Journal of THE INSTITUTE OF FUEL

VOL. XII. FEBRUARY, 1939. No. 63.

The Modern Portable Gas-Producer

THEORY, DESIGN, FUELS, PERFORMANCE, UTILISATION AND ECONOMICS

By BOSWORTH GOLDMAN and N. CLARKE JONES

A Meeting of the Institute of Fuel was held in the Meeting Room of the Geological Society, Burlington House, Piccadilly, W.1, on Thursday, December 8, 1938, when the following paper was presented. Lt. Colonel W. A. Bristow, M.I.E.E. (Vice-President) was in the Chair.

SUMMARY

I. *The Importance of Gas Producers.*

PROVEN oil reserves are sufficient to meet the 1935 consumption for the next 14 years. During 1931 to 1934 consumption exceeded discovery, while the reverse was the case in 1921 to 1925. Any shortage, in peace or war, would be a danger to the country. Apart from compressed gas, alcohol, etc., the principal supply of home fuel is coal, and a Table shows that to use coal (or its solid derivatives) in gas producers is between two and three times as efficient as any oil-from-coal process.

II. Past Developments

Gas producers, by means of which solid fuels such as anthracite, low-temperature coke, charcoal, wood, etc., can be used for lorries, tractors, railcars, etc., in place of petrol or diesel oil, have principally been developed in Great Britain, France and Germany. During 1926 to 1935 the Automobile Club de France organised nine rallies in which standard vehicles equipped with gas producers took part.

III. *Theory.*

The basis of producer-gas practice, as is well known, is the conversion of carbon (through various stages) into carbon monoxide: a gas combustible in an engine when mixed with further oxygen. By adding steam to the primary air, hydrogen and more carbon monoxide are made. This is advantageous for a number of reasons, notable because of the increase in the calorific value of the mixed gas, and to reduce clinkering difficulties.

IV. *Producer-Gas Plants.*

The various types of gas producer are nearly all built of mild steel sheet, and some use a refractory liner about the fire zone. The units of which a complete equipment is made up are disposed about a lorry in several alternative ways, some of which cause a loss of load space.

V. *Designs of Generators.*

There are four distinguishable types of gas producer The updraught, in which the fuel and air move in opposite directions, generally provides the best gas. The downdraught can be used with advantage for dirty or tarry fuels. The cross-draught is the simplest in construction, and relies on a very high temperature in contrast to the other types. The double-draught and double-zone types seek to combine the production of good quality gas with the ability to use low-grade fuels.

VI. *Gas Purification.*

Gas purification consists of methods of cooling, shock baffling, and wet or dry scrubbing in various combinations. The simplicity of the equipment depends upon the fuel used and the generator in which the gas is made.

VII. *Fuels: Characteristics and Distribution.*

Fuels for gas producers preferably should be reactive, be of suitable size and grade, have low moisture and ash, and have sufficient volatile constituents. Anthracite has a high volume/calorific value ratio, is not very reactive and has little volatile ash or moisture. Wood is bulky, but reactive has high moisture but little ash. Charcoal is less bulky than wood and is highly reactive; its ash, moisture, and volatile vary within very wide limits unless it is the product of retorts. Low-temperature coke is homogeneous and otherwise has good characteristics, like charcoal. Suitable fuel is available here. Not manufacture or production, but the lack of distribution of standardised and classified fuels, is the problem to be tackled. Steps in this direction have been taken in certain Continental countries.

VIII. *Gas Produced.*

Analysis of gases made from various fuels indicates that the updraught type of producer yields the best gas.

IX. *Fuel Consumption.*

Fuel consumption per b.h.p. hour is about 1 lb. This varies with the fuel, the generator, and the engine. A low fuel consumption is important in reducing the bulk of fuel carried for a given journey. Figures show anthracite to be the best fuel by this standard.

X. *Engine Design.*

In England the loss of power of a petrol engine running on producer-gas gives rise rather to prejudice than to serious difficulty from the operator's standpoint. Various methods of decreasing the power loss by engine modifications are discussed, and the merits of supercharging instead of raising compression ratios are examined. The desirable features of a specially designed engine are also mentioned.

XI. *Performance and Utilisation.*

Performance figures for certain types of converted vehicles are given which show that acceleration and hill climbing are but little inferior to petrol operation, while vehicles have been in use for long periods of time and great mileages. Many more producer-gas vehicles are in use abroad than in this country.

XII. *Taxation and Encouragement.*

The relatively small utilisation here is attributable to the handicaps which users suffer due to the Government's unwillingness to remove unfair discrimination against producer-gas vehicles, or to make its wishes clear. Differentiation centres around taxation and speed-limit categories for various fuels. Abroad great encouragement is given, and to overtake numerical progress overseas positive Government action is advocated.

XIII. *Comparative Operating Costs.*

Comparative operating costs for lorries on various fuels show that producer-gas is the most economical source of power, but in some cases its value is offset by the handicaps to which reference has been made.

XIV. *Lines of Development.*

The Fuel Research Station is doing valuable work on fuels which will enable progress to be made in generator and cleaner design. At present the requisite technical knowledge exists but the facilities are lacking. The suggestion is made that progress would be hastened by co-operation between those interested—viz., certain Government departments, the Transport Producer-Gas Plant Makers' Association, and the coal and automobile industries.

I. The Importance of Gas-Producers

(i) *Introduction.*

Portable gas-producers are now an important means of mobile power in many countries, but before coming to an examination of their design, use and economics for vehicular, agricultural, power and other purposes, it is perhaps advisable to state upon what considerations their importance rests. These considerations are two in number: First, if the world resources of petroleum were to become exhausted, the utilisation of other fuels for vehicular propulsion would be necessary in order to continue the operation of existing methods of transport. Secondly, if the supply of petroleum to countries not possessing their own resources were to be interrupted or restricted by war, financial stringency or "rationing" of supplies, the utilisation of other fuels would become vital to the national economy.

In either case, the best economic means of utilising other fuels becomes a matter to which attention should be directed. From this paper the authors believe will emerge the conclusion that the portable producer-gas plant justifies the importance attached to it by several governments overseas and would justify its encouragement by the Government of this country.

(ii) *Possible Shortage of Petroleum.*

As regards a possible world shortage of petroleum the observations of Garfias and Whetsel (1) may be taken as authoritative. The proven oil resources covering all known fields are given as 22 billion* barrels, sufficient to meet an average yearly demand of 1.6 billion barrels (the 1935 consumption) for 14 years. While new fields may be discovered, it is pointed out as regards the United States (who are already importers on balance) that further fields *must be discovered*, if demand is to be met without greatly increased imports. Moreover, while the rate of discovery exceeded the demand for the five years 1921 to 1925, during 1931 to 1934 the additions to resources annually were substantially less than the consumption. In conclusion, it is stated: "the figures given . . . illustrate that as a whole they (the proven oil resources) are far from impressive and in individual countries like the United States are inadequately small."

Any shortage of supply would raise petroleum prices, and, while perhaps making economic further exploitation of the oil fields, would in turn make the use of certain alternative fuels economically attractive as well as desirable on defensive grounds, without discriminatory taxation favouring the one or the other. In any case, a possible shortage would result without doubt, in the limitation of exports by those possessing natural oil, a serious matter for all countries without resources of their own.

(iii) *Defence.*

In war, irrespective of the above considerations, the utilisation of home-produced fuel is clearly desirable to reduce imports on financial and defensive grounds. To meet by imports the war demand for oil and its derivatives occupies man power for the construction and operation of shipping; naval and aerial units for escort purposes. Unless the import can be continued, not at the present level, but at a 50 per cent. higher level (2) the defensive capacity of the country will be threatened, except that deficiency be made up by using home-produced oil or alternative fuels. It is perhaps also prudent to recall that as a result of the last war, the average c.i.f. value of crude oil in pence per gallon was still 13.6 in 1920, against 3.2 in 1913, 3.7 in 1925 and 2.0 in 1936.(3)

While it would be agreed by most authorities that the defence forces are likely to depend upon oil on account of operational simplicity, the same argument does not apply to the country's civil transport, power agriculture, etc. Since the last war there has been an increasing dependence upon road transport both for passengers and goods. Any considerable reduction of this road transport in order to conserve oil for the use of the defence forces might seriously dislocate munitions production and food distribution, to take two obvious examples.

Indigenous natural oil has not been found in any considerable quantity in Great Britain. Oil from coal, though expensive, is superficially attractive, but production units require heavy capital expenditure, and are necessarily large and therefore good targets, while oil derived in this way has to be stored just like natural oil. Substitutes, such as compressed gases, are expensive

---

* 1 billion = one thousand million.

as well as inconvenient; and alcohol can only be of importance in countries where molasses are cheap.(4)

The most widely available and cheapest source of power in this country is obviously coal. Coal can be converted entirely to oil by synthesis or hydrogenation; or can be used to raise steam for steam engines; or can be partly converted to liquid hydro-carbon, the solid residue being consumed (if suitable methods have been used) in portable gas-producers; or, in the case of certain coals, directly used in portable gas-producers.

The efficiencies of various methods of coal treatment are compared in Table I (5) in which the following prices have been assumed for bulk purposes: petrol at 1s. a gallon; diesel oil at 1s. a gallon; coke at 45s. a ton; coal at 18s. a ton.

TABLE I

Process.	Equivalent gals. petrol per ton of coal treated.	Thermal efficiency per cent.	Overall efficiency: b.h.p. hrs./cal. value of primary fuel per cent.	Primary fuel costs per b.h.p. hour (pence).	Net fuel costs per b.h.p. hr. (pence).
Hydrogenation ...	83.3	39.55	9.887	0.2117	0.99
Synthesis ...	56.6	26.86	6.715	0.3118	0.99
Synthesis and low temperature carbonisation ...	65.1	30.90	7.725	0.2710	0.99
Low temperature carbonisation ...	30.0	14.24(*a*)	3.559	0.5884	0.99
Low temperature carbonisation and producer-gas	163.3	77.51	19.378	0.1080	0.295(*b*)
Steam	—	(100)	18	0.1160	0.116
Diesel	—	(100)	35	0.1867(*c*)	0.56

(*a*) Petrol only. (*b*) Producer-gas only. (*c*) Imported diesel oil, 4d. a gallon (without duty).

NOTE.—At present home-produced fuel (exempt from duty) is sold at same price as imported fuel plus duty.

The use of solid fuel for gas-producers is limited to applications where the extra weight of the gas plant does not unduly affect efficiency; and also on the fuel side, by the desirability or necessity in many applications of limiting the size and weight of the apparatus by the use of selected fuels. From the standpoint of the general economy in the case of applying gas-producers to vehicles, it is also desirable to make use of existing resources in the shape of vehicles already on the road and manufacturing facilities for standard types. This consideration eliminates the direct coal-burning steam engine for transport purposes.

