TRANSACTIONS OF THE INSTITUTION

Producer Gas Vehicles.

BY MACDONELL WATKYN WOODS, D.PHIL. (OXON.), B.SC., B.E.
*Student.**

Summary.—This paper deals with recent developments in France and England in the application of producer gas plants to motor vehicles. Some typical plants are described and the performance and economy of producer gas vehicles are examined.

1. INTRODUCTION.

In a paper presented to the Melbourne Division of The Institution, and published in the April, 1930, issue of THE JOURNAL†, Mr. E. J. C. Rennie drew attention to the increasing application in France and other European countries of producer gas to motor vehicles. He discussed the problems associated with such vehicles, and described the equipment provided by several manufacturers. Since that date, development of these vehicles, and, in particular, their producer plants, has proceeded.

The author has recently commenced some experimental investigations on the high speed gas engine in the Engineering Laboratory of the Melbourne University, under the direction of Professor A. F. Burstall, D.Sc., Ph.D., M.I.E.Aust., and arrangements were made for him to visit a number of firms manufacturing producer gas vehicles in France *en route* from England to Australia in September, 1937. It is thought that the advances that have taken place in Europe, and particularly in France, in the application of producer gas to motor vehicles since Mr. Rennie's paper on the subject was published, and the importance to Australia of the subject warrant the publication of an account of recent progress in this field.

The suitability of gas-driven vehicles depends to a great extent on local conditions. The circumstances prevailing in Australia are very similar to those that exist in France. Both countries are obliged by lack of local supplies to import practically all the motor spirit they require—an obvious source of weakness from the military point of view. Further, both countries have extensive available supplies of wood. In France, a charcoal-burning industry has been in existence for centuries, and many producer gas vehicles burn wood-charcoal. While there is no such industry of any great extent in Australia, there is no reason why it could not be developed if a market were provided for the product. Alternatively, producers which operate satisfactorily burning raw wood have been designed, but this type of plant has certain disadvantages which will be discussed later.

2. GAS PRODUCERS.

In the design of producers for motor vehicles, efficiency and economy are frequently sacrificed for the sake of lightness and simplicity. This is well illustrated by modern practice with regard to admission of water to the producer along with the air. The supply of a small quantity of water enriches the gas produced and leads to increased efficiency by reducing the temperature of the issuing gas, so that the loss in the form of sensible heat is smaller but, nevertheless, water injection has been abandoned in the great majority of modern French producers.

In some of the earlier types of producer, water was admitted, and the quantity admitted was under the control of the driver of the vehicle. For efficient running, this quantity must be varied according to the power demand and speed of the engine, and it was found that the drivers, who already had to operate a valve regulating the mixture of gas and air in addition to all the normal motor vehicle controls, tended to neglect the water control. Systems of automatic control of the water quantity were tried but were not very successful, and modern French practice is to admit no water to the producer, except that contained in the fuel. This may, however, amount to as much as 10% in charcoal and up to 25% in so-called " dry " wood.

Most modern producers are of the down-draught type, and the tendency is towards concentration of the combustion and reduction zones into a small space. As an example, the Gohin-Poulenc producer, which is widely used in France, and has been very successful in the trials conducted by the Automobile Club de France, will be described.

The most striking feature of this producer (Fig. 1) is its simplicity. It consists merely of a cylindrical steel shell, 3 mm. in thickness, with a water-cooled tuyère, a charging door at the top, a door at the bottom for the removal of ash, and a perforated plate to prevent comparatively large pieces of solid matter being carried out by the gas.

The upper part of the cylinder serves only as a reservoir from which the fuel is fed by gravity to the fire which is concentrated in a small zone near the mouth of the tuyère. The only part of the producer itself which is subjected to a high temperature is the tuyère, which is cooled by water-circulation, usually from the radiator of the vehicle. The body of the fuel surrounding the fire serves as an insulating layer, so that no refractory lining is required. Cooling fins are provided on the shell in the immediate vicinity of the tuyère and it is found that the shell does not become unduly heated. The tuyère is made of bronze, which is found to stand up to the action of the fire better than other materials.

This producer is designed to burn wood-charcoal or anthracite. On charcoal, it is claimed that it can be started up from cold in less than two minutes, and on the road, after a short halt, in half a minute. Slightly longer times are required when the fuel is anthracite. The producer is not considered suitable for burning coal containing more than 10% of volatile constituents. No water is injected. On account of the high speed of the air-injection, a very high

*This paper, No. 621, originated in the Melbourne Division of The Institution. The author is Commonwealth Research Fellow of the Engineering School, Melbourne University, Victoria.

†" The Application of Producer Gas to Motor Vehicles."—E. J. C. Rennie, I.E.Aust.—*Jour.*, Vol. 2, No. 4, April, 1930, p. 101.

temperature (about 1,500°C.) is developed, which is favourable to the production of a gas rich in carbon monoxide. At this temperature, the ash fuses into a single thick piece of clinker which deposits at the bottom of the cylinder, and

