooled one, a gas-engine for small powers is more or less effectively obtained.

Sketches of two-cycle Engines.

FIG. 3.—Vertical Type (Bolinder).
Arranged for Oil.

FIG. 4.

Horizontal Type. Arranged for Gas.
With Stepped-Piston and water-cooled Cyl.-head.

For larger powers it is usual to separate the air and gas in the pump, and the engine becomes therefore not quite so simple a proposition to change over from the use of oil to the use of gas. In the four-cycle engine, the change from oil to gas involves a removal of the unjacketed part of the combustion head for that of a gas type, with electrical ignition.

A variation of this type, employing air-injection for the fuel, combined with pocket-firing for the ignition of the charge, secures

considerable economy when used with oil. The advantage, however, in using more or less the same compression for both oil and gas is lost through the need of a high-pressure air-compressor (as with the Diesel) and the employment of double-injection needles. For higher powers and the best economies, it is necessary to go considerably further, for, unless the economy upon oil is approximate to that of the Diesel engine, the convertible type will not become of any real lasting value.

FIG. 5.—*Engine Indicator Diagrams. (Traced from Cards.)*

In considering the next division, namely (*b*), a useful comparison of its possibilities is given in tabular form, for engines of the same cylinder dimensions:—

—	Compression.	Abnormal Max. Pressure.	M.E.P.	B.Th.U. per b.h.p. hour.
Oil-Engine	250/280	600	80	8,100
Gas-Engine	150	600	80	8,500

It will be seen from this that the outputs and general figures relative to the engine bear a great similarity. Further, as in Fig. 5, the diagrams actually taken when running on oil and gas are also shown to be of very similar nature. The possibilities, therefore, of this type of convertible engine appear, from these indications, to be very great; and an engine which has at present been made in considerable numbers to fulfil these conditions is shown in Figs. 6 to 8 (Messrs. Ruston, Proctor and Co., Ltd.). These show clearly that in both cases the engine presents the ordinary features of the four-cycle engine, and the only change

FIG. 6.—*Diagram of Cylinder,
Flywheel, etc., of Convertible
Engine.*

Fig. 7.—When using Oil.

Fig. 8.—When using Gas.

FIG. 7.
Arranged for Oil.

FIG. 8.
Arranged for Gas.

involved in converting from oil to gas lies around the combustion bulb of the oil-engine, in which the fuel-oil is injected, and in the change from an oil-type to a gas-type piston.

Fig. 7 indicates the arrangement of parts when running on oil, and Fig. 8 when running on gas. As the essential feature of the convertible engine (as has been pointed out) is that it must maintain the economy when on either fuel, the curve is given in Fig. 9 showing the consumption of this type of engine when running on Russian crude oil. On gas, where it is seen that the engine resembles the well-known four-cycle type, the consumption figures

FIG. 9.—Consumption Curve of 130 B.H.P. Engine (Fig. 6).
Fuel—Russian Crude Oil.

are in parallel with those which have been taken on various occasions by different experimenters.

Group (c).—The use of the arrangements grouped in this division may be said to be one of mechanical and constructional convenience, for they can hardly be defended on the score of efficiency. In one method the jacket of the cylinder-cover or breech-end is formed to withstand a pressure, and is worked in the manner of a boiler. The increased heat is impressed in the charge of air during the compression stroke to raise the temperature sufficiently to afford ignition. This arrangement thus replaces the hot-bulb or unjacketed end of the cylinder. It has some advantages, in that it is perhaps

more controllable and the steam generated may be used for some useful purpose, perhaps in conjunction with an exhaust-heated boiler for an auxiliary steam-cylinder on the main engine. The water injection of some hot-bulb engines is also done away with. This type of engine is unusual in practice. When in use as a gas-engine, such a convertible engine would have to dispense with the pressure-jacket temperature when using the lower compression and temperature needed for such an engine. Actual heating of the inlet air may be a practical convenience for dealing with a

Fig. 10.—Valve-Setting. Compression Curves for Oil and Gas.

particularly refractory oil not amenable to the available compression of the engine. The valve-setting of an engine may be modified, as in Fig. 10, to give suitable compressions for oil and gas; this can be worked in conjunction with the temperature arrangement just described. The gas-engine suffers in loss of output, as is shown in the diagram.

Group (d).—The Clerk super-compression engine is a much more suitable and promising type for dealing with the variable compression problem of the convertible engine. In this engine,

FIG. 11.—*Diagram of Super-Compression Engine. (Clerk.)*

(Continued below.)

(Continued from above.)

the principle of which is probably well known (an actual engine built some years ago being shown in Fig. 11), an extra charge of air or inert gas is added to the working mixture at the end of the suction-stroke. By this means, owing to the, so to speak, "watering" of the charge, much lower maximum flame temperatures are obtained and a higher mean cylinder-pressure rendered possible. For the purpose of the convertible engine, it is mainly suitable, as by varying this amount of added air the compression can be adjusted between wide limits, the final temperature being controlled by any of the previously indicated means. For instance, with a compression of 300 lb. maximum, the full displacement of the air-pump may be used; for the lower compression of the gas-engine one can, by any

FIG. 12.—Indicator Diagram. *Super-Compression Engine.* (Clerk.)

suitable valvular means, as an ordinary by-pass, reduce the amount of discharge as required.

The commercial value of this type has hardly been determined in practice, but it would almost appear that its possible usefulness will only come in for large engines, for after all it is an addition, if not a complication, to the ordinary engine of everyday use. The diagram of such an engine, from one of Dr. Clerk's Papers, is given in Fig. 12. The engine really uses a two-stage compression, but not expansion.

The conclusion the author arrives at is that, for powers up to say 1,000 b.h.p., the type of engine represented by the "Ruston," Class B, Fig. 13, is the most suitable as a convertible engine, whilst for still larger powers, when tandem engines and size and weight

of removable parts become a problem, the Clerk super-compression type offers very interesting and hopeful possibilities.

FIG. 13.—*Diagram of 4-cyl. 520 B.H.P. Oil Engine. (Ruston.)*
Elevation.

Plan.

The Paper is illustrated by 13 Figs. in the letterpress.

Discussion in London.

The PRESIDENT, in proposing a cordial vote of thanks to the author, said the Paper dealt with a subject which was a novel one to most of the members, but which looked as if it had not an inconsiderable importance from the commercial point of view. The Paper was of very great interest, and he hoped it would evoke a good discussion.

The Resolution of Thanks was carried by acclamation.

The PRESIDENT stated that it had been hoped that Dr. Dugald Clerk would have opened the discussion, but a telegram had been received from him saying that he was very sorry that he had been prevented from attending the Meeting.

Mr. W. A. TOOKEY, in opening the discussion, said that although the author had demonstrated what might be called the constructional practicability of a convertible combustion engine, he had not dealt, to the extent that one would have wished, with the question of whether such an engine would be practically possible, and still less had he dealt with its commercial value. It might be a more or less easy matter to make a convertible combustion engine, but the point that always had to be kept in view was the position it would take in the engineering world. Naturally, when two fuels, oil and coal, were being dealt with, the question of the gas-producer was interposed. In the relative figures given in the Table (page 163), the author had taken the thermal efficiency of the oil-engine as 8,100 B.Th.U. per b.h.p. hour and of the gas-engine as 8,500. Town gas, however, would rarely be used for an engine of any considerable size, and an engineer would hardly think it worth while commercially to convert a small engine from one fuel to the other. Therefore, as he had previously said, the producer must be interposed; and although proof had been obtained that

the gas-producer would give fuel-to-gas efficiencies of 80 per cent., yet in order to cover the leakages or waste due to sifting of the fuel, standby losses, and things of that kind, he thought, from a commercial rather than a technical standpoint, it would be much more correct to take the efficiency of the producer for that purpose as being of the order of 75 per cent. On that assumption, the figure of relative thermal efficiency would be 8,100 for oil and 11,300 for coal, in B.Th.U. per b.h.p. hour.

It was advisable, he thought, to gain some idea as to the relative value in an engine of a ton of either fuel, for when a note had been obtained as to the relative costs, it would then be possible to form an idea as to the probable commercial value of a convertible engine. It would be possible by such means to ascertain whether any saving resulting would cover the actual cost of the conversion. After all, it depended upon whether an engine was being converted from gas to oil or from oil to gas. It might be taken that petroleum gave roughly 18,000 B.Th.U. per lb., whereas good anthracite coal gave about 14,000 B.Th.U. per lb., so that a ton of oil would give 40,000,000 B.Th.U. and a ton of coal 31,000,000 B.Th.U. Those were very big figures, but they meant that when the toll of the producer was taken into account, oil had a greater advantage on the ton basis to the extent of a ratio, expressed by oil divided by gas, of 0.716. That was a useful figure to keep in one's mind, because it gave a basis for considering the commercial possibilities. Taking the size of engine which the author had referred to as 130 rated b.h.p., and presuming the engine would run normally at a mean load of about 100 b.h.p., it meant that, working for 3,000 hours in the year at 100 h.p., about 60 tons of oil or 108 tons of coal would be burned. Those values would be equal, on the basis he had suggested, if oil were obtainable at 42s. a ton and coal at 30s. a ton. Those were roughly the relative market prices they could afford to pay for equal operating costs for fuel only. There must therefore be a very considerable variation, either in the cost of oil or in the cost of coal, before they could afford to pay the amount that would be involved in converting an engine from one type to the

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other. The author had stated that a new piston would have to be used, and those who had had practical experience with gas-engines knew it was sometimes not a wise thing lightly to undertake to change the piston of an engine after it had been working for some time, especially when it meant that the piston would have to be either longer or shorter, and therefore bring the wear on a different part of the cylinder. That was quite a practical point which must be borne in mind, although for the moment he was only dealing with the question of the commercial value. Supposing that 80s. per ton of oil and 30s. per ton of anthracite were taken, it would be found that, on the basis he had given, provided that everything went well and that there was no hitch, a saving would be obtained in one year of £77. Out of that saving a deduction would have to be allowed for the cost of conversion, which, with a new piston and other gear, labour, etc., for an engine of the size mentioned in the Paper, might possibly amount to about £50 or £60. By the time that amount had been saved, it was possible that the 80s. per ton for the oil might have been brought down to a little less, or the coal figure might have varied in the same way. He would like to know whether the author had dealt with the matter on the basis he had suggested. Personally, he quite accepted the fact that it was constructionally practicable, but was it likely to be commercially valuable; in other words, whom would it pay? Which class of user had the author particularly in mind when he put forward the idea of a convertible combustion engine?