The utilisation of gas-producers can be urged upon grounds of commercial economy even in peace, while producer-gas propelled vehicles would not present a concentrated target in war, nor would suitable fuels be so costly or so difficult and dangerous to store. Moreover, producer-gas has the advantage of requiring no expenditure from State funds comparable to that entailed by oil from coal plants, a most important point at a time when national resources are already strained to meet defence budgets of unprecedented size. Thus the portable producer-gas plant provides a reliable and practical means of using a cheap and readily available home-produced fuel.

II. Past Developments

(i) *Great Britain.*

It is generally assumed that French technicians originated the portable gas-producer, but most of the initial developments were carried out in Great Britain. The first portable gas-producer of English design was patented by Samuel Brown in 1836. This gentleman also designed a gas engine for propelling carriages and vessels,(6) but no specification was filed. It is, however, said that Brown operated in the London district and that his gas-driven vehicle ascended Shooters Hill at a good speed.

In England progress between 1836 and 1900 was very slow, but development received an impetus in 1901 when James William and Graham John Parker patented (7) an "Improvement to Motor Vehicles," which comprised a gas-producer to use coke or charcoal as motor fuel. This patent was followed by a series of improvements patented by J. W. Parker.

In the years 1913-19 the exigencies of war caused considerable work to be carried out to find alternative motor fuels, and portable gas-producers were designed by Parker in 1917, by D. J. Smith and by Mensforth and Hutton. Later workers in this field were Wells, Thornycroft, Whitfield and Bamber in conjunction with Parker. It is not without interest to note that in 1920 a patent (8) was taken out to use engine exhaust gases wholly as the supply to the gas-producer with the object of using the carbon dioxide and steam for gas production. This was evidently a method of achieving perpetual motion by re-using the *same* fuel!

All these designers were ultimately faced with problems connected with fuel, and in so far as the mineral fuels, coke and anthracite were concerned, these presented considerable difficulties owing to varying quality due to source, condition, method of treatment and manufacture, and marketing. Clinkering was a serious bugbear and standardisation and classification of fuels left much to be desired. Following the success of low temperature carbonisation processes, about 1926 an impetus was given to producer-gas development and in Great Britain development was carried on by Clarke Jones (1926 27), Tullock and Reading (working on the D. J. Smith system (1926), and MacDonald (1930). Clarke Jones had also patented charcoal plants in 1924.

In this period considerable attention was given to fuel quality and engine modification for using producer-gas. During the years 1926–30, Clarke Jones carried out trials on motor trucks and farm tractors, using all the low temperature cokes and charcoals which were available. While certain of these tests were reported, the information was never collated and it is unfortunate in view of present requirements that greater note was not taken of these developments at that time.

(ii) *France.*

In France the economic position following the war necessitated the utilisation of home resources as far as possible and producer-gas plants to use charcoal and wood as fuel received attention. Development naturally followed this line since these fuels are the easiest to gasify and also are widely available and marketed in that country.

The first recorded French investigation was in 1785 by Lebon. Then nothing of importance was done until Ringelmann in 1900 tried to fit a tractor, and a Paris bus was equipped with a producer in 1910 (9).

An important development was patented by Imbert in 1924,(10) and a considerable number of producers are based on this system (see Figs. 15–17).

The following notes on the rallyes organised by the Automobile Club de France may be of interest:

In the second Rallye of 1927,(11) the distance covered was 2,812 km. These Rallyes were non-competitive in character but exhibitional in purpose. All vehicles in this rallye had to average 25 km. during running time. Participants included four lorries equipped with charcoal producers, three lorries running on carbonite and three on wood, while one lorry used a special type of peat coke. Other participants on producer-gas used by officials were producer-gas buses and two military vehicles and one car. The Panhard vehicle had a specially high compression ratio of 6 : 1, and a vehicle equipped with a Rex gas-producer had double ignition. The fuel "carbonite" was made up from compressed charcoal which gave advantage in weight in relation to volume. It was also not so friable as charcoal and homogeneous, regular in shape and free from tar.

In the third Rallye of 1928, 1,664 km. were covered in 16 days. There were 11 vehicles using producer-gas plants, among them such plants as Sept, Sagam, Hydroxygaz, and Gepea.

In the fourth Rallye of 1930, two cars and five lorries used producers. These included the Pava Supragaz (Leytens), Bellay and Van Hemelryck producers. Diesel vehicles made their first appearance in this rallye and also anthracite and semi-coke were used for the first time.

In the fifth Rallye of 1931, 2,076 km. were covered in 16 days. There were four producer-gas propelled vehicles all using wood. The Berliet producer was able to use undried wood and had a special apparatus for getting rid of excess moisture.

In the sixth Rallye of 1932, 2,897 km. were covered in 18 days. There were three producer-gas vehicles, one using wood, another charcoal and the third anthracite. A supercharger had been fitted on a Laffly vehicle equipped with a gas-producer using semi-coke. Unfortunately the supercharger was damaged before the start of the rallye and consequently the vehicle, with a compression ratio of only 5 : 1, did not show up very favourably.

In the seventh Rallye of 1933, 1,400 km. were covered in 11 days. Four producer-gas vehicles participated, two using semi-coke, one wood and one charcoal. Of these four vehicles three belonged to the Army authorities.

In the eighth Rallye of 1934 there were seven producer-gas lorries and one car. On a Chenard Walker vehicle equipped with Gohin-Poulenc producer, comparative tests were made on anthracite, charcoal and a mixture of the two. It is interesting to observe that on three 100 km. tests more of the mixture was used than either of the other two fuels by themselves, though the speed was some 10 per cent. higher. In addition to the vehicles mentioned above, there were five private cars in a special class, equipped with light producers which used either wood or charcoal.

The ninth Rallye of 1935 was international, 2,628 km. being covered in 14 days, from Rome to Paris via Brussels. There were special trials during the run at Rome and Le Mans. Six producer-gas lorries covered the whole distance and others, including various cars took part in the speed trials at Rome and Le Mans. Italian gas-producers included Dux, Nostrum, Eva and Roma (Imbert licence). One of the Panhard vehicles had a compression ratio of 9 : 1, the highest so far recorded.

In the conclusions at the end of the report of the last rallye, the regularity of the operation of the gas-producers is stressed, though it is pointed out that in almost every case the performance varied considerably with the quality of the fuel available. In the case of charcoal and wood operated producers, the moisture content was held to constitute an important factor, whereas for semi-coke and anthracite the ash content was of particular importance.

During the military manœuvres, 1937, a squadron of 140 producer-gas-plant-equipped vehicles took part. All vehicles covered between 3,000 and 5,000 kilometres, doing exactly the same work as petrol-driven lorries. Many of these lorries were as much as nine years old(9).

Considerable attention has also been given to gas-producers in Germany, Sweden, and Italy during the last few years, and consideration will be given to work in these countries later in this paper.

III. Theory

The methods of making producer-gas and water-gas have been established for many years. (12, 13, and 14) However, Smith (15) pointed out that the application of producer-gas plants to vehicles involved considerable departure from standard practice with large stationary units. He instanced particularly the reduction in fuel bed depth, and the much higher capacity of the generator per unit grate area, while drawing attention to the consequently increased importance of keeping the relatively shallow fuel bed well fed with fuel and the grate free of obstruction.

Solid fuels are complex substances and their conversion into gas is attended by intricate reactions, many of which are not yet fully understood. It is, however, fairly easy to trace the thermo-chemical changes, and the authors would wish to summarise briefly those formulæ which cover the principal changes taking place in a gas-producer :—

$$\begin{array}{llllll}
CO_2 & + C & \rightleftharpoons 2CO & - & 38,800 \text{ cals.} & (a) \\
2C & + O_2 & = 2CO & + & 58,800 \text{ cals.} & (b) \\
C & + O_2 & = CO_2 & + & 97,650 \text{ cals.} & (c) \\
2CO & + O_2 & \rightleftharpoons 2CO_2 & + & 136,400 \text{ cals.} & (d)
\end{array}$$

and where water is used, or considerable moisture from the fuel drawn through the fire bed :—

$$\begin{array}{ll}
H_2O + C = CO + H_2 - 28,800 \text{ cals.} & (e) \\
H_2O + CO \rightleftharpoons H_2 + CO_2 + 9,400 \text{ cals.} & (f) \\
C + 2H_2O = CO_2 + 2H_2 - 18,800 \text{ cals.} & (g)
\end{array}$$

Broadly speaking, the aim of the producer designer should be to encourage the changes resulting in the production of the combustible gases CO and H_2, while keeping the non-combustible CO_2 and N_2 as low as possible.

It is accepted that the fuel bed in normal practice is divided in four zones—viz. 1, ash ; 2, combustion ; 3, reduction ; 4, distillation—which merge into one another. In a portable producer, by reason of the selected fuels, the ash zone is almost eliminated.

In the first place the incoming air reacts with the hot carbon to form CO_2 exothermally (equation *c*). Immediately the CO_2 is reduced to CO endothermally (equation *a*) ; CO_2 also dissociates reversibly to O_2 and 2CO by equation (*d*). The direction of the reaction is decided by the position of equilibrium (*d*), (in turn dependent upon the temperature) and by the contact time. Above 1000° C. (the precise figure varies with the fuel, 1200° to 1300° for coals and 900° to 1000° for charcoals, (16) (17)) the conversion of CO_2 to CO is nearly complete ; but below 1000° the CO_2 tends to remain unconverted. In that case, and because not all the heat resulting from CO_2 formation is absorbed by the reduction to CO, the temperature will rise (unless the heat is dissipated), resulting in clinker formation. The addition of steam therefore serves a dual purpose ; to control the process of gasification while tending to reduce the formation of clinker. It is of interest to recall that the equation (*e*) predominates above 1000° C. and the equation (*g*) below it.

Thus with the maximum of CO and H_2 (and the minimum of CO_2) as the aim, a temperature of about 1000° is desirable for a fairly pure carbon fuel. In this connection Guillon (18) states that more than 16 per cent. H_2 is impossible with less than 2 per cent. CO_2.

Direct production of CO without CO_2 is claimed exclusively for cross-draught producers ; but in fact this happens in all producers with a clean fuel bed.

The nitrogen remains inert throughout the whole reaction, and in fact acts as a diluent.