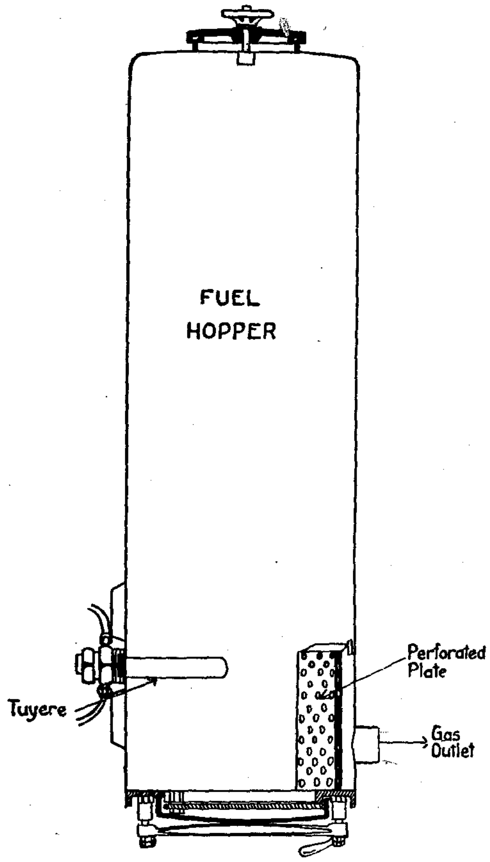

Fig. 1.—*Gohin-Poulenc Producer.*

is removed occasionally. It has not been found necessary to provide a grate of any kind. It is desirable that the ash-content of the fuel should be small.

The Gohin-Poulenc producer is constructed in four sizes, suitable for lorries, ranging from 14 to 20 inches in diameter and from 3 ft. 6 in. to 6 ft. 6 in. in height. The smallest model for light touring cars is approximately 12 in. in diameter and 3 ft. high. Journeys of from 125 to 150 miles can be made without replenishing the producer. A fuel consumption of about 400 grams (0.9 lb.) of charcoal per horse-power hour is given as an average figure.

The Sabatier producer, which took the first three prizes in the 1937 trial of the Automobile Club de France, is also of the down-draught type and is of as simple construction as the Gohin-Poulenc plant from which it differs in having two or three tuyères of an ingenious air-cooled design (Fig. 2). These tuyères consist of three concentric tubes arranged in such a manner that the entering air is itself the cooling agent. The amount of cooling thus varies with the temperature of the fire. This system avoids all danger of destruction of the tuyères consequent on a blockage or a break in the water supply line but the increased air resistence of this type of tuyère is an argument against its use. The temperature attained in the producer is claimed by the makers to be in the neighbourhood of 2,000°C.

The Franco-Belge producer, which has been developed by the Mines of Anzin, is another down-draught producer but differs from the two already described in having a refractory lining. The tuyères, which are built into the refractory lining, are inclined downwards at 45 degrees towards the centre of the producer and the gas outlet pipe is at the bottom.

The Panhard producer, which was described in Rennie's paper* is still in use with only minor modifications; it will not be described in detail in this paper. It is much more complicated than the Sabatier and Gohin-Poulenc types and, during normal running, air passes to the fire through an annular space and not through tuyères. This reduces the air velocity while the fire is of greater extent than in the two producers mentioned. A refractory lining is used and the producer as a whole is larger and heavier than the simpler types. A recent modification is the introduction of a vertical tuyère for starting. This has greatly reduced the time required for starting up.

A producer which was developed in Africa has been on the market in England for the past three or four years but is not yet in service on vehicles to any great extent. It is known as the High Speed Gas Producer, and has been described in several articles in the English technical press (See Bibliography, Reference No. 6). Several favourable reports of the performance of vehicles fitted with this producer have appeared during 1936 and 1937 in *The Commercial Motor* and *Motor Transport*, and it is surprising that the equipment has not come into more general use.

The High Speed producer is similar in some respects to the Gohin-Poulenc producer which has already been described. The fire is confined to a small space by admitting the air at high speed through a water-cooled tuyère, exactly as in the Gohin-Poulenc type, and no refractory lining is required. There are various differences of detail—for instance, in the British producer a movable clinker-box is provided—but the essential difference is that water is injected along with the air in the High Speed producer while the Gohin-Poulenc plant operates without water.

The High Speed producer has been found to give good results when consuming an amount of water in excess of the theoretical optimum quantity. It is claimed that, if an excessive amount of water is admitted, the excess "falls by gravity to the lower part of the producer where it forms a reserve and facilitates the maintenance of the steam zone when the demand for gas is suddenly increased. It thus,

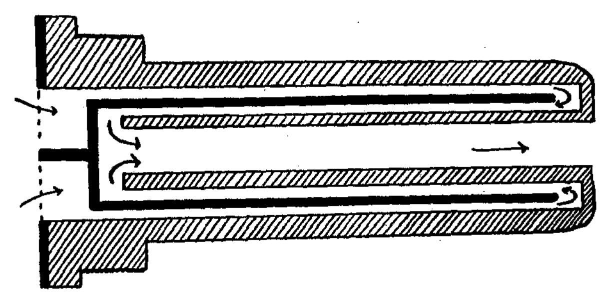

Fig. 2.—*Sabatier Air Cooled Tuyere.*

in effect, constitutes a reserve which renders close regulation of the supply unnecessary." This explanation is, in the author's opinion, not entirely adequate. However, satisfactory results are said to have been obtained without closely controlling the water supply.

**loc. cit.*

In the Wishart producer, which is being made in Melbourne, Victoria, under licence from High Speed Gas, Ltd., an ingenious automatic device controls the amount of water admitted. The water supply is regulated by a valve actuated by a diaphragm which moves according to the pressure in the upper portion of the producer in such a way that, when there is an increased demand for gas, as shown by an increase in the engine suction, more water is admitted. Until more data are available regarding the operation of both this and the simple High Speed Gas unit no opinion can be expressed as to whether water injection is worth while or, as is the opinion in France, it involves unjustifiable complication of the producer and its controls.