He desired, in conclusion, to mention one point arising from the reference to Dr. Clerk's super-compression engine. He knew very little about this particular engine, but, apart from super-compression, had the author considered the utilization of a certain proportion of the exhaust gases escaping from the engine cylinder and introduced with the new admission charge, such as was done by the engines provided by one well-known firm for working with coke-oven gas which had a high calorific value with a high percentage of hydrogen, and therefore presented a great similarity to the oil mixtures which were used in a high compression or a "semi-Diesel"

oil engine? The added exhaust-gases had a very useful effect in decreasing the rapidity of ignition of otherwise highly inflammable gas-mixtures, and thus might be of equal service for convertible combustion engines, such as were described in the Paper.

M. R. MATHOT in the first place desired to apologize for his small knowledge of English, but he was more proud of the little English he knew than if he had a first-class knowledge of the German language. He desired to ask for a further explanation of the Table on page 159. He noticed that in the second line of the Table the B.Th.U. for a producer-gas engine were given as 12,000 per hour. If he understood that correctly, it meant a thermal efficiency of 20 per cent. Did that relate to the gas or to the coal itself, because if it related to the gas it was rather a low figure, and it was not a great encouragement, in following the scheme proposed by the author, to converting an oil engine into a producer-gas engine?

He wished to know, from the author's personal experience of the semi-Diesel engine of the two-cycle type, how he proposed to deal with the conversion of such an engine from liquid fuel to producer-gas or town gas, and whether it did not involve the replacement not only of the piston but of the breech-end and certain other parts. He also desired to know to what extent of power the author thought the convertibility of the engine from oil to gas, or from gas to oil, was practicable, presuming that the constructional proposition was a commercial one. From the information he had been able to derive from the Paper, it seemed to him it must be confined more or less to small engines not above 10 or 20 h.p.

Mr. F. H. LIVEYS thought the Paper should be looked upon rather as suggestive of what might be future developments, although it also correctly described what had already been done. It was really an outline to be filled in by those who had that kind of work to carry out. If half a dozen people who were not accustomed to the design and manufacture of engines were asked whether it was possible to convert a gas-engine into an oil-engine, or vice versa, he had no doubt whatever that five out of six would at once say it was

(Mr. F. H. Livens.)

quite possible; he thought probably all the six would. He was also quite sure that if half a dozen people who had had long experience in the construction of oil and gas engines, and knew the difficulties connected with them, were asked a similar question, a different reply would be received, particularly if they were asked whether it was possible to change an engine having a compression of 120 lb. when using gas into a serviceable crude-oil machine having a compression of 280 lb. The problem was thus shown to be open to a good deal of discussion.

He thought it would be of interest to the members if he told them how the engine shown on page 164 came to be designed. It was not a fact that, in the first instance, the idea was to supply to any user an engine which he could convert from gas to oil, or vice versa, just as he pleased. The particular design shown in Figs. 7 and 8 came about through the requirements of the oil-fields. Those who were acquainted with the oil-fields knew that the bore-holes were put down at very small distances from each other, and that sometimes a great deal of gas came up with the oil. On the other hand, sometimes there was very little gas. But if gas were available it was used, because otherwise it went to waste, and oil during the last year had become very valuable. A few years ago nothing but steam was used upon the oil-fields. Where gas existed, it was burned under the boilers; where there was no gas, or of not sufficient quantity, then crude oil was so burned; that system was now to a large extent being superseded.

It happened also in oil-fields that were only a few miles apart that one would have a rich gas in plenty, and another would have hardly any. If the gas could be piped, and brought where new bores were being put down, it was naturally very convenient to have an engine which could use the gas. If, on the other hand, gas was not present, it was much more convenient to bring oil by a small pipe-line to the place required and use oil. Supposing a bore were complete, and both gas and oil were available, then it was most economical to use gas and sell the oil. It might, however, happen, and did happen, that the gas "petered out," and then the user must fall back upon oil. That was the origin of this particular design some

four years ago when the question was brought to his attention, after investigation and a visit to the countries concerned. It was a fact, therefore, that a good heavy-oil engine could be constructed which could also be made to use gas advantageously. Speaking as a manufacturer who sent such machines into many countries of the world, the term "gas" meant many qualities, and had a wide application. There was, first, the gas obtained from a producer, say a poor gas with perhaps 160 B.Th.U. per cubic foot; secondly, a town gas which contained perhaps 650 B.Th.U. per cubic foot; and, thirdly, there might be, as existed on the oil-fields, a natural gas which contained up to 1,050 or 1,060 B.Th.U. per cubic foot. So that for commercial purposes, for the convenience of the user, it was useful for the manufacturer to be able to supply a machine which would meet all needs, whatever they might be. M. Mathot was perfectly correct when he stated that the ordinary low-compression engine could not be converted with any great advantage, except for small powers.

He had not quite followed Mr. Tookey in his argument as to the difference in economy. A producer-gas engine would work very successfully with about a pound of coke per b.h.p. hour, a crude-oil engine of the type to which he was referring would work with a consumption of about half a pound of oil per b.h.p. hour, so that the fuel cost when using coke, presuming oil to be 70s. per ton, was just about half. He desired to give an instance in which it might be convenient for the user to change his engine. Supposing, for good reason, a manufacturer put down an oil-engine, and then, as conditions altered, he wished to use gas, and put down a producer, by so doing he would save half his fuel cost. The other point which had been mentioned was that, where small engines were supplied, it was a great convenience to be able to change from one fuel to the other without sending the engine back to the manufacturer's shop, and if the agent could stock the engine and parts, the change could easily be made.

As he had already said, the Paper dealt with possible developments in a very large trade not confined to this country, and in criticizing the Paper, and in following out the lines of

(Mr. F. H. Livens.)

thought, it should be considered from the point of view that engineers had to make such engines to fulfil many conditions and to send them to many parts of the world. Therefore, whilst he was free to admit that, if it was desired to make the most perfect oil-engine or the most perfect gas-engine for a particular gas, more modifications would be required in the design than were apparent in the Paper, he contended that for a great many purposes the engines described in the Paper were practicable. It would be appreciated at once that, where natural gas was being used, a slightly greater consumption was of no particular moment, and the same remark applied where a poor gas like a producer-gas was being employed. Therefore, in the first instance, the engine should be designed perfectly to use crude oil, and then the changes be made in the most economical manner in order that it might use gas.

Mr. E. W. PETER said that there were one or two questions he would like to ask. As an ardent disciple and firm believer in the two-cycle type of engine, he was most interested in Figs. 3 and 4 (page 162), and he was sorry the author had dismissed that type of engine with so few remarks, as many of the members would have been very interested if particulars had been given of the results the author had obtained, assuming he had actually made experiments on the designs shown in the Paper. He was not sure, from looking at the figures, whether the engine had actually been made, and he would like to know if that was the case or not. It would also be of interest if the author would say what he meant by the statement, "A gas-engine for small powers is more or less effectively obtained." What did he mean by "small powers"?

Mr. Livens had dealt with a point which was very much in his mind, namely, that a much greater alteration to the engine than was shown in the diagram was evidently necessary to make it work with gas. All manufacturers of oil-engines quite understood the object of the Paper, as explained so clearly by Mr. Livens. They were frequently asked, for special conditions, to provide engines which would work and change over from gas to oil, and apart from

any question of whether they were applicable to domestic or farm use at home, there was no doubt that an engine which really gave approximately the same results with both fuels had a great field before it. If the practical difficulties could be overcome, he thought the two-cycle type of engine lent itself very much to the change over, because the compressions, as stated in the Paper, were approximately, or even exactly, the same.

Referring to Figs. 7 and 8 (page 164), he noticed from the Table on page 163 that the compression in the gas-engine was reduced from 250/280 to 150 lb. per square inch. He could not see from the illustrations how a reduction occurred; it appeared to him there was an increase in the compression, and he would therefore be glad if the author would be kind enough to explain the point further.

Mr. E. M. GIBSON said he represented a different class of user from those who had previously taken part in the discussion. In the works of his firm in Russia two 400-b.h.p. Körting type of gas-engines, made by Messrs. Mather and Platt, Manchester, which were really the author's children, had been installed. In the previous year, owing to the War, the export of coal from England to Russia was first of all curtailed and then stopped altogether, and a considerable portion of his firm's coal that was lying at Kronstadt was commandeered by the Government. Owing to trouble in Scotland, they could not get their usual brand of Scotch coal for producers, and as a result had to use wood in the boiler-house, eking out the remaining stock of producer-gas coal with ordinary coal. He was glad to say that had proved successful, but if the War went on for another six months he did not know what they would do to keep their gas-engines running. If the author could assure him that he had some practical means for converting these gas-engines to oil-engines, he would be very pleased to give him a provisional order on the spot.