Water gas from $C + H_2O \longrightarrow CO + H_2$ contains only 4 per cent. of nitrogen, while pure producer gas from $C + air \rightarrow CO + N_2$ (*i.e.*, $C + \frac{1}{2}O_2 \rightarrow CO$ in the presence of other gases in air) gives a gas with about 62 per cent. nitrogen. Thus purely on grounds of thermal efficiency the greater the ratio $\frac{\text{carbon oxidised by } H_2O}{\text{carbon oxidised by air}}$, the greater the calorific value of the gas, other factors being equal. The aim of the maximum of water gas to the minimum of producer-gas involves an economy of solid fuel, since water is used to a greater extent. Naturally this aim cannot be satisfied without compromise, since during the formation of water-gas heat is absorbed, and the combustion of the solid fuel must be maintained. Thus air has to be used to make good the heat losses in the producer and to keep the fuel alight.

Any improvement in the thermal insulation would reduce heat loss and permit a greater utilisation of water, but the effect may not be very great. Superheating of both incoming air and steam, for example by outgoing gases, are also of value in reducing heat losses.

If the fuel contains volatile matter, this undergoes a process of destructive distillation which results in the production of methane, hydrogen, traces of unsaturated hydro-carbons and tarry bodies. These mix with the gases from the generator; the amount of these substances depends upon the volatile content of the fuel and the design of the generator in which the fuel is gasified. In general, it can be said that the presence of volatiles is desirable as long as no harmful substances or vapours reach the engine.

IV. Producer-Gas Plants

(i) *Units.*

A producer-gas plant as employed for mobile power purpose includes :—

(*a*) Generator, combined with fuel-hopper

(*b*) Coolers ;

(*c*) Scrubbers and or filter ;

(*d*) Air-inlet device ;

(*e*) Gas-throttle and, in some cases, starting-fan and water-regulator.

These items are connected by piping. Description of (*a*), (*b*) and (*c*) are given elsewhere. Certain manufacturers have employed a valve which attempts to synchronise the air and gas required for the engine mixture.

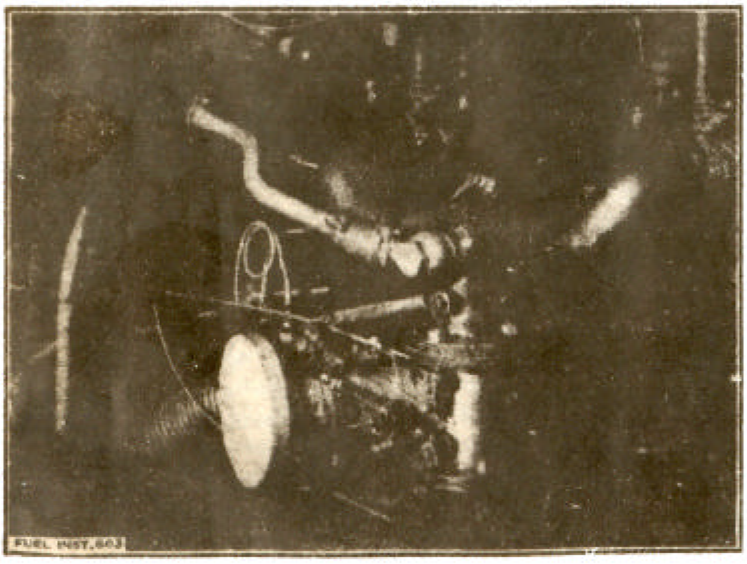


Plate 9.—*The induction arrangement used with a Wisco producer.*

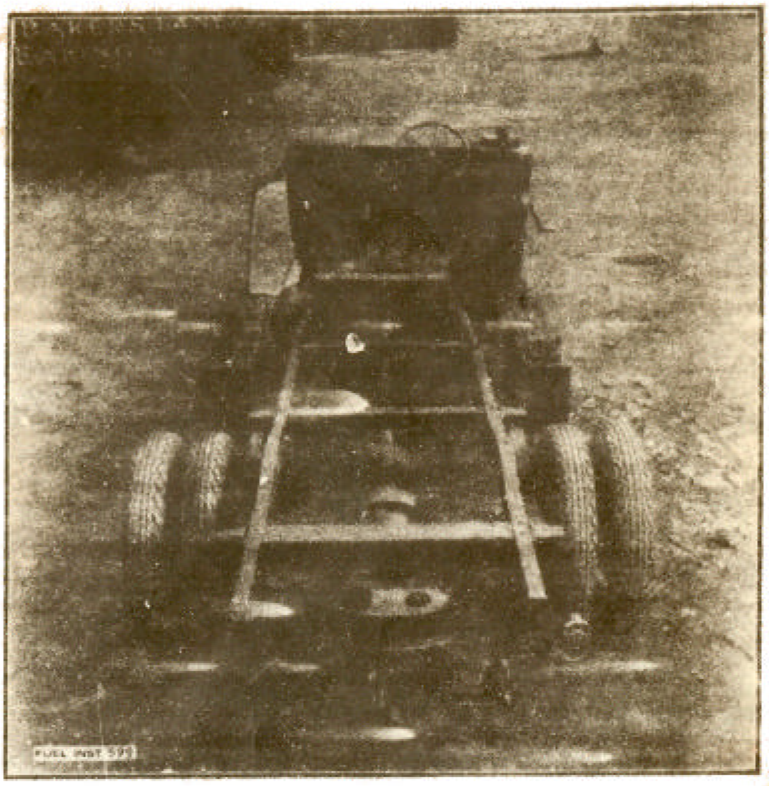


Plate 1.—*The layout of the units of a Koela plant on a Bedford chassis.*

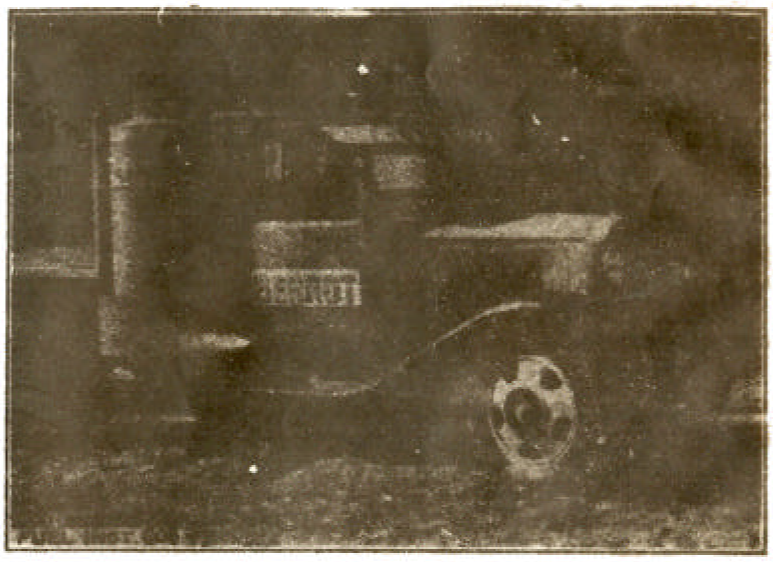


Plate 6.—*A Ford lorry fitted with a Malbay producer.*

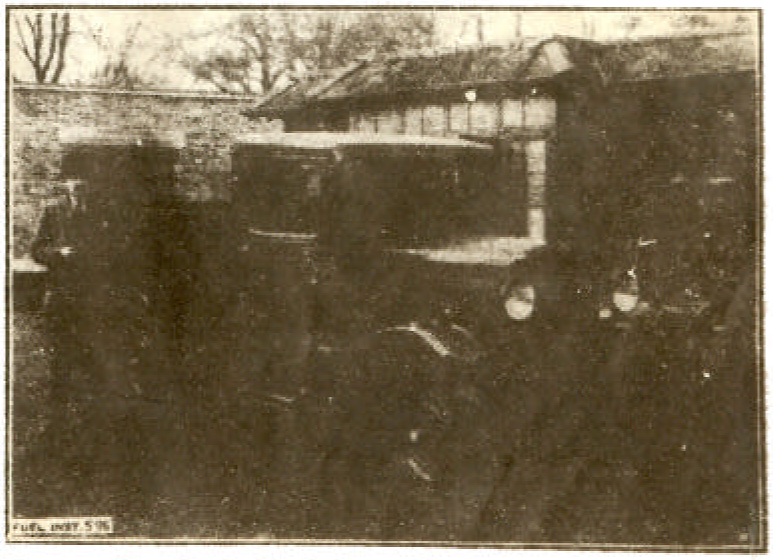


Plate 12.—*A Bedford lorry fitted with a Koela plant*

Such synchronising valves are largely used in the U.S.A. for natural gas and give satisfactory service. It has, however, been found that with producer-gas, whilst these valves are effective at low and medium speeds, the maximum efficiency is not achieved over the whole speed range. There are so many factors to be taken into consideration that automatic linkage of air and gas can hardly always achieve the best result. In other cases the valve to control secondary air supply is under the driver's control, and may be of the mushroom, butterfly or slide-slot type.

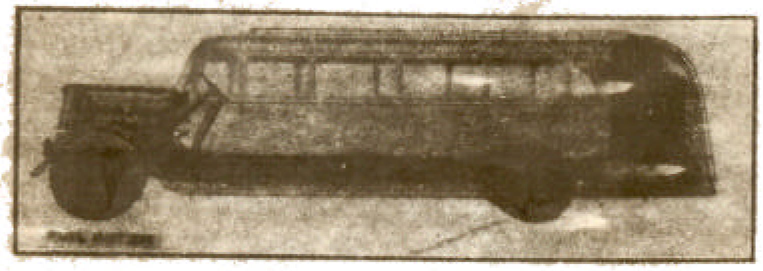


PLATE 2.—*Installation of a Brandt producer on a bus.*

The gas-throttle is usually connected to the standard accelerator controls. A petrol carburetter is generally retained as a stand-by and its throttle either controlled by a separate lever or a main throttle controls either petrol or gas, a two- or three-way valve being used to supply the one or the other (Plate 9).

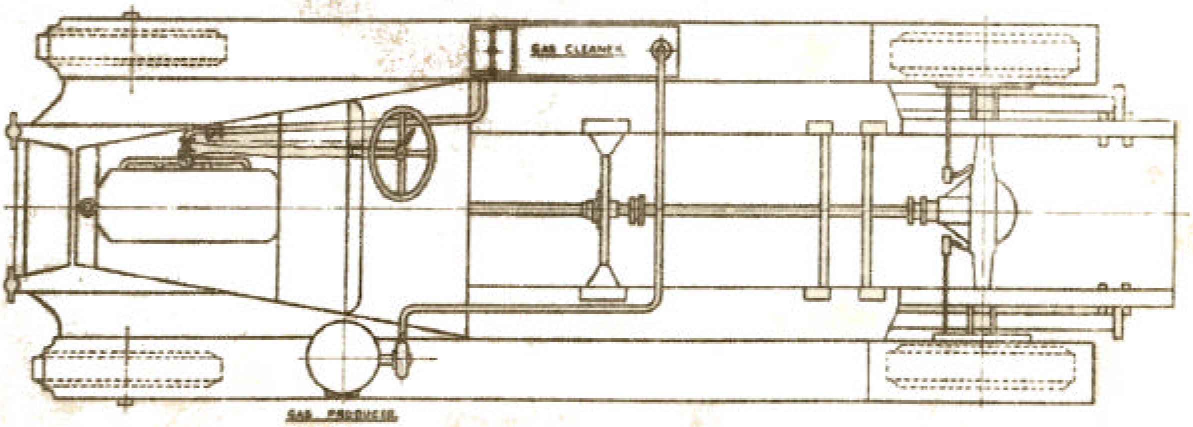
(ii) *Constructional Materials.*

For the fabrication of generators, combustion chambers, hoppers, coolers and filters, mild steel sheeting is employed. This material is usually from 24 to 12 S.W.G., according to requirements.