All the producers so far described are intended to operate on charcoal, anthracite, or some varieties of coal. Other producers are designed to burn wood. The process is then necessarily more complicated. In effect, the wood must first be burnt to charcoal, and the tars produced must either be removed from the gas or "cracked" to more volatile gases. This necessitates a much longer passage through the fire. In addition, the moisture content of wood is rarely less than 15%. Part of this water is reduced to hydrogen and serves to enrich the gas, but, in most practical forms of producer, a considerable quantity of water vapour remains in the gas and condenses when the gas is cooled. Some means for its removal must be provided.

Oak has been found to be the best fuel but any hard wood is said to give satisfactory results. Softer woods such as pine may be used but a greater depth of fire is required to break up the volatile constituents. The wood should be used about six months after cutting when its moisture content is from 20 to 25%. If wood which is green or too damp is used there is an appreciable loss of power. The pieces of wood which may be with or without bark, should be about six to eight centimetres long, and pieces of irregular shape are preferred.

A typical wood-burning producer, manufactured by Berliet, was described by Rennie.* This plant is still supplied with only small modifications. The alterations which have been made tend towards simplification. The outer air jacket has been dispensed with on the newer models and the grating and ash-pit at the bottom of the producer are also no longer provided. The water vapour which is present in the gas is condensed in cooling tubes and in a vertical gas purifier where it is arranged that the condensing liquid shall fall in an opposite direction to the ascending gas, thereby serving to wash the gas. The water, which collects at the base of the purifier, is drained off when the vehicle is stopped.

The Brandt wood-burning producer (Fig. 3) is of a different type. It consists of two concentric cylinders, the outer one serving as a reservoir for the wood which is fed by gravity to the fire in the lower part of the cylinder which is lined with refractory material. Air is admitted through orifices in the refractory lining. As the wood approaches the fire, moisture and tar are distilled out and pass through the fire, where much of the tar is broken up. The normal combustion and reduction to carbon monoxide take place in the fire and the gases enter the central column which contains coke or charcoal, maintained at a high temperature by conduction through the inner cylinder. Here the water vapour reacts with the carbon to form hydrogen and carbon monoxide and the gas generated is said to contain only about 48% of inactive constituents (nitrogen) as against about 64% in a normal producer which does not make use of water.

*loc. cit.

The producers which have been described are typical examples of modern French and British practice. Development is proceeding on similar lines in Italy and Germany.

3. Gas Cleaning Apparatus.

The gas leaving the producer normally carries with it a certain amount of dust whose composition and quantity vary with the fuel used and the type of producer. This must be removed to prevent damage to the engine. Further, the gas is in a heated condition and must be cooled before passing to the engine if loss of volumetric efficiency is to be avoided.

The arrangements for carrying out these processes are simple and they vary with the different makes of equipment. In most cases the gas from the producer passes through a number of cooling tubes exposed to the flow of air past the vehicle; these are frequently carried underneath the frame and are sometimes provided with cooling fins. From the cooler the gas passes to a purifier which is usually a cylindrical vessel of approximately the same size as the producer. Here it deposits some of its dust in passing through beds of coke or other suitable material and is finally drawn through cloth filters before passing to the engine mixing-chamber. The Panhard purifier, which is a typical example, was described by Rennie.*

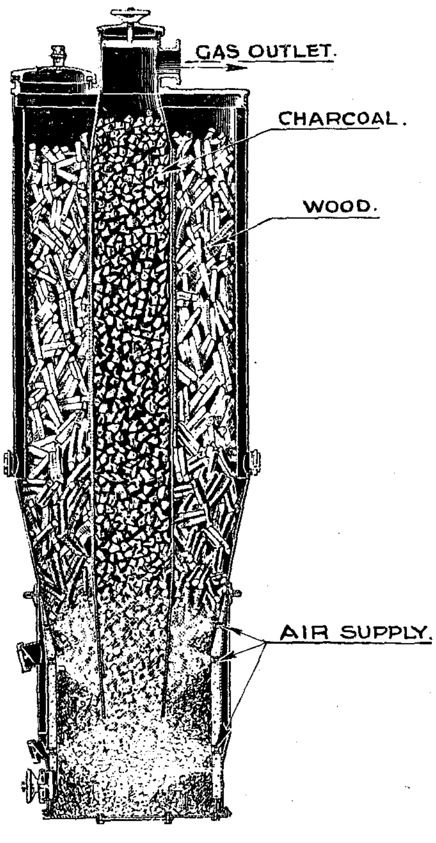

Fig. 3.—Brandt Wood-Burning Producer.

In the Gohin-Poulenc purifier, the coke-bed is dispensed with, and the gas on entering the purifier is caused by baffles to change its direction of motion suddenly several

*loc. cit

excess weight of the fuel carried over that of petrol for the same range. If the lorry carries sufficient fuel for a journey of 100 miles, about 160 lb. of charcoal are required for a Gohin-Poulenc producer, 250 lb. of wood for a Berliet producer, and 80 lb. of fuel for a petrol vehicle, that is, an excess over the petrol vehicle of 80 lb. for the Gohin-Poulenc and 170 lb. for the Berliet. Hence, the total extra weight involved with the Gohin-Poulenc producer is 700 lb. or 4.5% of the load and, with the Berliet producer, 1,370 lb. or 8.8% of the load.