Mr. HORACE BOOT said that Mr. Livens had answered most of the questions he had intended to ask. Users of oil and gas engines

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(Mr. Horace Boot.)

naturally wanted to know what the reliability would be if a change over were made. It would be an advantage to manufacturers if they could stock one type of engine, and, by a few changes, make an oil-engine suitable for a gas-engine or vice versa, because it ought to have the effect of reducing the prices of both types of engine. He had had some experience of the running of the particular oil-engines mentioned, as he had placed some of them on a rubber plantation. Those engines had been running with considerable success without any skilled attention whatever, as the natives had looked after them.

With reference to Fig. 9 (page 165), he did not quite understand why the particular engine referred to was apparently much more efficient in its consumption at about 105 b.h.p. when it was built for 130 h.p. He was aware that in all types of gas and oil engines it was always advantageous to run them at slightly less than their full load if reliability was to be obtained, but there was a considerable difference in consumption in the engine described in Fig. 9, which was not noticed to such a large extent in the particular engines that were built to his own specification. He was of the opinion that the consumption of oil per lb. per b.h.p. was slightly more than that given in Fig. 9, but probably, since his engines were ordered and sent out, the type of engine had been improved upon. He was able to say, however, that so far as oil-engines of the design shown were concerned, they worked satisfactorily, and had given no trouble during the years they had been in use.

Mr. WILLIAM H. PATCHELL (Member of Council) asked the author, in replying to the discussion, to state what he meant by the words "low power" and "higher power" that were used on page 158; in other words, what was the classification adopted, because as these terms stood in the Paper they were a little difficult to understand? The author in reading the Paper had apologized for its being so very short. In the present busy and strenuous times most people liked things in tabloid form, but it was necessary to see that the label was clear. He also desired to draw

attention to the statement just made in amplification of the Paper by the author's colleague, Mr. Livens, that if a manufacturer wanted to save money he should first of all buy an oil-engine and later on convert it to a gas-engine. But could he save money in that way? He might save money on his fuel, but he would not get the oil-engine for the price at which an equivalent gas-engine was sold, unless a very different price list existed from what he had often seen. It must always be remembered that the cost of the fuel alone did not regulate the cost of the power. The suggestion reminded him of what they heard some years ago, and had heard again during the past year in London: "If you will only trust me, I will give you electricity at a halfpenny a unit"; but the vendor did not stop and tell people what were their commitments before they would get the electricity at a halfpenny a unit! The capital costs were highly important, and he thought the purchaser would probably have been considerably out of pocket if he had included his capital charges in the cost per b.h.p. hour.

Previous speakers had referred to the thermal efficiencies given in the Paper, and he thought it would be useful if the author would make it a little clearer as to whether they were based on gas or on coal. Some of the largest and best gas-engines that had ever been installed in England ran on about 10,000 B.Th.U. per kw. hour, which, with a good efficiency on an alternator, was about 8,000 to 8,500 B.Th.U. per b.h.p. hour. But that was based on the gas alone, and not on the thermal value of the coal; in many cases the efficiency of a producer entered into the question and was a very important feature, as mentioned by Mr. Tookey. If the author had time to amplify these points in his valuable Paper, he thought it would be still more useful.

M. R. MATHOT asked the author whether, in his experience, it was simpler to convert a gas-engine into an oil-engine than an oil-engine into a gas-engine, and what possibilities there were for those two kinds of conversion. He supposed that both methods of conversion could be carried out, but he would like to know which of the two was the more economical. For instance, shoes could

(M. R. Mathot.)

always be converted into slippers, but it was difficult to convert slippers into shoes.

Mr. MICHAEL LONGRIDGE (Vice-President) said when he first read the Paper he was inclined to wonder where the market for the convertible engines described would be, and to think that conversion must simply be a device for manufacturing gas and oil engines in the same works at the cheapest cost, making one lot of patterns do for both types of engine. Mr. Livens, however, had explained that there was a market for these engines in the oil-fields; and on thinking the matter over further, it struck him that there might also be a market for small engines in out-of-the-way country places. In such places it was not always possible to get supplies just when they were required, and it might be convenient to have small engines which would work ordinarily with gas, and, if they ran out of gas, with oil, and vice versa. Again, where periods of variable and light load occurred at times, and a gas-producer was difficult to work, it might be useful to turn for the time to oil. But where small engines were used, they were generally run by attendants who knew very little about them, and could hardly be trusted to take out and replace a piston. Was it not possible to devise some means of altering the clearance volume on which the conversion depended, without taking out the piston? In the gas-engine the questions of the scavenging and pre-ignition had to be kept in mind in designing the breech end. There were not the same difficulties with the oil-engine. He would like to know if any experiments had been made with a view to reducing the clearance of the gas-engine by putting the hot chamber shown on Fig. 7 (page 164) inside the breech end, or to increasing the clearance of the oil-engine by adding a small chamber at the back of the breech end.

Captain H. RIAL SANKEY (Member of Council), in referring to the illustration M. Mathot had given of slippers and boots, said he would like to ask the author whether in engines of the same power the scantlings of an oil-engine (those of the crank-shaft, for instance) would not have to be greater than for a gas-engine. If that was

the case, then the oil-engine would be represented by the pair of boots and would have to be cut down to slippers to make a gas-engine, and vice versa it would be impossible to make the gas-engine into an equal powered oil-engine. That point was, he thought, well brought out in the Table (page 160), where it was stated that for an engine of the Diesel type the abnormal maximum pressure was over 1,000 lb. He thought if the author had said 1,500 or 1,700 lb. he would have been nearer the mark. It was obvious in that case that the scantlings of the Diesel engine had to be far greater for the same power than for the gas-engine, which explained the reason why such enormous crank-shafts and bolts to hold down the cylinder-covers were used in the Diesel engine.

He also desired to ask the author whether he had considered the question of altering the compression by altering the point at which the exhaust closed. Obviously, if the exhaust were closed less quickly, less compression would be obtained, which would do for the gas-engine; and by closing the exhaust at the beginning of the back stroke there would be a greater compression, which would do for the oil-engine. He knew that engines of that type had been proposed, but he did not know whether any had actually been brought into practical operation.

Mr. A. E. L. CHORLTON, in reply, desired in the first instance to thank the members for the kind reception they had given to the Paper. Mr. Tookey, who opened the discussion, dealt mainly with the Table on page 163, which had also been referred to by subsequent speakers, and had referred to the comparison of consumption figures in B.Th.U. between the oil-engine and the gas-engine. He inquired whether the figures in the case of the gas included the producer. They did not, and that was almost obvious from the figures in the Table. If they had included the producer they would have been the figures that Mr. Tookey gave. Mr. Tookey really answered his own query, because he went on to show that when the figures were reduced to a commercial comparison—the cost of the coal against the cost of the oil—it more than allowed for any loss due to the producer itself.

(Mr. A. E. L. Chorlton.)

Mr. Tookey then dealt with the possible uses of a convertible engine, and asked whether it would be worth while to make such an engine: would it pay for the extra cost of changing from one type to the other? For an answer to that question he desired to refer to the remarks Mr. Livens had made, who dealt with the subject very fully, and he had further explained that the Paper was really only a suggestion and did not discuss the whole situation with the various possible ways of conversion. He (the author) had not actually said so, but that was what it really amounted to. It had not been possible for him in the time he had at his disposal to go into the subject in as much detail as he could have wished, but it occurred to him that if he went part of the way, and set the ball rolling, other people would probably be able to carry it further. The Paper showed that a conversion could be readily done, and it was left to other people to make further suggestions of different ways of carrying it out. Mr. Livens had given particulars of an engine that had been constructed and the very good work it had done, and it was impossible for him to add to what Mr. Livens had said in that respect.

Mr. Tookey had referred to the question of town gas which was mentioned in the Paper. Members were probably aware that, during the last two or three years, the use of town gas for large power stations had been very seriously considered—not town gas as was understood by the ordinary buyer, but as understood by the large station engineer. Town gas when made in continuous vertical retorts could be put into the holder at a cost of about 4*d.* per 1,000 cubic feet, and at such a figure it became almost a better proposition to use town gas than to use producer-gas. It was an interesting fact that anything below 6*d.* per 1,000 cubic feet was, he believed, cheaper than the lowest steam-turbine figure. If an engine that could use town gas could be readily changed over to use crude oil, not necessarily in the way shown in the Paper, then obviously it was greatly to the convenience of the station. An engineer might have a battery of engines which were exactly alike, except that he decided to run one or two of them with crude oil and the rest on town gas, and he fitted them in

either way according to the market price of the fuel or according to the load on the station.

Mr. Tookey next asked him a question about the use of the exhaust in coke-oven gas. Exhaust was used in coke-oven gas, but it was not the same proposition as in Dr. Clerk's two-stage engine. It was used in coke-oven gas simply to reduce its activity, and had so been used for many years. He thought he knew of the particular instance to which Mr. Tookey had referred, which was a much later trial of the proposition. Within his own experience it was used ten years ago by Mr. Ernst Körting in some of his early engines, and it was really a convenience more than anything else. It enabled an engine with a higher compression to use a very rich gas where normally the compression might have to be reduced.