In the case of hoppers, coolers and filters it is usual to galvanise or treat with anti-corrosive paint after fabrication.

In regard to refractories, these are usually made in one piece. For the manufacture of liners, carborundum, magnesite, bauxite and high-grade fireclay have been employed. The last material, which is reasonably cheap, has proved quite effective in service. Liners made from special materials have also been employed. Amongst these is a patented refractory (19) made from chromite and ferro-silicon, mixed with sodium silicate. This material was very satisfactory, but expensive.

Grates and tuyeres at one time gave manufacturers much concern. At the present, special semi-steels and modern heat-resisting and non-corrosive steels are employed with satisfactory results.



Producer-gas plant on lorry (Koela).

FIG. 3.

The units are connected either by light weldless steel pipes or asbestos-packed flexible steel tubing.

(iii) *Applications.*

The layout of the gas-producer equipment on standard vehicles varies with the type of body and the position of the cab in relation to the front axle and engine.

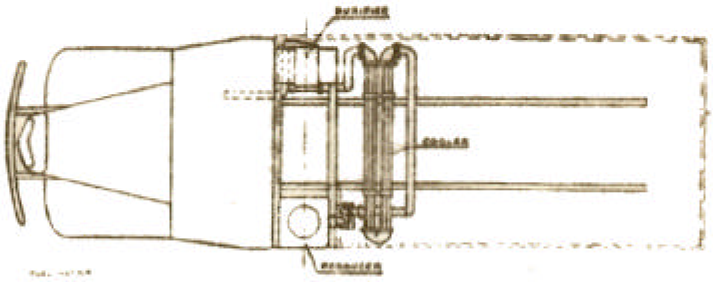
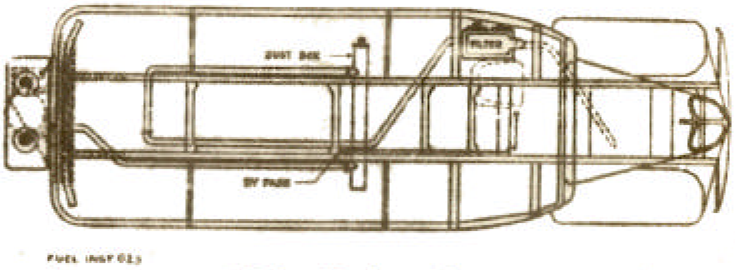


FIG. 1.—*General arrangement of Svedlund producer on a lorry.*



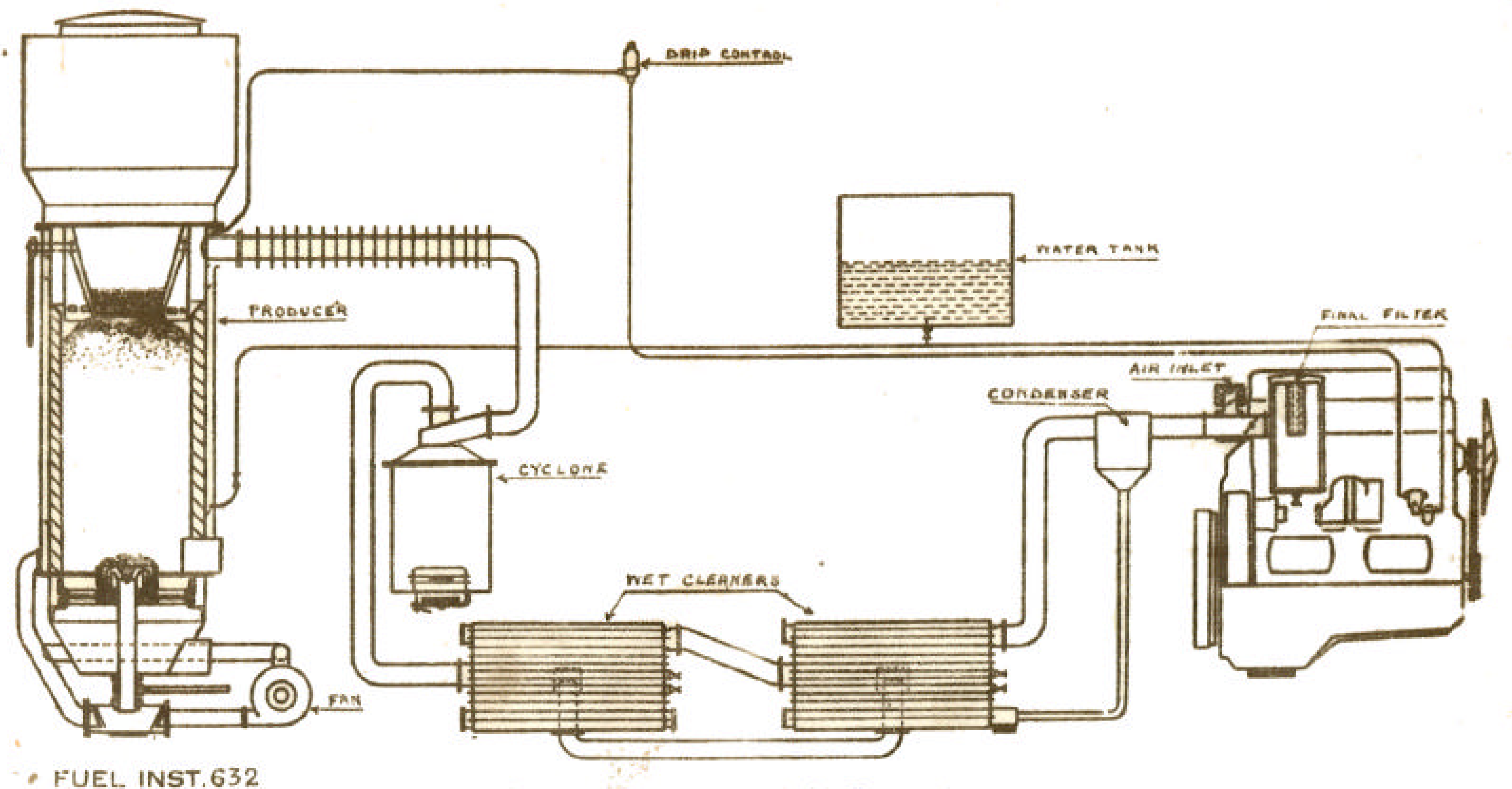
Arrangement of Gohin Poulenc plant on a motor bus.

FIG. 2.

As a rule, however, the producer itself is mounted on the side of the vehicle opposite to the engine induction. It may be fitted (1) On the running board, in line with or forward of the windscreen; (2) partially within the cab taking up most of the spare driver's seat; (3) or immediately behind the cab, where some of the body may be cut away to accommodate it (Plates 1, 6 and 12). In buses and private cars the producer is usually carried in the extreme rear of the vehicle (Plate 2).

The cooler, if fitted, may either be carried transversely beneath the vehicle, mounted in front of the radiator, or, in the case where the cooler also acts as a shock filter, it is generally to be found mounted longitudinally beneath the vehicle's body on the opposite side to the producer.

The filters may be divided into two classes for fitting according to whether they are vertical or horizontal types. In the first case, such filters are usually mounted immediately opposite the producer. This type almost invariably occupies load space, since, even if this producer itself is



Sequence of units, Humboldt-Deutz plant.

FIG. 4.

accommodated without loss, there is rarely room for a further vertical cylinder outside the body. On the other hand, the horizontal type can generally be secured beneath the body parallel to the main chassis members, or transversely beneath the body behind the back axle, without sacrificing load space.

A final filter for both gas and secondary air, if fitted, is generally accommodated beneath the bonnet as close to the induction manifold as possible, as is the mixing valve. Various applications are shown in Figs. 1 to 4.

V. Gas-Producers

The types of gas-producer employed for portable purposes fall into four categories :—

(*a*) Up-draught ;
(*b*) Down-draught
(*c*) Cross-draught
(*d*) Double-draught and double-zone type.

(i) *Up-Draught producers.*

In this type of producer the flow of air and gas is in an upward direction and counter-currentwise to the fuel flow. From the thermal point of view this method is the best, but for tarry fuels the method entails the necessity of providing effective means of preventing tarry matter reaching the engine. In this type of producer the various zones of chemical reaction are layered horizontally, one above the other.

The following makes of plant operate on this system :—

German : Wisco, Hansa, Humboldt-Deutz.
British : Koela.
Italian : Dux.
French : Malbay, C.G.B.

These designs of up-draught producer use low temperature cokes, anthracite, charcoal and charcoal briquettes as fuel.

Up-draught producers are characterised by giving better quality gas than the down-draught or cross-draught types, and are the easiest for starting the engine on gas. Gasification is carried out at moderate velocities, and in most cases steam is added to the entering air stream.