The usual manner in which the generator and other equipment are arranged on commercial vehicles is shown in Fig. 4, which is a line diagram of a Berliet 6-ton lorry taken from Messrs. Berliet's catalogue. The generator is placed immediately behind and to the right of the driver's cab and the purifier, of approximately the same dimensions as the generator, in a similar position on the left. The coolers, which in this model also serve as dust-boxes, are carried beneath the frame, immediately behind the generator. A similar arrangement is shown in Fig. 5, an illustration of a Renault 5-ton forward-control lorry equipped with Gohin-Poulenc producer. In this case the dust-box is at the rear

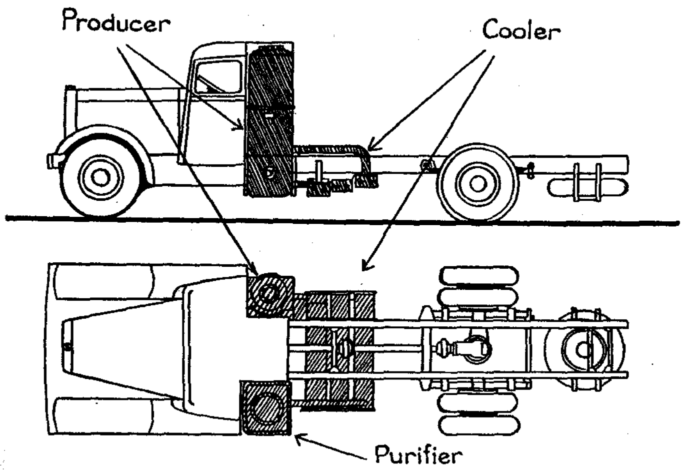

Fig. 4.—Berliet Six-Ton Lorry.

of the vehicle and the long pipes from the generator to the dust-box and from the dust-box to the purifier provide the necessary cooling surface.

The arrangement of the Brandt wood-burning producer and its accessories on a chassis is shown in Fig. 6 reproduced from Messrs. Brandt's catalogue. The producer is in a position similar to those already mentioned but the purifier, which is smaller than the other patterns, is mounted horizontally on the other side of the lorry. The cooling tubes have fins, and a water settling-pot and a washing vessel are provided. The arrangement of the Sabatier plant is somewhat similar but the cooling tubes are usually placed above the driver's cab.

A convenient arrangement has been adopted on several British lorries fitted with High Speed Gas producers. The vehicles are of the forward-control type and the producer is placed under a bonnet in front of the cab and engine giving the appearance of a petrol vehicle with the engine placed well forward. The cooling and cleansing equipment is placed on either side of the lorry beneath the tray.

Most of these arrangements, while suitable for lorries, would be harmful to the appearance of passenger vehicles. It is, therefore, customary in fitting producer plants to l buses to conceal the rather unsightly producer and pu in some way. The method adopted for a Berliet 27-pa ger vehicle is illustrated in Fig. 7. The producer purifier, which are identical with those used for lorrie: placed in a compartment at the rear of the body witl

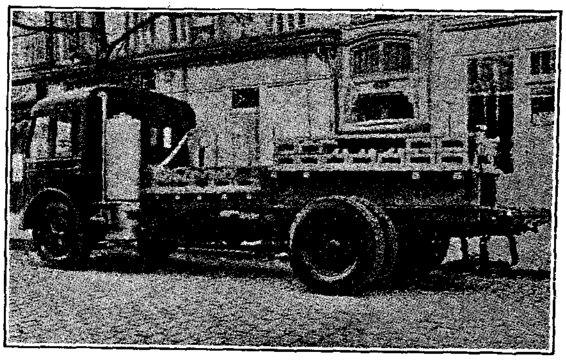

Fig. 5.—Renault Five-Ton Lorry with Gohin-Poulenc Produ

cooler in its usual position beneath the frame. A si arrangement has been adopted on a British passenger ve fitted with a High Speed Gas producer. This sy involves a slight decrease in the number of seats. In nection with the application of the producer to p service vehicles it is worthy of mention that, in 193€ City of Rome adopted producers as standard equipme: its buses.

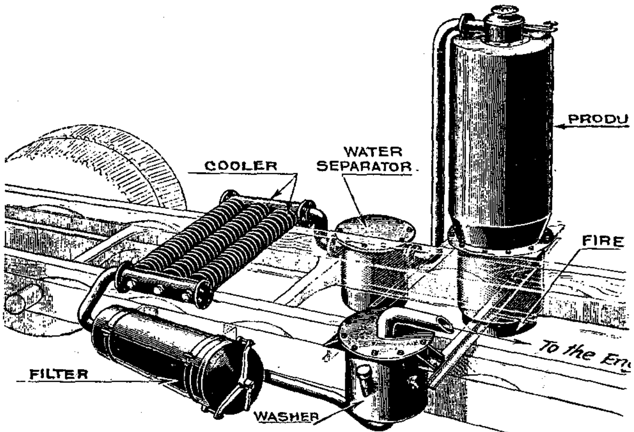

Fig. 6.—Brandt Producer Plant, Disposition of Equipm

In the past few years several firms have commenc make producers suitable for comparatively small pr passenger cars. In this field loss of power is a less se matter than is the case with heavy lorries since, as has mentioned already, most modern motor-car engines l when burning petrol, a power output considerably in e: of normal requirements. The two principal disadvan of the producer are the time required for starting and a fa off in acceleration. The first of these difficulties is of importance for fairly long journeys or where stops a: short duration, since the time for starting from cold has considerably reduced with modern producers.

The equipment for small vehicles is made of a sui shape to fit the space available. Two systems are in com excess weight of the fuel carried over that of petrol for the same range. If the lorry carries sufficient fuel for a journey of 100 miles, about 160 lb. of charcoal are required for a Gohin-Poulenc producer, 250 lb. of wood for a Berliet producer, and 80 lb. of fuel for a petrol vehicle, that is, an excess over the petrol vehicle of 80 lb. for the Gohin-Poulenc and 170 lb. for the Berliet. Hence, the total extra weight involved with the Gohin-Poulenc producer is 700 lb. or 4.5% of the load and, with the Berliet producer, 1,370 lb. or 8.8% of the load.