He was sorry that M. Mathot had, in his brief study of the Paper, missed one of the important points. The engine on page 159, to which he had referred, was quite a small convertible engine, and as normally arranged it did not have a low consumption. It could, however, have been made to have a lower consumption if required, but as it had to be attended to by very unskilled labour, it was designed accordingly. It was simply mentioned in the Paper to indicate how one might begin with the proposition. That engine, which might have been of only 10 h.p., could be changed over by an ordinary man to run with practically any fuel that was available. The compression was only 90, and if it had been raised to 150 the fuel consumption would have dropped in that proportion. M. Mathot had asked him whether it was easier to change from oil to gas or vice versa. If the engine had not been built for conversion, it was probably rather easier to change from oil to gas, but it was difficult to say without seeing the engine. With a specially-built engine, the necessary conditions were studied for each particular part for each particular fuel, but that might not be so with an oil-engine, which might have been so specially built for using oil that it would be rather difficult to convert it.

He was next asked to what extent, that is, to what power, he thought it was possible to convert an engine. The engine shown in

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Fig. 13 (page 169) was one of Messrs. Ruston and Proctor's standard engines which would do 600 h.p., and it was really easier to convert than was depicted in the Paper. The engine was stated in Fig. 13 to be of 520 h.p., but it would give 600 h.p., and to convert it from oil to gas would take about three hours. The pistons were not changed. He had referred to Mr. Livens' remarks so often that he did not think it was necessary to deal with them further in his reply, as they explained themselves. Mr. Livens had really been helping him all along to make some of the points clearer, and he was very thankful that he had been kind enough to do so.

Mr. Petter had referred to the two-cycle engine. Personally, he regretted that time had not permitted him to go into that question in detail, because for many years he had been in favour of the two-cycle engine, and had been concerned in building probably the largest two-cycle engines in this country. He had referred to this engine in order that he should not be charged with omitting all reference to it. The main difficulty of dealing with the Bolinder type of engine was that, in the oil-engine, air was used in the crank-case acting as a pump, and in the gas-engine it was therefore necessary to use a combustible mixture which was rather objectionable. The other engine shown in Fig. 4 (page 162) was not the same type at all; it was a stepped-piston type, the idea of which was that the mixture was taken away out of the crank-case. Such an engine would run perfectly well for small powers, but for large powers it was advisable to split the gas and air, and to have separate supply-pumps on the side, one for the gas and the other for the air; and when the engine was changed over to oil they both delivered air. There was otherwise very little difference except in the change of the cylinder head; it had to be water-cooled in one case and not in the other.

With regard to the question that had been asked as to what he meant by small powers, it had been stated that a very much greater alteration seemed to be necessary to change over to gas, but he thought that misconception arose from the fact that there were two distinct engines shown in Fig. 4, and probably it would

have been better to adhere to the Bolinder type in both cases. It was really done to show the two types.

With regard to Figs. 7 and 8 (page 164), to which reference had also been made by Mr. Petter, he was afraid it was not quite clear that in the oil-engine the piston filled the end of the cylinder, and in the gas-engine there was a straight flat-ended piston. There was a great deal more clearance than appeared from the Figures. Mr. Gibson had offered him an order, which he was very sorry he could not accept, because he had not given the proposition any thought. It was not impracticable, but it was difficult to convert an engine that had been built for gas alone. If it were possible readily to convert any engine from one type to another, there would be less novelty in the subject than he had thought.

In reply to Mr. Horace Boot, who referred to the question of the reliability of the change over from oil to gas, he did not think any decrease or increase was obtained; the engine would run equally well on either. Mr. Boot proceeded to state that the effect of conversion would, he thought, be to reduce the price of the engines. People who spoke at Meetings, who were not makers of engines, generally thought that whatever was done would have the effect of reducing the price. He would be very much beholden to any member who would state publicly that the suggested method would justifiably increase the selling price. With regard to the consumption diagram on page 165, he had been asked why the engine was more efficient at 105 h.p. than at 130 h.p. From 105 to 120 was what might be called the normal running load of the engine, and it was necessary to arrange for the engine to run most economically at that load, and therefore to set the atomizer to run at that load. That was the reason the curve rose on both sides.

He did not quite follow Mr. Patchell's criticism; he did not object to the Paper being called a tabloid, for he had explained the limited time he had available, due to work occasioned by the War; still, he believed the "tabloid" monoplanes at the Front had proved themselves to be the best flying machines. He had already answered the question Mr. Patchell asked, that the thermal efficiencies were taken on the gas and not on the coal. It was

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quite easy for anybody to convert them back to shillings and get the first costs. He thought, as he was only dealing with an engine and not including anything else in it—that is, the producer—the best course to adopt was to put the values down for the engines alone, not including the producer. If he had had time he would have been very glad to amplify the Paper as Mr. Patchell suggested, but he had hoped that in the course of the discussion more suggestions would have been made of various ways of dealing with the question, and he was grateful to Mr. Longridge for the kind remarks he had made in that regard. He also asked Mr. Patchell if he would kindly invent another name in place of the unsuitable word “semi-Diesel.” He could not understand why people insisted on using such a word. The engine that was called by that name was really the development of an English engine. It was originally a horizontal type of engine, the hot-bulb feature of which was gradually extended, and it was the evolution of the Akroyd engine. The extraordinary habit had grown up, however, of recent years of crediting everything to the Germans, and so they now even had to use a half-German name to denote a type of engine. He most strongly objected to such a proceeding, and he hoped Mr. Patchell would give them a good name in place of it. In connexion with this name, there was a tendency nowadays to use the expression “high compression,” but the engine to which he referred was normally a compression engine with added heat.

Mr. Michael Longridge had asked him if he had thought of a better way of changing over from one type to another without removing the piston. He had done so, and after the Meeting that evening he thought many of the members, if they had not already done so, would begin to think of ways for themselves. There was no doubt that the problem could be solved in a simpler form than was indicated in the Paper, but the idea of the Paper was to show how it could be done as things existed at present, without any material alteration in the form of any of the parts. An engine that was specially designed could, with their present experience, be made so that it could be changed over very readily from one type to the other in a very short time. The small engine that

Mr. Longridge thought would be useful for country places had been specially designed for that purpose, the idea being that it was possible for such an engine to run with practically any fuel that was ordinarily available in any country. As it was a small engine, the cost of the extra parts was very small indeed, and if they were not actually bought, they could be carried in stock, as the parts were strictly interchangeable, so that the machine could be run on coal, oil, wood, or any fuel that was available.

In reply to Captain Sankey, he desired to say that normally the scantlings of the engine depended upon the compression pressure, because the pre-ignition pressure sprang from the compression pressure. If an oil-engine were considered as an ignition engine in the way that a gas-engine was considered, it would have a higher pre-ignition pressure, and for that reason it was necessary to build it heavier. On the other hand, the type of oil-engine to which he referred did not work purely on the ignition cycle; it was a combination of the ignition and the constant pressure, so that normally a higher maximum pressure was not obtained than was the case with a gas-engine. If occasionally, however, at great intervals a pressure was registered that was higher than the gas-engine, it was taken care of by the ample factor of safety it was necessary to use. There was perhaps a tendency for the oil-engine to be rather heavier for that reason.

Discussion in Birmingham.

The CHAIRMAN (Mr. E. C. R. Marks) said that Mr. Chorlton had done much pioneer work in various directions, and, in particular, with the gas-engine. It was regrettable that he did not go on further with his work on large gas-engines, to which his attention was directed some few years ago. When they remembered that they could obtain with a gas-engine or an oil-engine up to 42 per cent.

(The Chairman.)

thermal efficiency, it made some of them who were responsible for the selling of electric energy, for cost price or somewhat less, as they did in Birmingham, wish that Mr. Chorlton had gone on with the large gas-engine problem, and had shown them how to get an efficiency of that sort instead of doing the poor best they could with steam-turbines, which now held the field. With steam turbo-generators they were not able to do better than about 17 per cent. efficiency from coal to electricity. He (Mr. Marks) felt it was only with internal-combustion engines that the fuel problem of this country was to be solved. He was constantly reminding his friends in the Birmingham Gas Department that they could nearly afford to give the gas away, because they got the price of their coal back in normal years from their residuals; whereas, in the production of electricity, the coal was burned to destruction, and with it most valuable substances which might be saved if they worked with gas-engines or with gas-driven generators of some kind rather than with steam-turbines.

At the top of page 156 of the Paper there was a very slight reference to the working of an engine with solid fuel. They knew that attempts had been made in that direction. Instead of drawing gas or liquid fuel into the cylinder or combustion chamber, solid fuel was drawn in, and one could imagine the state of the cylinder after a short time. Although many attempts had been made to use solid fuel, nothing had come of it yet.

It was news to him that there was a definite demand for an engine to work either with oil or with gas. One knew it had been done as a temporary measure, and Mr. Chorlton mentioned that the agricultural labourer would be able to make the change. A little later he told them the demand was chiefly on the Continent, or abroad. One would be a little sorry for the agricultural labourer who had to change the engine quickly from gas to oil. As to the arrangement shown in Fig. 2 (page 157), he gathered from the Paper that many of those engines had been made, and they were told, on page 159, that the engine was lately built with success. There were varying degrees of success; but the author pointed out that it was really the beginning, and would lead to something better.