Rämmler (²⁰) states that "there is better flexibility with water addition while servicing and cleaning intervals

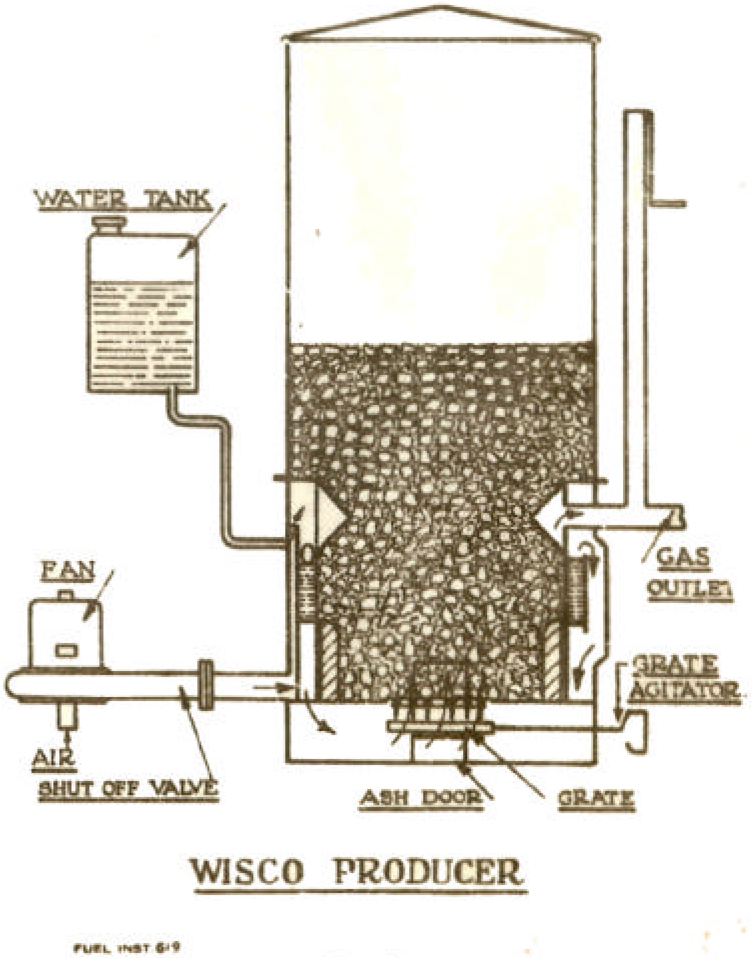


FIG 5.

are also longer." Certain types of up-draught generator are illustrated in Figs. 5 to 9.

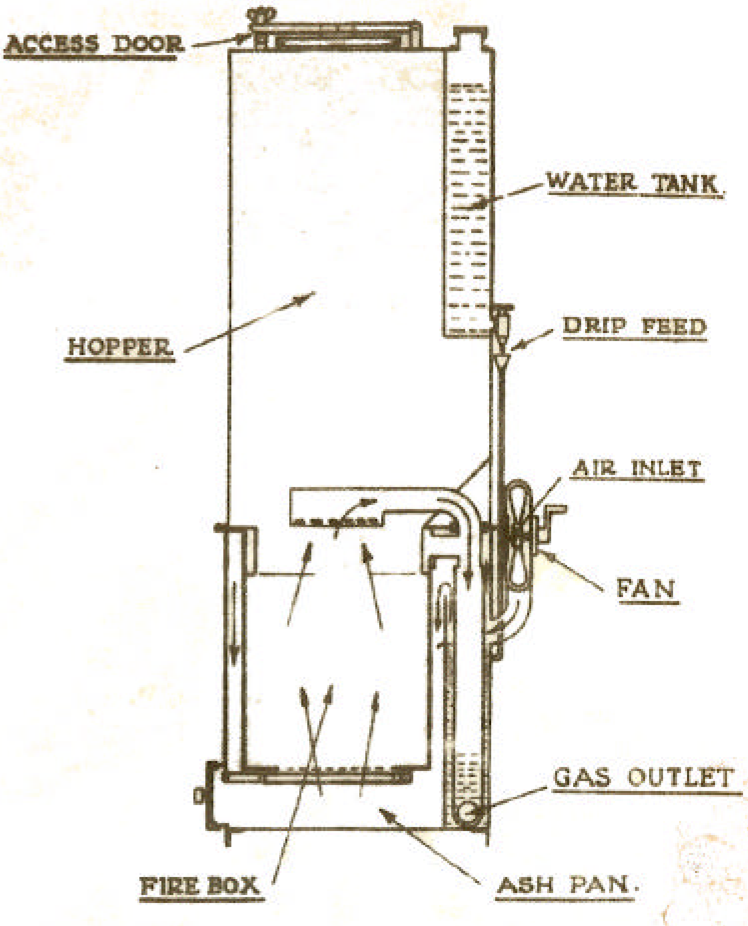
Wisco.

This up-draught producer (Fig. 5) is designed to run on charcoal, low temperature coke or anthracite; indeed, any fuel reasonably free from tar and/or sulphur. It is rectangular in plan, and the combustion space is arranged so that the air only passes through the lower part of the fuel bed and then is led off to the side. Thus gasification is accomplished without further carbonising unburnt fuel, which would reduce its reactivity. Only the lower part of the combustion space is fitted with a refractory liner, whereas the upper part (where the cross-sectional area increases) is surrounded by a water tank, or rather boiler, the level in which is automatically maintained. The air is led upwards through the water inside a pipe and then passes round the producer, picking up steam as it goes. This steam-air mixture is then led down outside the producer into a space surrounding the firebrick-lined lower part of the combustion zone. Here air and steam are superheated before passing down into the ashpit and upwards through the grate, which can be agitated from outside the producer. There are two doors in the base, one giving access to the ashpan and the other to the fire itself.

Koela.

This plant (Fig. 6) comprises a cylindrical hopper superimposed on a combustion chamber. The hopper ends in a spout which feeds fuel automatically into the combustion chamber. This chamber is provided internally in its base with an annular chamber for air distribution, the chamber also serving to support a grate of heat-resisting steel and a refractory liner immediately within the generator shell.

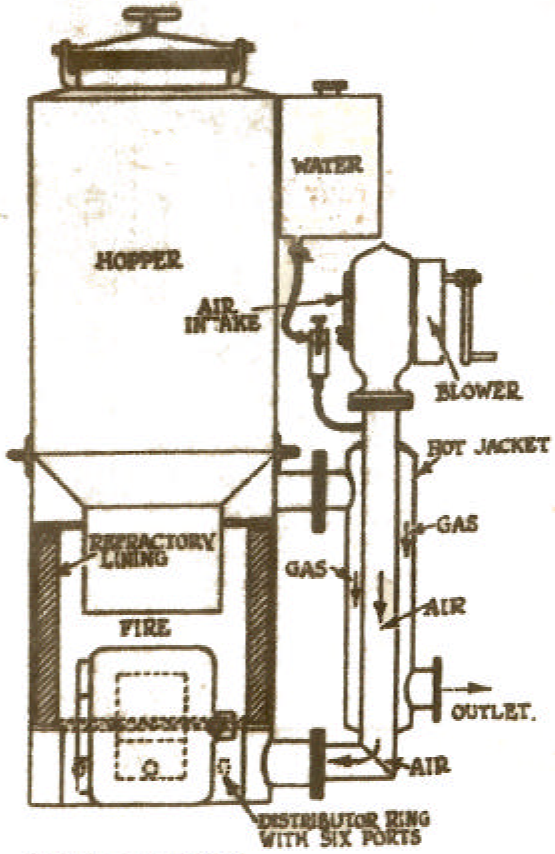
The refractory extends to a position slightly higher than the lowest point reached by the hopper spout. On top of the refractory a baffle plate is arranged, thus forming a gas-collecting chamber around part of the hopper spout. The



ARRANGEMENT OF C.G.B. PRODUCER.

FUEL INST 636

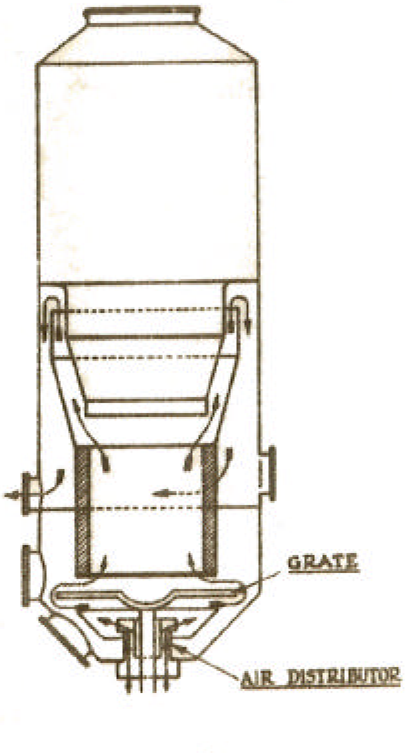
FIG. 8.



FUEL INST. 630

KOELA UPDRAUGHT PRODUCER

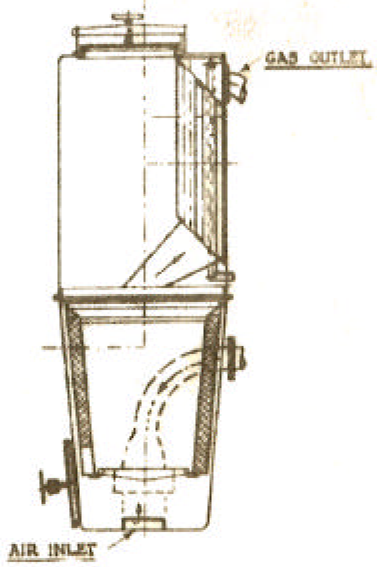
FIG. 6.



MALBAY PRODUCER

FUEL INST 629

FIG. 7.



HANSA PRODUCER.

FUEL INST 626

FIG. 9.

collecting chamber is connected to a preheater, separately mounted on flanges. Through the centre of the preheater passes the air inlet pipe, open at the top and connected at the bottom to the annular air chamber at the bottom of the combustion chamber. The air inlet pipe is fitted on the top with a hand or power pressure fan for starting up purposes and into this pipe a controlled water supply is fed when the producer is in operation. This double piping arrangement is an important feature because it serves the purpose of heating incoming air and vapourising water while cooling the gas as it leaves the producer. A door for cleaning out the ash is arranged so as to communicate with the ashpit and the combustion chamber above the grate. The Koela up-draught gas producer is designed to employ charcoals, low temperature cokes and anthracite as fuels, but provision is made to meet the varying requirements of these fuels by differing grate designs and fire depths.

Horizontal type grates are employed with charcoals, but with mineral fuels a vertical grate with centre cone is used. The grate for mineral fuels does not, however, rest on the annular air chamber as above described, but is arranged within the space made by the chamber. Provision is made to withdraw the entire grate from the generator if desired.

Attention has also been given to providing for fuel beds of various depths as required by different fuels.

The points of importance in the design of up-draught producers include :—

1. The area and type of grate ;
2. Fuel depth ;
3. Means of vapourising water ;
4. The position and method of primary air feed ;
5. Position of gas exit.