The usual manner in which the generator and other equipment are arranged on commercial vehicles is shown in Fig. 4, which is a line diagram of a Berliet 6-ton lorry taken from Messrs. Berliet's catalogue. The generator is placed immediately behind and to the right of the driver's cab and the purifier, of approximately the same dimensions as the generator, in a similar position on the left. The coolers, which in this model also serve as dust-boxes, are carried beneath the frame, immediately behind the generator. A similar arrangement is shown in Fig. 5, an illustration of a Renault 5-ton forward-control lorry equipped with Gohin-Poulenc producer. In this case the dust-box is at the rear

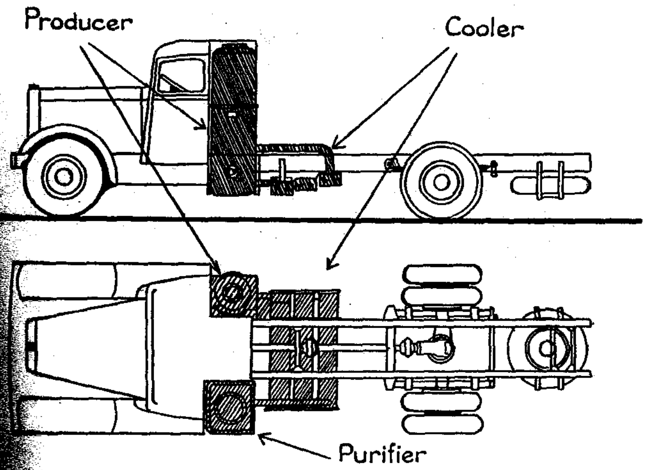

Fig. 4.—Berliet Six-Ton Lorry.

vehicle and the long pipes from the generator to the box and from the dust-box to the purifier provide essary cooling surface.

arrangement of the Brandt wood-burning producer accessories on a chassis is shown in Fig. 6 reproduced from Messrs. Brandt's catalogue. The producer is in ition similar to those already mentioned but the , which is smaller than the other patterns, is mounted ntally on the other side of the lorry. The cooling have fins, and a water settling-pot and a washing vessel ovided. The arrangement of the Sabatier plant is hat similar but the cooling tubes are usually placed the driver's cab.

onvenient arrangement has been adopted on several lorries fitted with High Speed Gas producers. The are of the forward-control type and the producer is under a bonnet in front of the cab and engine giving arance of a petrol vehicle with the engine placed ward. The cooling and cleansing equipment is either side of the lorry beneath the tray.

of these arrangements, while suitable for lorries, harmful to the appearance of passenger vehicles. It is, therefore, customary in fitting producer plants to heavy buses to conceal the rather unsightly producer and purifier in some way. The method adopted for a Berliet 27-passenger vehicle is illustrated in Fig. 7. The producer and purifier, which are identical with those used for lorries, are placed in a compartment at the rear of the body with the

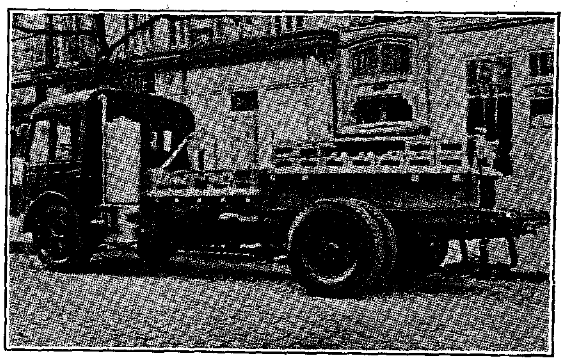

Fig. 5.—Renault Five-Ton Lorry with Gohin-Poulenc Producer.

cooler in its usual position beneath the frame. A similar arrangement has been adopted on a British passenger vehicle fitted with a High Speed Gas producer. This system involves a slight decrease in the number of seats. In connection with the application of the producer to public service vehicles it is worthy of mention that, in 1936, the City of Rome adopted producers as standard equipment for its buses.

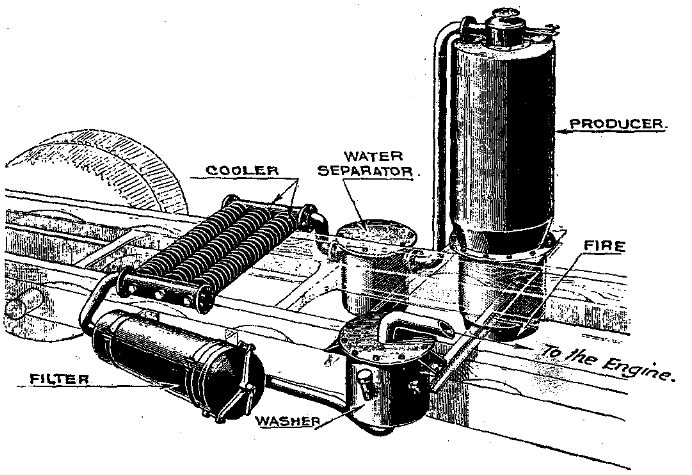

Fig. 6.—Brandt Producer Plant, Disposition of Equipment.

In the past few years several firms have commenced to make producers suitable for comparatively small private passenger cars. In this field loss of power is a less serious matter than is the case with heavy lorries since, as has been mentioned already, most modern motor-car engines have, when burning petrol, a power output considerably in excess of normal requirements. The two principal disadvantages of the producer are the time required for starting and a falling off in acceleration. The first of these difficulties is of little importance for fairly long journeys or where stops are of short duration, since the time for starting from cold has been considerably reduced with modern producers.