Coming to the engine which the author favoured—the engine in which they got a higher compression when working with oil than when working with gas—one of the modifications involved the taking off of one piston and substituting another. That did not strike one as being a final solution of the problem. The author had pointed out that they got lower temperatures with gas than with oil, and he (Mr. Marks) gathered that the engine was built with the higher temperatures in view; that was to say, the engine which might work very well with the comparatively moderate temperatures existing with the gas fuel, might give them trouble with the higher temperatures involved when they converted it for oil fuel. He thought that the author did not favour very much the semi-Diesel type of engine in which the oil was ejected on to a hot surface; yet, as far as the smaller sizes were concerned, it was a popular engine to-day. A considerable number were made, and they worked very satisfactorily.

The suggestion to use super-compression (introduced by Dr. Dugald Clerk) when they were running as a gas-engine, for the sake of keeping their temperatures down, and then to cut out the super-compression when they were working with oil, was attractive and promising.

Mr. A. G. HAFFENDEN said it was a great surprise to him to learn from the Paper that engines had actually been constructed and sold as convertible engines. Although the author stated that the conversion was a simple matter, and could be done by any farm hand, it seemed to him that it involved a considerable amount of work, and could not be done in a few minutes. The only adequate reason that he could imagine, to justify the installation of an engine that was particularly equipped for conversion from one kind of fuel to another, would be to meet emergencies that might arise at short notice. If an engine to meet those conditions required a large amount of work, its value was considerably depreciated. For instance, if they referred to the diagrams of the engine on page 164, the main alteration involved, apparently, was the change of piston, which was a large undertaking on an engine of 1,000 h.p. He

(Mr. A. G. Haffenden.)

thought Mr. Chorlton suggested it could be used to any power up to that size. A 1,000-h.p. engine would have several cylinders, and they had an equal number of pistons to take out and replace. The change of the back-end plate was a small matter, and there also seemed to be a change in the inlet-valve, which might not be an essential. The idea might be developed further, and the necessary change could be obtained by alteration in the design of the combustion-chamber, in order to dispense with the necessity of changing the piston. Apart from that, he did not think that there was any great scope for the proposal—at any rate, not in England. As the author himself had pointed out, the British buyer of machinery always wanted simplicity, and the man who offered a complicated engine as a rule was not in the running at all. If the type of engine in question was to be of practical use, it was essential that it should be simple and that the change should be made with the minimum of labour. It might be worth while developing the idea with that point in view—that was to say, to modify the construction of the combustion-chamber, or cylinder-head, to obviate the necessity of changing the piston.

Mr. A. E. A. EDWARDS observed that the author had introduced a subject which was more or less new to many present. It would no doubt prove the basis for very much experiment at the University, where they, perhaps, had more time to follow up such investigations than Mr. Chorlton had. The author had told them about the possibilities of the engine, but he had not said anything about the commercial prospects. Nobody would buy an engine to run on gas one day and oil the next, and therefore it was not the user who wanted an engine of that class. It was the branch establishments of the makers and the foreign merchants who stocked engines to whom that class of engine would appeal, and it was to them that Mr. Chorlton would have to look for his business. It would be very useful to be able to have one engine in stock and offer to sell it either as an oil or as a gas engine. But if one wanted to sell it as an oil-engine, they all knew the engine required adjustment even for different grades of oil; if they changed from Royal Daylight to

Russian oil, an adjustment had to be made, the compression altered, and so on. The foreign merchant would therefore require to know something about the class of oil before he would attempt to sell an engine to work with oil.

Gas-engine builders, to his mind, had run too much on "standard" lines. If anyone wanted a gas-engine, he could get one with a fly-wheel on the left and an outer bearing and a pulley outside that. But if he wanted any alteration, the makers would not do it, and his only remedy was to buy a steam-engine. The gas-engine makers would make no alteration to standard, and the user must buy an engine as it was, or leave it alone. On the other hand, one could obtain a steam-engine to do 20 revolutions or 1,000 a minute. But with gas-engines and oil-engines the makers had not adapted themselves to the necessities of what users would like, although gas and oil engines in themselves, it seemed to him, lent themselves to almost equal modifications. For instance, an ordinary commercial gas-engine weighed something like 200 lb. per h.p., while a motor-car engine weighed about 4 lb. per h.p., and one could obtain an aeroplane engine which weighed even less. In between the ordinary commercial gas-engine and a motor-car engine there seemed to be a field for development. The ordinary factory manager wanted an engine to which he could attend without calling in an engineer. He probably had a motor-car of his own, and if anything went wrong with it, he could doubtless attend to it, because the parts were so light he could handle them. But if anything went wrong with the engine in the factory, his men could not attend to it, because it was so heavy they could not tackle it. If factory engines were built running faster than the ordinary engine but much lighter, so that the change of piston or anything of that sort could be carried out by hand without any tackle, adjustments from oil to gas would be very much more readily done than they would be in large engines. Of course, it might be said that a motor-car engine had no length of life in it, but, as a matter of fact, it had a fair length of life. A motor-car engine would do 10,000 miles conveniently enough without taking down at all. He had known a Daimler engine run as many as 30,000 miles

(Mr. A. E. A. Edwards.)

without taking down, which would be equal to about three years' work on an ordinary factory engine. If an engine would run that length of time without taking down, they could not say that it would require any very large amount of attention; and so an engine of the lighter type seemed to lend itself to factory purposes. They could put one where they liked on an upper floor, and there was not the trouble in handling them that there was with the large ones.

The author had not mentioned anything with regard to the alteration in the governing which was necessary. The governing of a gas-engine was now, he supposed, usually regulated by the lift of the inlet-valve so as to govern the mixture of gas and air. That method would be quite out of the question with an oil-engine where they had to regulate the amount of oil injected. If that point were cleared up it would be an advantage.

Mr. Chorlton had not mentioned the well-known class of oil-engine in which the charge was ignited by a spark, like the gas-engine charge. This engine had neither a hot bulb nor high compression. He would be glad to have the author's opinion as to whether this type would not be the best to make for conversion from oil to gas. It would not be so economical as the high-compression oil-engines which the author had described, as they could only make use of refined petroleum; but, after all, what a manufacturer required was ease and convenience and reliability far more than economy in fuel.

Mr. W. A. JEBOULT remarked that the Paper struck him as a particularly useful one for a manufacturing engineer. The particular design which the author preferred appealed to the speaker very strongly, and it looked to him a nice arrangement that the various parts could be kept in stock, which would be quite suitable for either a gas-engine or an oil-engine. He would not like an agricultural labourer to do the job of converting, because it would be rather difficult for him to attempt to remove the heads which were held on by set-screws inside the water space. The question of the governing which Mr. Edwards raised was a most

important one, and he would be glad to know how that was to be got over on a convertible engine.

Mr. A. GOLDIE ENGHOLM said that, from the commercial point of view, he would like to know if the author could give any information with regard to the prices of convertible engines compared with the ordinary standard types of gas or oil engines, as he thought that the first capital outlay, as well as cost of running, was a very important factor for users.

Mr. A. JOHNSON (Birmingham) stated that there seemed to be considerable scope for an engine, like the one suggested by the author, in large agricultural districts, such as were found in Canada and Russia. The farmers joined together, or perhaps a company was formed, for the purpose of getting the grain in, and threshing it on the field, afterwards carting the semi-finished product to granaries and disposing of the straw at the base. If a company carried out this work, it was quite possible that the district was only capable of supplying a heavy kind of fuel, while at the next base of operation a totally different grade could be supplied. An engine, therefore, designed on the lines put forward would enable this work to be carried out economically and expeditiously.

Supposing one had to operate a very large electrical system, where constant output was of utmost importance and where the prime mover units were of this class of engine, what steps would be adopted for ensuring that a constant shaft horse-power, and consequently constant kilowatt output at the terminals of the generator, would be delivered? For example, a generator delivering 500 kw. would require a shaft horse-power at the engine of approximately 730 b.h.p. If the engine were capable of delivering this power when running from one grade of fuel, it was assumed that when changed over to a lower grade fuel, the power would not be the same, and the speaker would be interested to hear of the probable steps taken to ensure the maintenance of output.

Mr. W. H. THORNBERRY said that the subject of the Paper was of no practical importance to those in Birmingham, because there were comparatively few oil-engines installed. Most of the internal-combustion engines used in Birmingham were gas-engines, and he thought that the question of an engine which might be driven either by oil or by gas would be a purely academic one in that district, although he was given to understand that in certain districts abroad it was a very important question. The subject was of great interest to manufacturing engineers in this country who exported engines to districts where either oil or gas might be used. It affected at present a large amount of trade, and would do so more in the future.

Mr. JOHN A. LONES (University of Birmingham) thanked the Council of the Institution for extending an invitation to the Students of the Engineering Society to attend the Meeting. They had very little opportunity of studying the subject of oil-engines, and the Paper had therefore been very instructive.

Mr. OSWALD B. DAVIES (Coventry) said he thought there was a great opportunity for the development in this country of the ideas mentioned in the Paper. He had come from Coventry to hear the Paper, and he had been struck with the developments in the use of petrol and paraffin. Many of his friends had been trying to use paraffin on their cars and bicycles, and they had experienced a certain amount of difficulty. It would be a good thing if they could convert an engine to run from petrol to paraffin on the principle laid down in the Paper.