(ii) *Down-Draught producers.*

In this type of producer the flow of air and gas is in a downward direction and current-wise with the fuel flow. The following makes of plant operate on this system :—

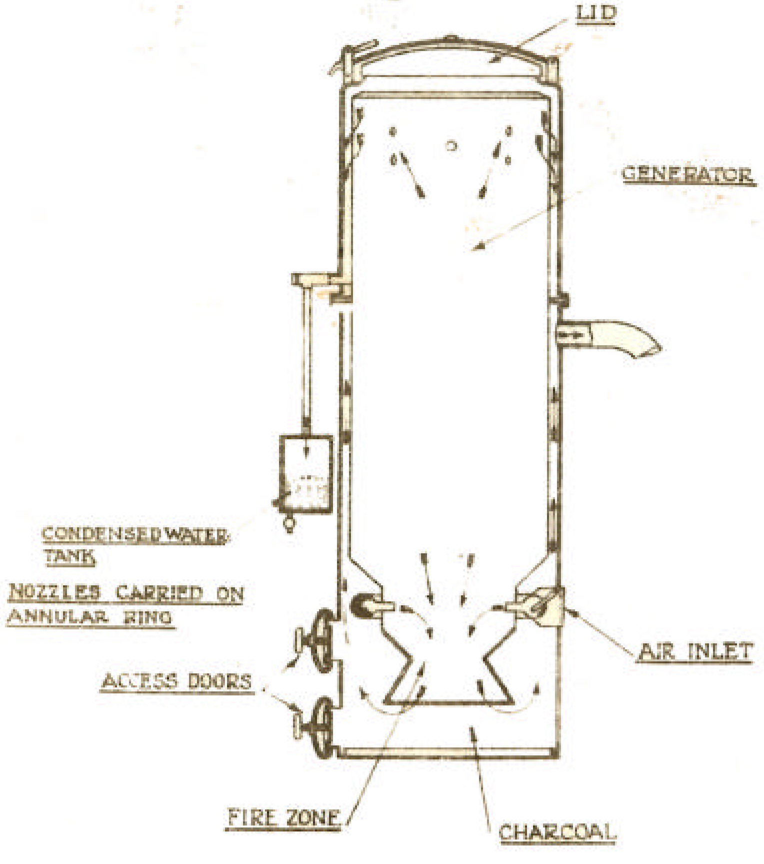
British : Koela.
Italian : Fiat.
German : Imbert.
Swedish : Svedlund, Graham-Stedts.
French : Imbert, Panhard, Sabatier, Sagam, Guillaume, Rustic.

These plants mainly use wood charcoal, charcoal briquettes, raw wood, or tarry fuels.

In regard to the gas quality from this type of producer, the figures given under the section dealing with gas are of considerable interest, and it will be noted that power is somewhat lower than in the case of up-draught generators.

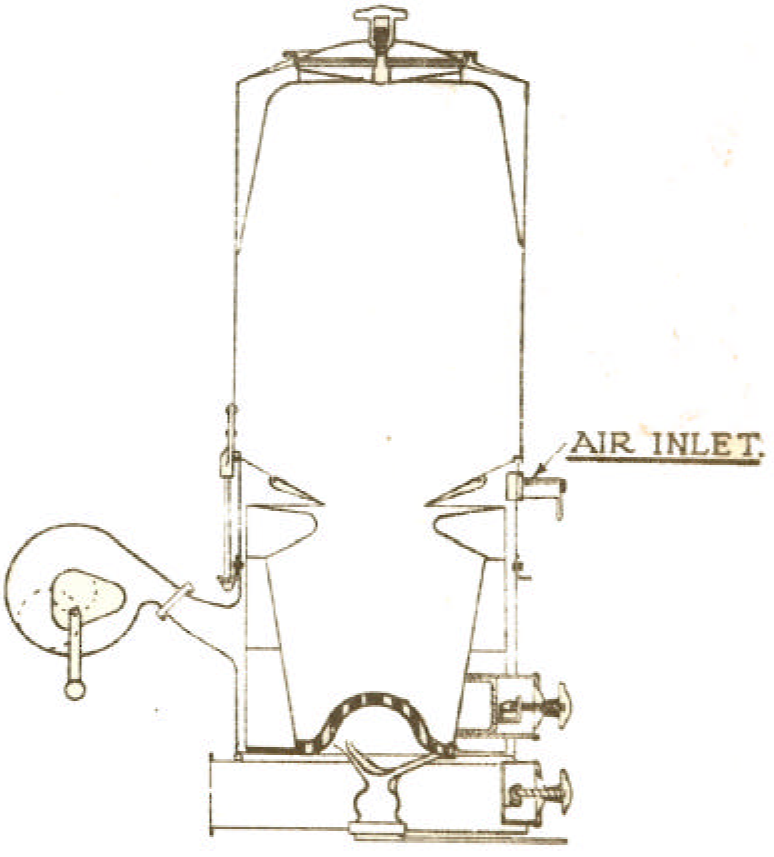
Down-draught producers are characterised by their ability to destroy tarry matter and fuel dust, but suffer to some extent from uneven thermal balance. Water is not used to any extent with down-draught producers, but certain manufacturers claim that charcoals containing up to 25 per cent. of moisture can be used with full efficiency. Panhard, however, indicates that low moisture content is desirable by quoting 8 per cent. moisture content for the charcoal used by their vehicle which took part in the Franco-Belgium Rallye in 1926.

With regard to wood producers, it is interesting to note that in the fifth rallye of 1931, Berliet claimed that they could use *very* wet wood, but a special apparatus was incorporated in the producer to remove excess moisture. Moisture content of the raw fuel is an important point in so far as wood-using producers are concerned, and



IMBERT PRODUCER.

FIG. 10.



PANHARD PRODUCER.

FIG. 11

Guillaume ([21]) states that the difficulty in getting the right size of wood and a sufficiently low moisture content and also the size of the wood producer, justified the use of carbonised fuel save in exceptional circumstances.

Down-draught producers are illustrated in Figs. 10 to 14.

The following brief description of three well-known makes will suffice :—

Imbert.

This cylindrical down-draught producer (Fig. 10) is designed to work on wood. It is manufactured in France, Germany and Italy under licence. The structure comprises three concentric cylinders (of which the central cylinder is the hopper), with narrow spaces between them. Air is drawn into the top of the space between the outside and intermediate cylinders and passes down until it enters an annular space before gaining the fire zone through horizontal tuyeres. The fire zone is enclosed by a sharply "waisted" hearth of heat-resisting steel, the "waist" in fact acting as a grate. As wood passes down towards the hearth it is carbonised, the moisture being driven off as steam and subsequently decomposed. The gas generated passes upwards between the intermediate and inner cylinder, which is protected against acetic acid, and leaves again near the top of the producer. The hot gases thus heat both the incoming air and the fuel. In the German version there are only two concentric cylinders, the incoming air passing directly to the annular space previously referred to.

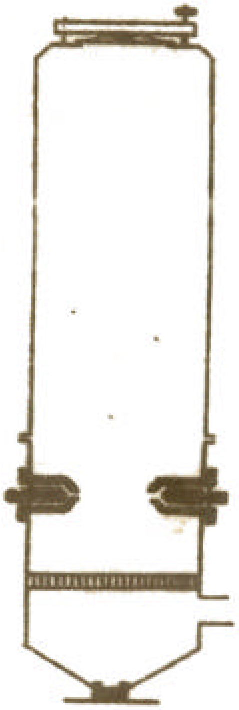


FIG. 12.

Ash, etc., is removed either through the base, which consists principally of a door, or through a smaller door on the lower circumference of a producer.

More than 1,000 of this type of generator are said to be in use.

It is interesting to recall that Imbert's patent of 1924, ([10]) appears to be the inspiration from which the cross draught producers such as Gohin, H.S.G. and Dupuy have been derived. Imbert himself, according to his patent specifications, is a French citizen, and not German as has sometimes been stated.

Panhard.

The Panhard down-draught producer is designed to run on charcoal and is circular in plan (Fig. 11). The combustion space has a refractory liner. Fuel is fed from the hopper to the fire by a cone from behind which the air enters the fire zone, having previously been heated

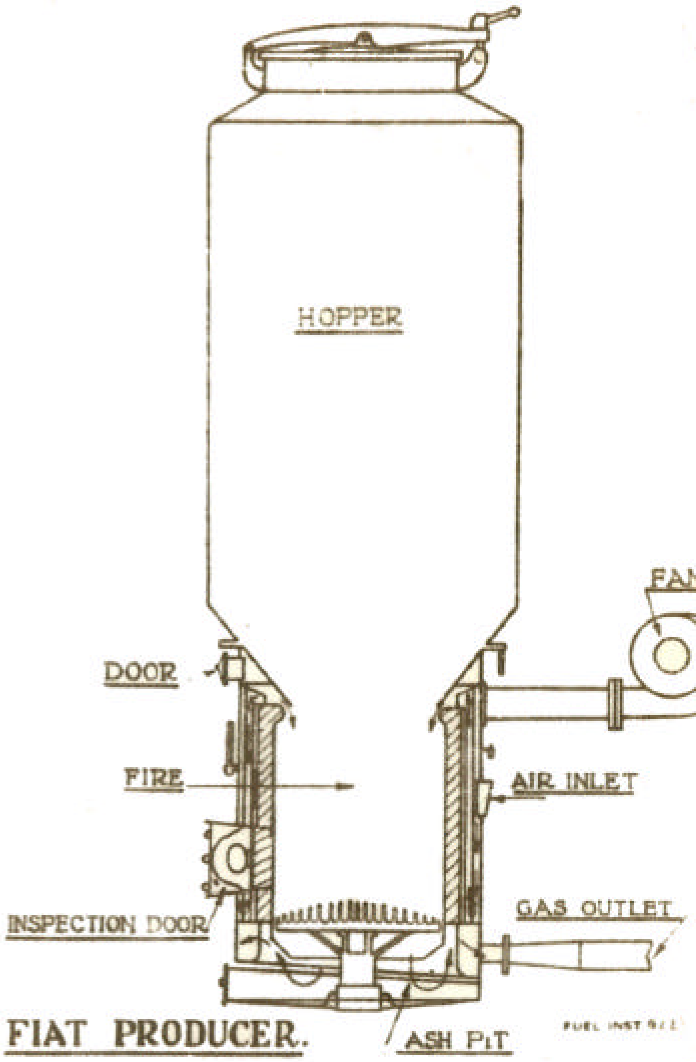


FIG. 13.