The equipment for small vehicles is made of a suitable shape to fit the space available. Two systems are in common use; in the first arrangement the producer and purifier are carried in two compartments placed immediately behind the front mudguards. This method is adopted for the Ford V-8 (Fig. 8) equipped with Gohin-Poulenc producer plant. It will be seen that the appearance of the vehicle is not greatly impaired.

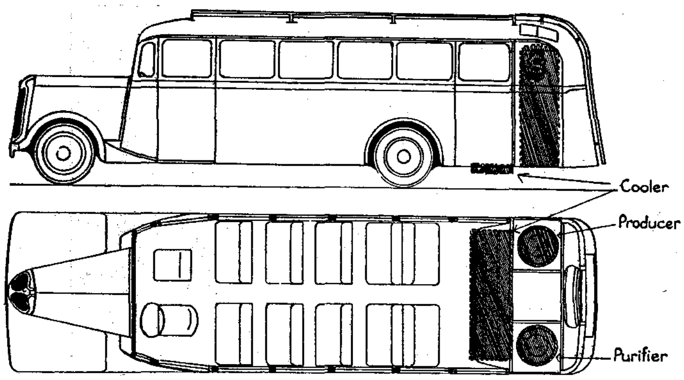

Fig. 7.—Berliet Omnibus.

A more widely adopted method is to place the whole of the equipment in a compartment at the rear of the vehicle similar to the luggage compartments already fitted to many motor cars. The Renault saloon car shown in Fig. 9 is a typical example; it would not be suspected from the appearance of this vehicle that it was fitted with a producer plant. This arrangement entails less alteration in the conventional lines of the vehicle than placing the equipment at the sides but involves the loss of the space normally used for luggage.

6. Methods of Starting.

Special attention must be given to means of starting producer gas vehicles. The producer does not generate gas until some minutes after it has been lit and, during this period, when the engine suction is not normally available,

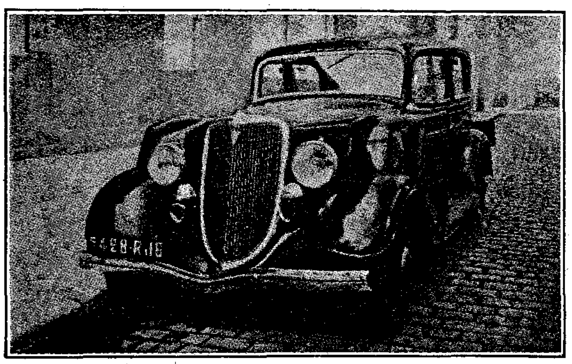

Fig. 8.—Ford V-8, with Producer Plant on Running Boards.

some other means of inducing the draught in the producer must be provided.

One method is to start the engine on petrol, a small carburettor being provided, and to run on petrol until good gas is generated. This method, although it is still used to some extent, is not generally favoured because it has been found to lead to fouling of the induction pipe system and inlet valves.

A better arrangement is the provision of a manu or electrically operated fan which induces the flow of through the producer and discharges the gas to the atm phere. When this gas will burn with a steady blue fla the fan is stopped and the gas admitted to the engine wh is started in the usual way. This method is used in Bran Renault, Sabatier and other producer plants. In the Ber and High Speed Gas plants, both an electric fan and arran ments for starting on petrol are provided. The Panh producer differs from the others in that the starting air blown into the fire, a special tuyère being provided for t purpose. In the Wishart producer an ingenious bello device is used to provide the suction while the produ is starting up.

With modern designs of producer the time required f starting up from cold has been greatly reduced. In International Trial conducted by the Automobile Club France in 1935, the starting times from cold of 13 vehic tested varied from 3 min. 53 sec. for a Fiat touring-car 24 min. 50 sec. for a heavy Panhard lorry. The man facturers of the Gohin-Poulenc producer now claim th

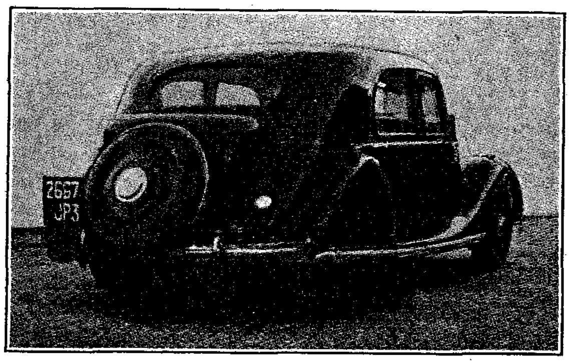

Fig. 9.—Renault " Viva Grand Sport," with Producer Plant at R

with their equipment, the engine can be running on within two minutes of lighting the fire, while start times of from three to four minutes are claimed for t Berliet and Renault producers. The author has seen High Speed Gas lorry running on gas within 4½ min. lighting the cold producer.

After a short halt the engine can usually be star on the gas remaining in the pipes and purifier. Spe arrangements are sometimes made for starting small priv motor-cars. With one device, for example, a small quant of petrol is injected into the producer and lit by an elec spark. This permits the driver to light the fire with moving from his seat.

7. Performance.

Primarily for reasons connected with defence, development of producer-gas vehicles has been encoura by the authorities in France. The Automobile Club France has conducted annual trials, or " Rallyes," si 1925. In 1935, an International Trial, comprising a jour from Rome to Paris via Brussels, was conducted and results published by the Technical Commission of Automobile Club de France. From this report the d set out in Table I have been compiled.

Ten vehicles are dealt with, comprising six lorries various sizes, one omnibus, and three private motor-c The table is, for the most part, self-explanatory. It be noticed that the compression ratios ranged betwee and 9; the higher figure, however (that of the Panh [illegible] Trial, Rome-Brussels-Paris, 1935.