Mr. CHORLTON, in reply to the discussion, said he knew Mr. Marks had had a great difficulty in getting people to agree with his power station problems, particularly when driven by town gas. Town gas, when generated in modern ways, in coke-ovens, or vertically continuous retorts, could be put into the holder at a very low figure, say, 4*d.* per thousand cubic feet. Anything under 6*d.* per thousand for town gas used in a gas-engine produced

cheaper power than any steam-turbine. It was possible to use solid fuel in the Humphrey pump, but the difficulty was not with the piston or the cylinder lining, but rather with the injection device.

There were sundry remarks by different speakers made about the agricultural labourer mentioned in the Paper. But the agricultural labourer was only mentioned on page 159, and yet various critics would carry him through to the end of the Paper. He was only supposed to deal with a very small engine which would probably go on a table, so that it was not a difficult job to change over. He ventured to think that this changing over had not been quite appreciated by various speakers. To Mr. Thornbery he would reply that if the coal in his district gradually went up in price, as it seemed to be doing, they would surely come to using oil at 42s. 6d., a figure at which they could buy Mexican oil that day. The proposition was therefore worth thinking about, even in Birmingham.

In regard to the criticism of the particular forms of the engine, he had commenced by saying that his Paper was written when he had but little time to spare, and consequently he could not go into all the different ways of change; it was a suggestion, and it should naturally occur to them that the idea could be carried out in different ways. He was sorry personally that more manufacturers had not spoken. There was in this country, he regretted to say, a great reluctance on the part of manufacturers to speak about the things they made.

Mr. Haffenden referred (page 189) to the change of piston in 1,000-h.p. engines. On page 165 was shown one way of doing it, not necessarily all the ways, and it did not follow that in a 1,000-h.p. engine the piston should be changed.

Mr. Edwards referred to the high-speed engine versus the low-speed engine. The ordinary motor-car engine weighed probably 40 lb. per b.h.p., and the gas-engine probably up to 200 lb. per b.h.p. There was no doubt that any discussion on the question of weights per horse-power was very interesting; but there were difficulties in using a high-speed engine for ordinary purposes.

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First, it was more difficult to follow if it went wrong; and second, its apparent life and success were due to the fact that the ordinary motor-engine did not run at anything like continuous full load, whilst the ordinary horizontal slow-speed engine did. They would find that these were really the important differences. When they came to hard work, they must depart from the motor-engine type in consequence.

Mr. Jeboult said he thought the design was convenient for the manufacturer. It was so in some ways, but not necessarily. Any reasonable manufacturer designed with a view to convenience in stocking and in manufacturing. The arrangement under discussion was brought forward as a commercial problem for the convenience of the buyer who might desire, by reason of the rise in price of one fuel and the fall in price of another, to change over. In reply to Mr. Engholm, he (the author) did not see that the price entered into the problem of conversion. He thought it would be useful in any agricultural district where, of course, fuel was more difficult to obtain, and where, if one ran out of oil, one could use another fuel. It was suggested in the previous week that it would be quite convenient and a good proposition if a man desired to put down a gas-engine but had not enough capital. He might, however, install an oil-engine first, and later he might add a producer and thus convert it into a gas-engine.

Mr. Davies mentioned the convenience of going over from petrol to paraffin by reducing the compression. There was no doubt it would eventually be done, although for commercial motor work it would not be carried out quite in the same way they were doing it now.

Mr. EDWARDS asked whether Mr. Chorlton had made any experiments with an oil-engine, in which the charge was ignited in the same way as in a gas-engine, by electric spark, and whether that would not be easier to convert from oil to gas.

Mr. CHORLTON said he could not answer that immediately, because there were several ways of doing it. If they were using a comparatively light oil which they could admit on the suction

stroke—a carburetted oil especially—they could, by making the bulb smaller (that is, uncooled surface), run electrically all the time. But if it were an ordinary gas-engine, water-cooled throughout, good paraffin was about all they could use, and then they must heat it very considerably before it was admitted to the cylinder. If crude oil were used, it would be almost impossible. It would have to be injected at the end of the stroke, and then there was not the compression to ignite it. An ignition oil with electrical initial spark might, however, be used.

Discussion in Manchester.

In the unavoidable absence of Mr. MICHAEL LONGRIDGE, *Vice-President*, the Chair was taken by Mr. DANIEL ADAMSON, who expressed his regret, in which he was sure the Meeting would join, that doctor's orders prevented Mr. Longridge from attending and presiding as a Vice-President of the Institution at this first Meeting in the Engineers' Club of Manchester.

He also expressed his feeling of gratification that the first Paper to be read under these circumstances should be by Mr. Chorlton, a Life Member of the Club, who had taken a very active part in its inauguration before leaving the district.

The CHAIRMAN (Mr. Daniel Adamson) said the Meeting was partly the result of Mr. Chorlton's own efforts of about three years ago, when he took an active part in expressing the feeling of local members that more might be done for them by the Institution. Mr. Chorlton had read the Paper to-night for the third time in the course of the last seven days. With those facts before them, the members would unite in thanking him heartily for his Paper, and show their approval in the usual way.

The vote of thanks was adopted unanimously.

The CHAIRMAN opened the discussion by pointing out the importance of the subject to engineers in Manchester, the-home of the successful manufacture of the Otto gas-engine, and later of the Diesel oil-engine.

Mr. G. E. WINDELER (Stockport) said that Manchester was the home of the internal-combustion engine, and it was fitting that they should have the opportunity of discussing any new principles or features which engineers had to put forward. Food for thought had certainly been given to the builders of small gas and oil engines who had to go in for intensive production on a large scale, and who had very often to deal with varying conditions in the territories where similar sized engines had to work on different kinds of fuel. It would be of particular value if the parts of such engines could be made interchangeable for different kinds of fuel. That problem concerned the manufacturing side of the industry. To others the economy of the engines was the more important point, and he was sure Mr. Chorlton's remarks in that connexion had been followed with great interest.

During the last two years there had been considerable progress made with small oil-engines, in regard to the use of cheaper grades of fuel and improved economy. It was said the fuel consumption per b.h.p. hour on such engines had been as low as 0.45 lb. when using heavy oils, and in some cases residual oils. These results, he believed, had been obtained on the higher compression engines, but he had not had any opportunity of seeing results obtained from the lower compression engine. Personally he was interested in the Diesel engine, and naturally thought it was the best—in fact he knew it was. Certainly the fuel consumption obtained with it was the very best that had yet been known on any heat engine; it was as low as 0.61 lb. of fuel oil per kw. hour. But the Diesel engine was essentially an engine for the larger powers, and the small ordinary oil-engine using heavy oils had undoubtedly met a long-felt want in providing a more economical prime-mover for the lower powers.

The author referred to the conversion of the Diesel engine to the gas-engine as not being a commercial proposition. During a

recent visit to Germany—it was before 4th August 1914—he was in what he thought were the largest works there that went in for extensive production of gas-engines, oil-engines, naphthalene engines and spirit engines. There he saw working side by side Diesel engines and gas-engines of precisely the same design, and working with exactly the same main parts, the only difference being that the fuel-valve had been removed from the breech-end and an ignition arrangement fitted. A certain modification would of course be made to the gas and air valve, and the air-compressor would be removed. The parts of the engine had been specially designed to admit of its convertibility from a Diesel engine to a gas-engine. The compression for the Diesel engine cycle was produced by introducing a distance-piece between the top end of the connecting-rod and the brasses, thus reducing the compression space. The engine worked smoothly and efficiently, both as a gas and as an oil engine, and the firm considered that they had a sound commercial proposition. He could not vouch for this, but could only tell the members what he himself had heard and seen; there were however a considerable number of these engines going through. They were certainly not big powers, but were convertible, working smoothly and efficiently. He was not sure that the convertibility was carried out by farm hands, as was instanced on Mr. Chorlton's engine, but he was sure that the modification was made quite easily.

With regard to the utilization of varying qualities and kinds of fuel, he thought the Diesel engine held the field. At his company's works, coke-oven tar had been utilized quite successfully. The engine worked economically, smoothly, and cleanly on that product. This opened up a new field for the Diesel engines in times when, as Mr. Chorlton stated, we might be in difficulties for want of fuel, because there was produced in this country a great quantity of coke-oven tar, which was available for use in this way. The modification to the engine which made it possible to employ this fuel was a great advantage, and was quite a simple apparatus and easily adaptable to engines of his firm's design.

He was sorry he could not add any remarks about Dr. Dugald Clerk's engine; he had followed with much interest Mr. Chorlton's

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account, and it was evidently one to which careful thought should be given. The conversion of engines from one fuel to another was of special importance in Germany and other countries where all grades of fuel were comparatively expensive, compared with the conditions ruling in this country. Therefore the Germans had studied the subject much more carefully and in a very able manner. They had thus made progress and got abreast of the English makers in many ways. Whilst our friends were fighting at the Front, those who remained at home had to deal with these problems, and he thought many firms would come into their own in connexion with internal-combustion engines. A short time ago they heard that the National Gas Engine Company had obtained a very large order for high powered gas-engines, and he believed Messrs. Galloways also had participated in a similar contract. It was very gratifying to know that Manchester was holding its own in this direction, and he was sure it would continue to do so.

Mr. JOSEPH BUTTERWORTH said it was about thirty years since he was actively engaged in the manufacture of gas-engines, but he had always maintained an interest (somewhat academic, no doubt) in the subject. At first sight the Paper might seem useless in some respects, because it was absolutely impossible to make a convertible engine that should be the most economical for both oil and gas; they must sacrifice in one direction or the other. But of all commodities oil was the most likely to be cornered, and in the past it had been cornered most effectively in many countries. To take one instance. When the Diesel engine started, the price of crude oils was rushed up. There was comparatively no use for them previously, but directly it was seen that the engine was a commercial proposition to use for power, prices rose rapidly. That would be accentuated in the future as oil came more and more into use for power purposes. Hence the necessity for engines of this type and the useful purpose which was served by Mr. Chorlton bringing the subject before them.