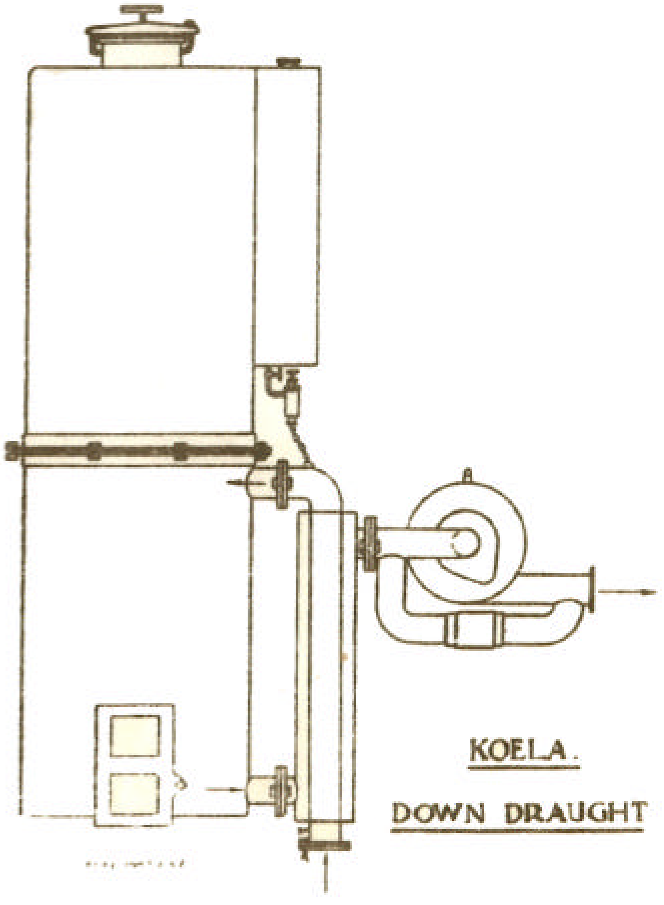


FIG. 14.

by passing upwards through an annular space between the refractory liner and the outside shell. This upper entrance to the fire zone is narrow; then the cross section expands rapidly through one fifth of its depth and contracts gradually through the remainder. The gas generated passes immediately to the coolers. The grate is spherical in shape and can be rotated by means of a shaft and handle projecting beneath the base of the generator. Doors give access to the fire and ash pan.

Koela.

The producer used for down-draught purposes is substantially as employed for up-draught operation (Fig. 14). The air-heating-gas-cooling arrangement is, however, reversed and a suction fan operated by hand or power drive is employed in place of the pressure type. The water supply is also fed into the top of the air inlet pipe and in counter direction to the air flow, whereas in the up-draught type the air and water flow in the same direction.

The majority of down-draught producers do not employ steam. Points of importance in regard to the design of down-draught producers include:—

1. The area of the combustion chamber;
2. Fuel depth;
3. Method and position of primary air feed.

(iii) *Cross-draught producers.*

In this type of producer the flow of air and gas is across the producer, though not necessarily in the same horizontal plane. The fuel flow is downwards.

The object of this design is to concentrate the combustion and reduction zones into a small space, the fire being in fact built up in concentric zones.

In this system gasification is achieved by admitting air at very high velocity into the fuel bed through a narrow water-cooled tube (blast pipe) or tuyere. This results in the development of high temperatures (2000° C. is claimed) in the combustion zone and rapid reactions.

These producers are characterised by their simplicity of construction and quick starting. The following makes of plant operate on this system:

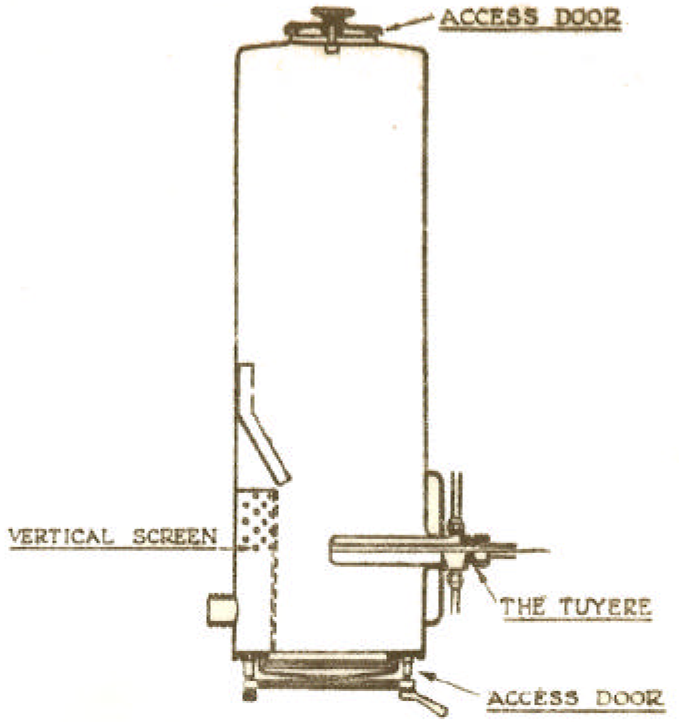
British: H.S.G.
French: Gohin-Poulenc, Dupuy.
Belgian: Bellay.

This type of producer uses charcoal, low temperature cokes and anthracite as fuel. The Gohin-Poulenc plant employs a mixture of anthracite and charcoal and this mixed fuel is recommended.

An examination of Figs. 15-17 will indicate the close relationship of the various cross-draught producers. There are, however, differences of detail and method of operation and these will be indicated in the text. The following brief description of four well-known makes will suffice to show the construction employed.

Gohin-Poulenc (Fig. 15).

This cross-draught generator of cylindrical form is designed to use charcoal, low temperature coke and anthracite, or preferably a special mixture of the first and last, upon which the performance is guaranteed. Only slight variations are desirable for the different fuels. No refractory liner is employed with this producer. The air is drawn into the combustion zone through a single small horizontal tuyere or blast pipe, and creates a very hot fire zone. The gas leaves by an orifice slightly lower and diametrically opposite the tuyere. This orifice is covered by a grille, the purpose of which is to hinder the passage of solid fuel along with the gas, while impeding the latter as little as possible. The most important part of this design is the tuyere, made of copper and bronze, between which water from the radiator is made to circulate. Even so, it burns away from time to time, but can be readily replaced. The cross-section of the tuyere, through which the air passes, is proportioned according to the power to be developed. Ash is withdrawn through a door in the base.

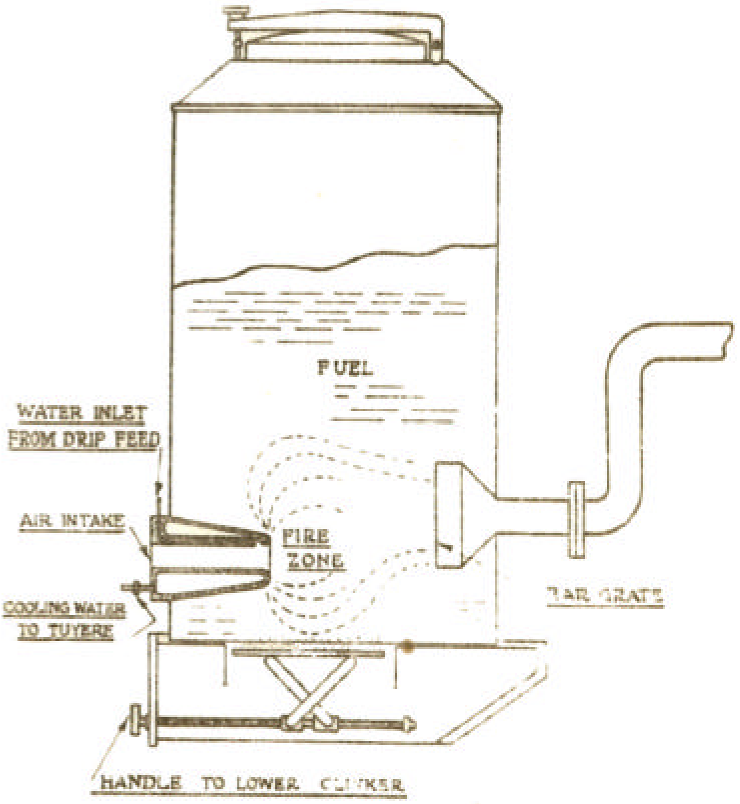


ARRANGEMENT OF GOHIN POULENC PRODUCER.

FUEL INST.435

FIG. 15.

This producer is widely used in France where it has been



H.S.G. PRODUCER.

FIG. 16

adopted by a number of vehicle manufacturers. Over 3,000 are said to have been sold.

Modified types of Gohin-Poulenc producers are available and the authors note patents by Gohin (22) dealing with a means for melting slag by arranging a nozzle with limited output below the main blast pipe. A water-sealed slag chamber is also provided together with means for cleaning tuyeres by means of a pricker. Other modifications include a poker arrangement universally mounted, a means for removal of slag, when the apparatus is stopped, by means of a cylindrical shovel which is introduced through a door and holds up the fuel while slag is removed. Apparatus is also provided for regulating the pressure of the gas generated.

The Latil modification of the Gohin-Poulenc includes a gas pipe from the tuyere up the side of the producer to save danger from blow back. No water is used in the plant.

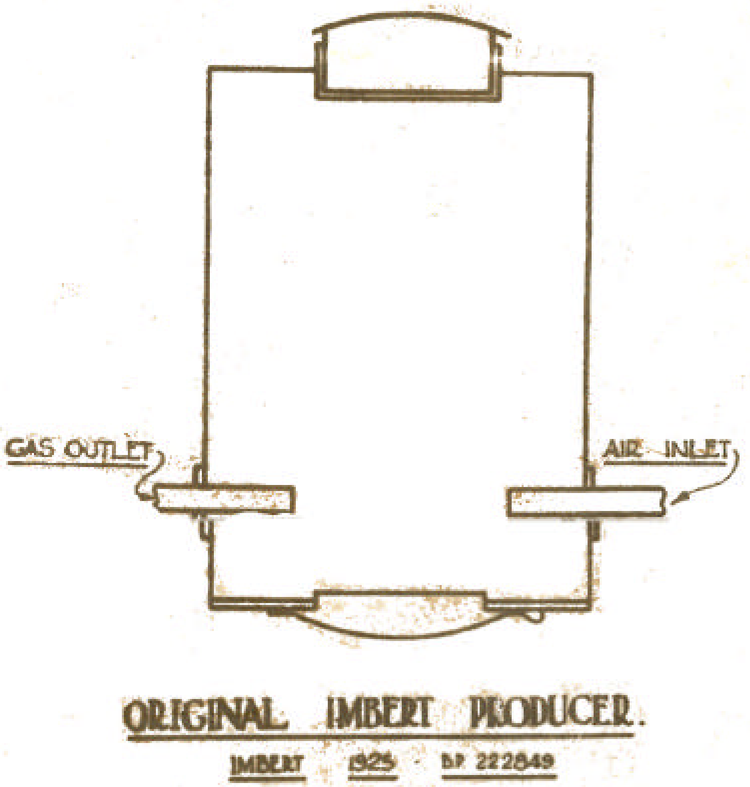


FIG. 17.
H.S.G.