	Vehicle				Engine				Producer			Performance				
Make	Type	Weight empty tons	Load tons	Total weight tons	Bore mm.	Stroke mm.	No. cylinders	Compression ratio	Make	Fuel	Fuel calorific value B.Th.U. per lb.	Fuel consumption lb. per 100 miles	Net ton-miles per lb. fuel	Heat consumption B.Th.U. per load ton-mile	Average speed m.p.h.	Starting time min. sec.
Alfa-Romeo	lorry	6.9	6.9	13.8	125	170	6	8	Roma Imbert	wood	8,350	400	1.7	4,840	22.0	7 42
Fiat	lorry	6.9	5.2	12.1	115	160	6	8	Nostrum	charcoal (water-injection)	14,000	285	1.8	7,630	20.9	14 36
Panhard	lorry	5.8	4.9	10.7	120	140	4	9	Panhard	charcoal	14,300	162	3.0	4,730	25.5	24 50
Berliet (average of 4)	lorry	4.4	3.9	8.3	110	155	4	8	Berliet Imbert	wood	8,250	298	1.3	6,270	24.0	4 56
Panhard (average of 2)	lorry	4.2	2.5	6.7	85	140	4	6	Gohin-Poulenc	anthracite	16,500	118	2.1	7,950	21.2	—
Fiat	lorry	3.4	2.0	5.4	110	125	4	7	Nostrum	charcoal (water injection)	14,100	139	1.4	10,000	25.0	17 0
Fiat	omnibus	6.7	27 pass'gers	—	115	160	6	8	Nostrum	charcoal (water injection)	14,000	230	—	—	27.8	14 40
Fiat	touring car	2.2	4 pass'gers	—	82	118	6	7.5	Eva	charcoal	13,900	85	—	—	32.7	3 53
Berliet	closed car	2.1	4 pass'gers	—	90	130	4	8	Berliet Imbert	wood	8,050	129	—	—	37.8	5 41
Alfa-Romeo	closed car	1.5	4 pass'gers	—	65	88	8	6.5*	Dux	charcoal (water-injection)	13,500	68	—	—	42.3	8 9

* Supercharged.

5-ton lorry), is unusual, and the adoption of compression ratios of more than 8 is not the general practice. The Alfa-Roméo car, the lightest vehicle participating, had a compression ratio of only 6.5 but was fitted with a supercharger. The four vehicles employing water-injection to the producer were of Italian manufacture; this practice is not favoured in France.

The performances quoted are average figures for the total distance of approximately 1,700 miles, mostly over good roads but including a certain amount of mountainous country. The highest point on the route was 6,700 ft. above sea level but the heaviest vehicles followed a deviation for this part of the journey and the maximum height reached by them was 5,900 ft.

This was primarily a trial of the reliability and economy of the vehicles, so that the speeds tabulated must not be regarded as the maximum speeds at which the journey could have been completed. The fuel consumption falls in a fairly regular manner with the weight of the vehicle for those burning charcoal or anthracite; with the wood burning producers, the consumption is increased approximately in inverse ratio to the heat values of the two fuels. The fuel consumption in B.Th.U. per ton mile is an inverse measure of the overall efficiency of the vehicle and, as would be expected, it decreases in general as the size of plant increases. As a basis for comparison the corresponding figure for a 7-ton lorry, running at 9 miles to the gallon* of petrol of calorific value 20,000 B.Th.U. per lb., is 2,400 B.Th.U. per ton-mile. This is about 51% of the best of the tabulated producer figures so that, as would be expected, the producer is less economical than the petrol engine on the basis of the heat value of the fuel consumed. This is less important than the financial aspect of the comparison, which will be dealt with in the next section.

In the 1937 trial in France 28 producer vehicles took part, including nine small motor-cars most of which were equipped with the light Gohin-Poulenc and Sabatier producers. The maximum speeds attained were in the region of 55 miles per hour and average speeds of up to 50 miles per hour were maintained over considerable distances. The acceleration of these vehicles has been much improved, without being in any way comparable with that of similar vehicles burning petrol. Many vehicles are fitted with small carburettors and the mixture is enriched by the addition of a small proportion of petrol when climbing hills and when quick acceleration is desired. The quantity of petrol consumed in this way is generally small.

The author is not permitted to publish the results of this latest French trial. The most up-to-date information which may be included in this paper is set out in Table II which shows the performance of some French and British units. The information concerning the French vehicles has been extracted from the makers' catalogues and the figures for the British producer are taken from tests in England and Scotland in 1936. All the vehicles included burned charcoal or coke and the consumptions in B.Th.U. per ton-mile have been calculated assuming the calorific value of the fuel to be 14,000 B.Th.U. per lb. It will be noticed that the British producer compares favourably with the French units on B.Th.U. per ton-mile basis.

A six-ton High Speed Gas lorry is being used in Victoria by Australian Paper Manufacturers, Ltd. By courtesy of Mr. R. T. Gepp, of that company, the author was permitted to inspect the vehicle and some details of its per-

*This figure is taken from test results published in *The Commercial Motor*, 17th July, 1936.

TABLE II.

RECENT PERFORMANCE FIGURES OF GAS-PRODUCER VEHICLES.