The only point that he wished to criticize in the Paper was with regard to heating the gas before it was put into the cylinders.

His experience was that wherever that was done, the M.E.P. was reduced, with the result that they did not get the same horse-power per weight of engine or per cost of engine, and that, of course, condemned it as a commercial proposition. In his opinion there was a far better method. Seeing that there were so many methods of ignition, it was much better to compress the air first and even cool it by means of intermediate cooling before it was introduced into the cylinder. For example, suppose they had a rotary compressor of any well-known type. Only one additional working part was introduced, but if they compressed up to 3 lb. pressure and admitted the air first, they subsequently got an absolute pressure of, say, 18 against 15. When they came to calculate that, taking into consideration the cooling, they would find the effect was to raise the compression pressure from 150 lb. to nearly 200 lb., which brought it within the range as a fairly commercial oil-engine.

Mr. H. N. BICKERTON said he was closely associated with Dr. Dugald Clerk, whose name had been mentioned in the course of the evening, and perhaps the members would like to hear what his opinion was of the suggested use made by the author of the super-compression engine. He (Mr. Bickerton) saw Dr. Clerk last week, who mentioned that the Paper was to be read in London, and that he should attend the Meeting. It must have been a great disappointment to Dr. Clerk that he was not able to be present.

The author suggested that the super-compression engine might be a means of raising the compression. That was not quite Dr. Clerk's idea when he suggested super-compression; his object was to add to the volume of the charge in the cylinder, and thereby increase the charge. In the engines which were made, it was very successful, and the only objection was that it necessitated further mechanical contrivances; of course, it was a matter for consideration whether, in small engines, the result justified the extra complication, the extra expense, and the extra weight involved. But there was another method of super-

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compression which was more favourable, and which Dr. Clerk carried out successfully—experimentally. That was super-compression by exhaust gases. He bottled up some of the exhaust gases at the end of the power stroke before allowing them to escape from the cylinder to the atmosphere; having retained them under considerable pressure, he cooled them and introduced them into the cylinder, after the latter had been fully charged by the suction stroke of the engine and the inlet-valve closed in the ordinary way. That was a much simpler method and much less expensive to carry out, and it did not involve a great amount of complication.

The author suggested that in an oil-engine the object to be attained—of course, it was the object in dealing with crude oils and semi-crude oils—was to raise the compression by a simple alteration and by the method of ignition. Whether the compression could be raised in that manner sufficiently, he did not know. In fact he would like to have the author's opinion whether it would not be better to introduce the bottled-up exhaust gases in a hot state. Then they would not only raise the compression, but they would also heat the charge, which would be an advantage in an oil-engine of that description. Of course, it would be quite correct to say that, if they heated the incoming charge of an internal-combustion engine before or during admission, they diminished its efficiency, but the reply was that they would not heat the incoming charge—they would first introduce a charge as cool as the atmosphere and heat it afterwards when it was enclosed in the cylinder. He did not think they would lose any efficiency in that way. In fact he rather expected they would improve it.

The engine which the author suggested as a crude-oil engine, he could not accept as such. It was certainly an engine which would work with heavier oils than the ordinary paraffin engine, but it was quite unfair to compare it with the Diesel engine. The difference between the two was simply this, that in the crude-oil engine suggested by Mr. Chorlton, one had to be very careful in selecting the oils for good working, but the Diesel engine could work well with any oil of a fuel character.

Mr. FRANK FOSTER said he would like to suggest to the author that he had omitted one important conversion of the combustion engine, namely to steam working. It might seem rather outside the scope of the Paper, but as a matter of fact a great many gas and oil engines in this country were situated in places where steam was always available. It was quite possible for gas-engines, particularly of the two-cycle type, to be converted to steam. Some members might think the conversion of gas and oil engines was not a very practical suggestion. He happened to know that it was done to a considerable extent outside this country. Some time ago a Continental firm asked him to obtain particulars of a convertible engine of English make on the ground that it was found to be a competitor of their Diesel engine in Russia. He did not think it was quite right to obtain the particulars, and he did not forward them, but the incident was interesting as showing that conversion was an important commercial matter.

He was rather disappointed that the author said little about the mechanical features involved in the change over. The fact that the gas-engine was substantially the same thing as the oil-engine in its main working parts and general cycle of operations had been known for thirty, or more, years. The problems of the conversion were primarily mechanical ones. Although they were indebted to Mr. Chorlton for what they might call the analysis of the general conditions, their debt would have been greater if he had dealt with the mechanical problems involved. The difficulty presented by the air-compressor on self-igniting oil-engines was mentioned in the Paper. He thought that difficulty could be removed, because he knew that some Diesel engines were at work in this country without compressed air for oil injection. He had had some experience of that class of fuel injector, and knew that many difficult problems arose. It was possible to solve them, and the main line of progress lay in having ample pressure—not a few hundred pounds per square inch, but several thousands—with jets fine enough, and proper oil filtration. All dirt should be kept away. There was dirt even after they had passed it through ordinary filters. By that means they could get a spray so fine that it was

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barely moist to the hand. The spray burned without smoke, which was a proof that it was sprayed as finely as they required it in an oil-engine. If they could spray oil without compressed air—and undoubtedly they could—one of the difficulties of conversion was removed.

He knew very little about the Clerk super-compression engine, and therefore would not speak of it, but there were other engines not altogether dissimilar in aim, to which he might refer. The use of scavenging had been long known in this country through the Premier gas-engine, and up to a certain point it was a success. On the Continent the two-cycle engines also used scavenging, and several firms had endeavoured to develop the four-cycle scavenging engines. There was, to his mind, a radical difference between their aims. In the two-cycle they scavenged because they must blow the gases out, in order to take in a fresh charge. In the four-cycle they scavenged for something entirely different. First of all, they scavenged to blow the waste gases or the burnt products out of the clearance space. That in itself had this effect, that at the end of the suction stroke the gas-engine contained a charge full of gas and air, which was useful, and burnt products, which were useless, from the point of view of developing power. By blowing out the burnt products before commencing the suction stroke, a greater weight of charge was obtained, and therefore a greater M.E.P. By reducing the compression pressure so that they did not get a higher total pressure, they obtained a higher power from a given gas-engine, and therefore the capital costs were kept down. Undoubtedly the greatest obstacle in the way of the gas and oil engines to-day was capital cost and not any question of fuel efficiency, nor even of reliability. The scavenging in the four-cycle system was pushed to this further point. Not only did they sweep out the burnt products in the clearance space, but they did it at the instant when the piston was at the compression end of its stroke, and when there were exposed to the scavenging air only the piston face and the combustion chamber of the engine—the two parts which were most heated and were most in need of cooling. In this way the walls were cooled and the ability to advance to higher temperatures

and develop more power was obtained. Moreover, the whole of the gas during the charging stroke was supplied under steady pressure, so that at the end of the suction stroke, instead of having the total gas in the charge (whatever it might be composed of) at a pressure less than atmospheric, the pressure was slightly above atmospheric. That system was introduced, he thought, by Messrs. Ehrhardt and Sehmer, in Germany. It was being developed in this country by Galloways, Ltd., and it had been copied with certain modifications by other firms on the Continent. The results in practice had justified expectations up to a certain point. For instance, there were engines in this country and on the Continent which now developed regularly from 35 to 40 per cent. more power (at the same speed) than they did before under the old system. While it was obvious that that meant a very great gain under certain conditions, it did not pay, as a general rule, to do it with one engine alone. The advantages were felt where there were a number of engines in a power-station. In that case it was a great advantage to have relatively few engines, and this scavenging system enabled them to go up to 35 or 40 per cent. overload without the slightest fear, because they did not get a greater pressure or temperature in the cylinder, although they went up to 35 per cent. higher M.E.P. Also, they got a higher mechanical efficiency because the suction losses were avoided. Moreover, the engines had a much flatter consumption-curve than before, with the result that the range of economy was far greater than in the ordinary engine. The limited range of economy was one of the drawbacks of the ordinary four-cycle gas-engine. He had referred to this question of scavenging because it seemed to have some bearing upon the super-compression system which Mr. Chorlton and Mr. Bickerton had mentioned.

He would like to make a few further remarks upon the change over from oil to gas, and vice versa. Personally, he was not commercially interested in the small engine, and in the large engine one did not come across the question of using oil or gas very much. But they were faced more with the question of using different qualities of gas. For instance, at many ironworks they

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had coke-oven gas and blast-furnace gas, the one about 400 to 450 B.Th.U. and the other about 90 to 100. An engine could be run without change of valve-gear upon either of those gases, but the results were not altogether satisfactory if maximum economy were wanted. It was all right for a temporary change-over, but to obtain the maximum economy one had to alter the valve details, such as the inner valve-box and the air and gas distributing arrangements. If that were done there was no difficulty about it, except the change of compression. Among the small-engine makers there seemed to be a good deal of hesitancy about the changing of the compression, and he did not know why that should be. In the larger engine it was a very simple matter. For instance, instead of making a joint on the flange, it was made on a shoulder in the cylinder. By turning that shoulder down more, they could reduce the compression; by putting in a ring they could increase it. It could be done very rapidly without any change of the other mechanical parts of the engine. He did not know why that system should not be adopted upon smaller engines, as it would avoid such devices as plates on the connecting-rod end, which he thought was a wrong method, as the piston then altered as to the part of the cylinder on which it ran, and ridges were formed by the ring. In that way they contravened at one time or another one of the great rules of engine design, that the piston-ring should just run to the edge of the bell mouth, no farther and no less. He put that forward as an example of the problems which arose when they came to change over.

Mr. ALFRED SAXON said the author had brought before them a problem that was interesting to engineers even outside the ranks of those connected with the combustion engine. Although the experimental stage had been passed, the engine had only been made up to a certain size, and its possibilities and limitations would be determined under actual working conditions and with larger sizes. Mr. Chorlton gave something away in his Paper and naturally expected to get something in return. To judge from his own remarks, he wished to obtain information as to how to advance a

step further towards the convertibility of gas and oil engines of the large sizes. At the bottom of page 156 he said it might be taken generally that the degree of compression was the governing factor. He was quite right in that statement. On page 163 he remarked, "The possibilities of this type of convertible engine appear, from these indications, to be very great; and an engine which has at present been made in considerable numbers to fulfil these conditions is shown in Figs. 6 to 8." There could be no question, judging from other evidence which had been given that evening, that the author's firm had made those engines up to a certain size. He (Mr. Saxon) would like to know what that size was. Further, what was the size of the gas or oil engines which they had been able to make convertible? Fig. 13 (page 169) was a diagram of a four-cycle 520 b.h.p. oil-engine, but it was not stated whether that was the limit upon which tests had been made.

In his concluding remarks the author said he had come to the conclusion that, for powers up to, say, 1,000 b.h.p., the type of engine represented by the Ruston Class B was the most suitable as a convertible engine. Had the author's firm made such an engine, or was he asking for information? Mr. Chorlton knew something of the difficulties of the large gas-engine, and he would realize they were already sufficiently great without the further handicap of this question of convertibility. The existence of such difficulties was clearly shown by the reports of firms who had in hand the manufacture of large gas-engines; there were, for instance, as Mr. Foster suggested, the variations of the gas and the stuff that came along with the gas. Bearing those points in mind, it was to be anticipated that any step towards the sweeping change of making the engines convertible would be taken very carefully indeed.

Mr. CHORLTON, in replying to the discussion, said that Mr. Windeler had told them of similar gas and oil (Diesel) engines of a well-known type (he thought, Deutz) working side by side in Germany. He himself had seen a similar couple; they were built to use the same common parts, but were not convertible engines

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in the sense he meant it. What the stresses were in the Diesel engine of the pair he did not know, but judging by the appearance, the stresses would be higher than in the gas-engine. If it was the Deutz, he thought he was right in saying it was of the direct injection type without the use of air-bottles, and that in consequence the initial cylinder-pressures were higher. The engines he had seen appeared to be working well, but at what load he could not say.

Mr. Windeler also referred to the use of coke-oven tar, which could be used in the Diesel engine successfully. But was it not a question of height of temperature? Therefore he did not see why the argument was brought forward that it could not be used in other engines than those described in the Paper. These engines also did not require special oils. The Ruston engine had run on most of the oils that had been submitted for trial; it had also run successfully on the ordinary oils submitted in general practice, even without going to a higher degree of compression than was given in the Paper. As the compression was raised, it became easier to use heavy oils, or perhaps it was better to say that the result was effected in a rather different way. Undoubtedly the ability to use tar-oil was a considerable advantage, for it increased the range of fuels available, by adding a fuel which was outside the power of oil combines. At the present time oil was very high in price as generally understood, but the Anglo-Mexican was sold at about 42*s.* 6*d.* per ton, and the fact that it was in competition with the Standard Oil Trust ought to help to bring these prices down. Mexican oil could be readily used in the Ruston engine described.

Mr. Butterworth stated that there did not seem to be anything of commercial value in the proposition in the Paper. He (the author) thought there was. As he had said at the beginning, he did not want to suggest that the subject had been completely gone through in the Paper, but he wished to furnish an opportunity for others to help with suggestions during the discussion. The rotary compressor suggested by Mr. Butterworth was not strictly germane to the subject of the Paper; it introduced an entirely different type of machine. As ordinarily understood, it was not an efficient

contrivance for working in connexion with gas-engines in the way suggested. When it was used (as Mr. Foster described later) to supply a supercharge or scavenge charge to a large power-station, it became a different proposition, which could then be dealt with in a different and probably more economical way. But when the question was how to deal with an individual engine and convert it from one fuel to another, it was not a way that ought to be considered.

He was very glad that Mr. Bickerton had told them something about Dr. Clerk's engine. It was quite true that Dr. Clerk's idea was to increase the charge in the cylinder; still, his particular way of dealing with it was designed to get over the very high maximum temperature which such a heavy charge would otherwise involve. For the purpose of making that a little clearer in regard to the conversion problem, he considered it as a two-stroke compression and less as an extra charge which was added at the end of the stroke. The use of the inert gases, that is to say exhaust gases, in the way suggested by Mr. Bickerton was good. The ordinary two-cycle crank-case charging engine, which they all knew had been used a great deal for the ordinary classes of fuel-oil, really worked somewhat upon that principle, not with a material increase of the initial pressure of charging—that is, above atmosphere—yet it worked always with a large amount of exhaust gases left in the cylinder. The result was that there was a very much increased final temperature at the end of the stroke, so that one really secured in a modified way what Mr. Bickerton was suggesting, though the economy was lower, as it only worked at 150 lb. compression. It used added heat (exhaust) as well as a hot bulb at the cylinder end. There was no doubt that, speaking generally, the present waste of the exhaust of any internal-combustion engine was regrettable, and it ought to be made use of in some way. Very often the release pressure was about 40 lb. per square inch; with a super-compression engine it was about 60 lb., which was quite a material pressure and could be used either as pressure or as temperature.

Mr. Bickerton also mentioned the comparison between the Diesel engine and the oil-engine as described, in the use of fuel-oil.

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He quite understood Mr. Bickerton's point of view, and he thought that the complication of the Diesel engine needed some accounting for. It was a wonderful construction, but he did not think it was now in the form it would become eventually. Was he to understand that Mr. Foster suggested a convertible engine that would work with either gas or steam?

Mr. FOSTER: Yes.

Mr. CHORLTON said he held that idea originally. A two-cycle engine was essentially a uniflow engine, and when Stumpf brought out a uniflow engine in Germany he (Mr. Chorlton) thought that steam had been simply applied to a two-cycle gas-engine. Therefore the easiest thing for him to do would be to build a uniflow engine on the two-cycle principle in this country. That was before anybody here had taken up the idea which he obtained from the original German communications, but his firm did not think it was worth their while to do so. A steam-gas convertible engine could, he thought, be made without great difficulty, but the use of steam in the cylinder created a certain form of rubbing surface quite different from the surface of the cylinder created in a gas-engine, and he doubted whether for this reason they could take a gas-engine and turn it into a steam-engine with the same cylinder surface. The point had yet to be proved, and there was considerable doubt about it. The use of water in a gas-engine or an oil-engine, particularly if used in quantity, tended to create wear.

A further criticism was made that he had not gone far enough in the description of the mechanical features of the change from one type to another. He did not feel he was concerned to deal with every detail. He wanted to present the proposition in principle, and to bring forward what he believed was a commercial suggestion. As a matter of fact the mechanical features were nearly all described; the same governing was used, but a different attachment to the oil-pump or to the throttle-valve was necessary. Mr. Foster also dealt with the question of mechanical atomizing, which subject was always with them. In fuel-oils it had been

developed considerably of late years, and was becoming a very efficient way of dealing with them. In his opinion, this method would ultimately become the recognized way of solving the problem.

He quite agreed with Mr. Foster about the high capital cost of combustion engines, which had been the bane of all large internal-combustion engines. But he did not know that even the supercharging which was described, such as was used at Skinnin-grove, was going to help them materially out of the difficulty. It was more likely that the advance in the cost of every fuel that was used would make it essential for people to secure the highest efficiency at almost any reasonable first cost, and therefore, as the different fuels rose in price, the large gas-engine maker would eventually benefit; he certainly deserved it. He (Mr. Chorlton) had been trying for many years to surmount this difficulty, and there was now a great deal more hope for the large gas-engine as a commercial proposition than in the past. The method of altering the compression by moving the cylinder-cover was quite a good one; it could be used and had been used in these types of engines. It was one indication—he had thought more would have been given—of how to make the change of one compression to another.

Mr. Saxon had rather alarmed him by expressing a belief that he (the author) had given something away. An engineer connected with an important business had to be careful how he dealt with these problems; at the same time he might go far in reading a Paper dealing with principles without giving away anything that was of material value to his firm. In other words, if he only dealt with the principle of the idea, it would still be a help to others. With regard to the size of the engine, at present they were not building, for this purpose, cylinders larger than 150 h.p. To get larger powers they had to multiply the number. They would not stop at that size, but it was an indication of what was being done. He quite agreed with Mr. Saxon's view that any progress should be made very carefully. He would be very pleased and gratified if this problem came up again at a later date in the hands of some

(Mr. Chorlton.)

other engineers who would give the results of their thoughts since this Meeting.

In replying to a vote of thanks moved by Mr. Bickerton, the CHAIRMAN (Mr. Adamson) said the Committee of the Club were only too glad to welcome the Institution, as the holding of such meetings was one of the main objects of the Club.