Vehicle	Producer	Pay-load tons	Fuel consumption lb. per 100 miles	Net ton-miles per lb. fuel	Heat consumption B.Th.U. per ton-mile	Speed average m.p.h.	Source of information
Berliet	Gohin-Poulenc	6.9	211	3.3	4,290	18.7	Gohin-Poulenc catalogue, 1937.
Latil	” ”	3.9	141	2.8	5,060	25	” ” ” ”
Ford V-8	” ”	3.3	148	2.2	6,300	25	” ” ” ”
Renault	” ”	1.5	95	1.6	8,900	25	” ” ” ”
Latil	Sabatier	2.5	148	1.7	8,300	—	Sabatier Pamphlet, 1937.
H.S.G.	High Speed Gas	6.0	184	3.3	4,300	—	Test by *The Commercial Motor*, 1936.
”	” ” ”	4.6	135	3.4	4,110	26.3	Royal Scottish Automobile Club Test, 1936.

formance were furnished. The unladen weight of the lorry is 4 tons 5 cwt. and its acceleration is as good as that of a petrol vehicle of like size. The average consumption of charcoal, including both short runs in the city and long country trips, is 2.5 lb. per mile. This corresponds to 2.4 net ton-miles per pound, and a heat consumption (assuming 14,000 B.Th.U. per lb. for the fuel) of 5,800 B.Th.U. per net ton-mile. Water is admitted to the producer but the amount is only of the order of one pint per 100 miles.

8. ECONOMY.

From the point of view of the owner of a vehicle a low fuel cost is of more importance than economy of heat units. A convenient comparison between petrol and charcoal costs can be made for a Ford V-8 lorry. It has been found that this vehicle, carrying a pay-load of 3.3 tons, consumes 1.48 lb. of charcoal per mile (see Table II). Charcoal suitable for producers costs at present £3 per ton in Melbourne so that the cost of fuel per mile is 0.48 pence. According to test figures published in *The Commercial Motor*, 5th June, 1936, this type of lorry, with a load of 3.3 tons, covers 13 miles per gallon of petrol. With petrol at 1s. 8d. per gallon, the fuel cost is 1.5d. per mile, or three times the cost of charcoal.

It is probable that the price of charcoal could be reduced considerably with a greater demand. The price in England at present is about £2 per ton, and this price might be approached in Australia if producer vehicles came into common use. The fuel cost for the lorry considered above would then be 0.32d. per mile, representing a saving of nearly 80% of the cost of petrol.

The cost of a well-known make of French producer equipment for a lorry of this size is 6,500 francs, equivalent at present (October, 1937) rates of exchange to £60 Australian. If the useful life of the vehicle is taken as 150,000 miles, this cost involves an increase, as compared with a petrol vehicle, of 0.1d. per mile in the allowance to be made for depreciation. Another charge which must be taken into account is the driver's wages while removing ash and dust, charging the producer, and lighting the fire. Half an hour per day is considered sufficient for these tasks and, with a daily mileage of 120, this represents a further charge of 0.1d. per mile.

Assuming that all other charges are the same for the producer-gas vehicle and the petrol lorry, the saving by using the gas vehicle is 0.7d. per mile at the present price of fuel. If the annual mileage covered is 30,000, the total saving involved is £87 10s. 0d. per annum.

In outlying districts where petrol is expensive on account of transport costs, and charcoal can be produced locally, the saving is considerably greater than the figures which have been quoted. The whole question of costs is bound up with that of taxation, and it seems that, on account of the advantage from the defence point of view of encouraging the consumption of a home-produced fuel, remissions of taxation might be made on producer vehicles. In France, large taxation concessions have greatly assisted the development of such vehicles. In Australia there is, at present, no fixed taxation scale laid down for gas-driven vehicles which have generally been taxed the same amount as petrol vehicles of similar size and power.

ACKNOWLEDGMENTS.

Much of the information contained in this paper was supplied to the author by firms manufacturing producers in France including Messrs. Gohin-Poulenc, Sabatier-Decauville, Edgar Brandt, Automobiles M. Berliet, Panhard and Levassor and Gazogènes Carbor. The author is particularly indebted to Col. P. Lucas-Girardville, of the Automobile Club de France, for information regarding trials of producer vehicles and for introduction to some of the above firms; to Mr. T. F. Hurley, of the Fuel Research Station, Greenwich; to Col. T. R. Williams, C.M.G., D.S.O., of the Australian Staff Corps, Capt. C. A. Jillett, B.Sc., B.E., A.M.I.E.Aust., and Lieut. A. Milner, A.M.I.E.Aust., of the Australian Army Ordnance Corps, and Mr. R. T. Gepp, for information concerning the High Speed Gas producer; and to Professor A. F. Burstall, D.Sc., Ph.D., M.I.E.Aust., and Mr. E. J. C. Rennie, M.E., A.M.I.E.Aust., whose criticisms and advice have been extremely helpful.

The proposed research on the suction gas engine, preparatory to which the author made the inquiries which have resulted in this paper, has been made possible by a grant to the University of Melbourne from the Council for Scientific and Industrial Research.

BIBLIOGRAPHY.

1. " Experiments on the Power and Efficiency of the High-Sp Gas Engine "—A. F. Burstall, *Inst.Auto.Eng.—Proc.*, Vol. 1925, p. 670.

2. " The Application of Producer Gas to Motor Vehicles " E. J. C. Rennie, *I.E.Aust.—Jour.*, Vol. 2, 1930, p. 101.

3. Report of International Trial, Rome-Brussels-Paris, *Techni Commission of the Automobile Club de France*, 1935.

4. " Producer Gas," *The Automobile Engineer*, Vol. 26, 19 p. 475.

5. *Revue Internationale du Bois, Paris*, number entirely de voted to articles on producer gas, February-March, 1937.

6. " Gas Producers on Lorries in France," *The Engin* Vol. 164, 1937, p. 110.

7. Articles describing the High Speed Gas Producer, *Engin ing*, Vol. 137, 1934, p. 512; *Engineering*, Vol. 141, 1936, p. 50 *The Engineer*, Vol. 163, 1937, p. 682.