The general form of the H.S.G. producer follows that suggested in the Imbert patent (Fig. 17) (10) and is not unlike the Gohin producer. Hartner-Seberich (17) draws attention to the general similarity of the cross-draught producers. In this case there are several modifications for which advantage is claimed.(23) The principal features are the unusual location of the gas exit above the air tuyere, and direct water injection carried in the air blast. The combustion zones take pear-shaped forms, the base being at the tuyere. There is not, as might be expected, a tendency for the fire to rise into the fuel hopper. As regards the water flow, this should preferably be too great rather than too small, when the power falls off noticeably. Any surplus falls into the producer base, where it remains as a reserve against a sudden demand on the producer.

Immediately below the tuyere is a platform which can be lowered by a handwheel outside the circumference of the generator. The handwheel actuates a spindle on which right- and left-hand threads are cut. Nuts connected to the platform by links, moving towards or apart from one another, raise or lower the platform. The platform extends only about half across the producer, and the whole assembly is carried in a drawer, the inner part having a top which still supports the fuel if the drawer is only half withdrawn. Thus it is claimed clinker can be withdrawn during a halt without emptying the remaining fuel from the hopper.

As fitted to a specially designed vehicle the producer is lit by means of a paraffin-soaked wick in the tuyere, the suction being made by an electric fan near the induction manifold. The fan is driven by the vehicle's battery.

During a test run the consumption of solid fuel (anthracite peas) was 157 lb., while 5½ pints of water was used. The water solid fuel ratio therefore was only 4.4 per cent.(24)

Dupuy.

The Dupuy producer is characterised by having a blast pipe which does not protrude into the generator in the usual manner.

The blast pipe is water-cooled and is fitted with a valve controlled by a connection to the gas throttle so that as the throttle is opened or closed the cross-sectional area of the air inlet is altered The object is to maintain a constant air velocity through the fire despite the varying load on the engine. The admission of secondary air is controlled by a valve mechanism also linked to the throttle. Another important feature is the provision of a movable platform which serves to support the fuel in the generator. The platform is provided with suitable gear so that the ash and slag can be lowered from the air inlet and gas exit from time to time. Through a door in the base that platform can be lowered until clear of the producer, so that clinker can be readily removed.

Bellay.

The Bellay producer is characterised by the water-cooled blast pipe being arranged in the form of a slot. Another interesting feature is the arrangement by the gas exit from the producer of an insulated carborundum block which is provided with a number of holes. This block becomes highly heated by the hot gases and serves to crack any tar which passes from the generator.

Points to be considered in relation to the design of cross-draught producers are mainly connected with the air inlet pipe and the gas outlet and may be summarised as follows :—

1. Their intrusion into the generator.
2. Their distance apart.
3. Diameters.
4. Relative distances between their axes and the distances from the bottom of the producer.

In regard to operation by cross-draught, it is claimed that the fire zones become concentric. Certain users of this system advise injection of water direct and contend that the use of steam in this type of producer is not advisable because steam rises and ultimately tends to drive the fire lower. It is also contended that steam is more easily drawn through the fire. Refractory liners are not fitted in cross-draught producers.

(iv) *Double-Draught and Double-Zone Producers.*

Double-draught producers work on the principle of the upper part of a bed of fuel burning downwards and causing volatile matter to be driven off, the volatile matter then passing through the upper incandescent zone of the lower up-draught part of the fuel bed, thus causing complete decomposition. Alternatively, in double-zone producers two fuel beds may be employed, these being arranged one within the other and separate fuel feeds being provided for each bed. The air supply may be downwards only through the outer bed, the hot gases then passing upwards through the inner fuel zone or alternatively two air feeds may be employed.

In double-draught producers the air flow may be arranged in two separate feeds both current-wise with the downward fuel flow, or one air feed downwards and the other upwards.

The design of these producers aims at taking advantage of the benefits of the up and down draught systems of operation

The following producers operate on this system :—

French : Brandt.
British : Koela.

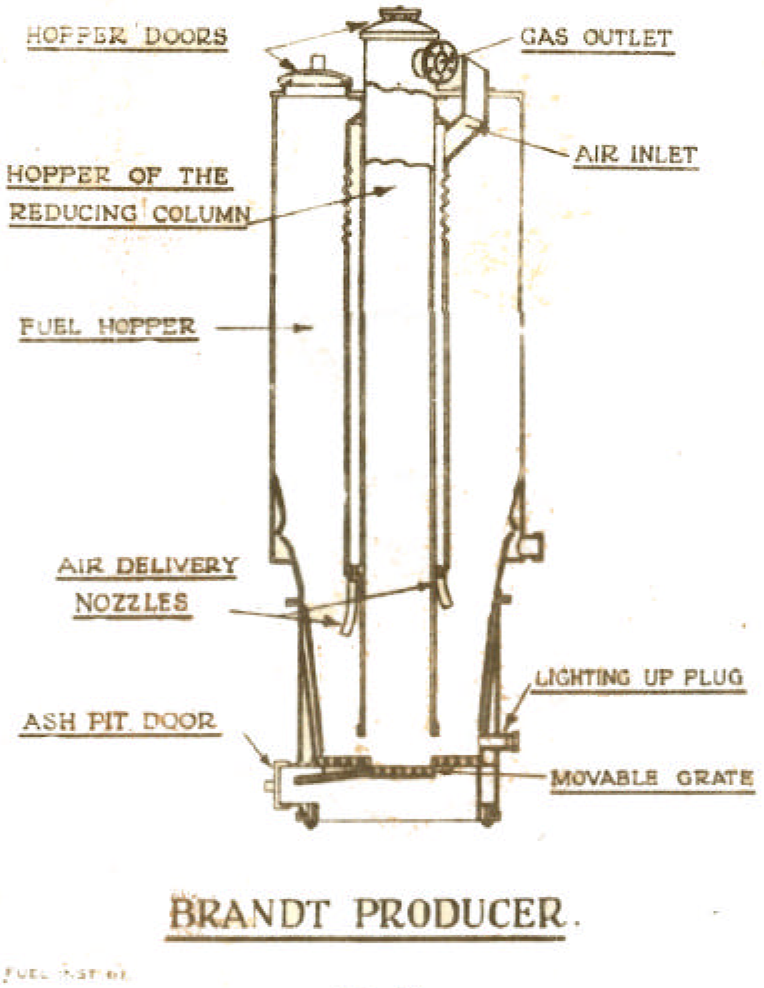


Fig. 18.

These producers are designed to use wood and charcoal, brown coal, brown coal char and tarry mineral fuels. The following brief description of these producers is not without interest.

Brandt (Fig. 18).

This interesting double-zone generator is designed to use wood, though a certain quantity of charcoal is also consumed simultaneously. The cylindrical producer shell has within it a second cylinder of approximately one quarter of the outside diameter. The inner cylinder contains charcoal, and between the two is wood. Immediately without the circumference of the inner cylinder is an annular space through which air is drawn from the top of the generator, and is delivered to the first fire zone by vertical tuyeres.

The air passes downwards through the wood towards the grate, the fire zone being insulated against heat loss both by a refractory liner and an air gap. The inner cylinder descends about four-fifths of the vertical distance between the tuyeres and the grate. Under its lower rim the gases pass, and then rise through the charcoal reducing column. A pure and clean gas is said to result from this construction.

The grate has a rotatable centre section, access to which (as to the ashpan) is obtained through a door on the circumference of the base.

A further novel feature of this design is the method of drawing off excess moisture, etc., during periods of light load. Tubing connects the outside envelope of the producer to the engine's exhaust pipe, the gas being led through a condenser. The passage of gas through this system is regulated by an automatic valve, the opening of which is made to depend upon the degree of suction or otherwise in the engine's inlet manifold. Moreover, a set screw in the valve itself regulates the degree of its opening, the setting being more open for resinous than for other woods.

Koela (Fig. 19).

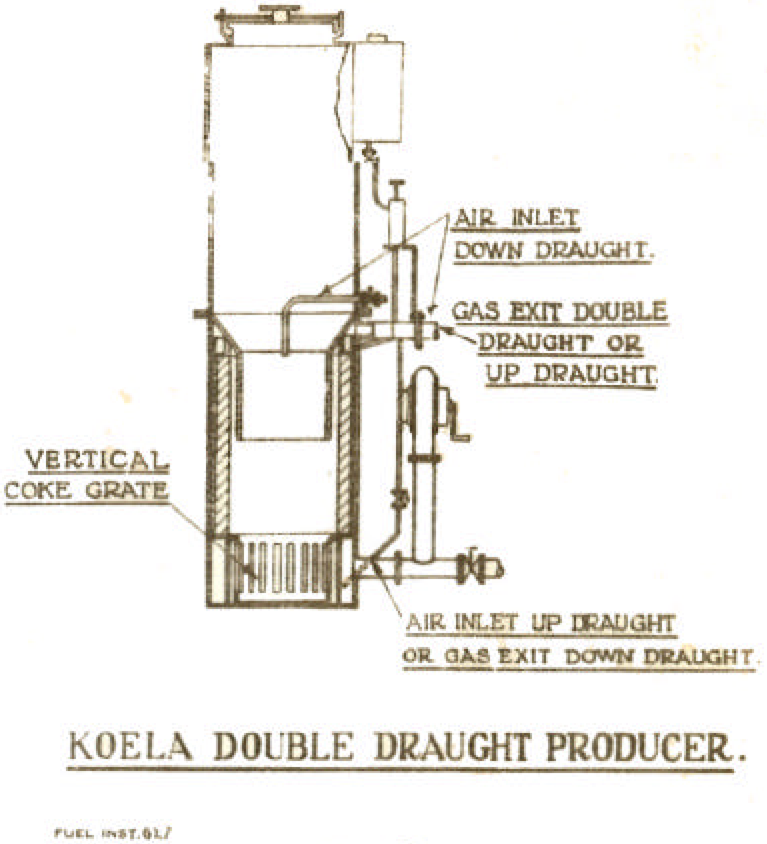
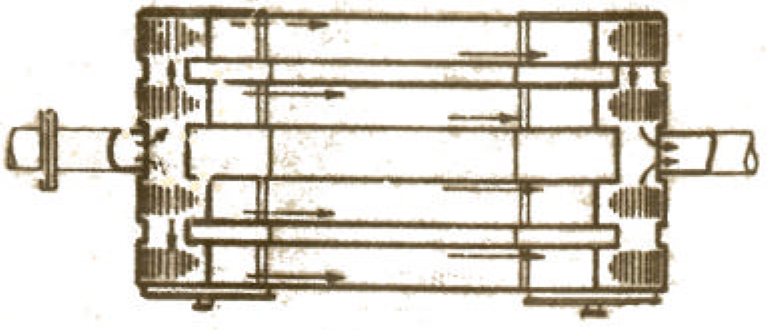


Fig. 19.

This generator comprises a circular combustion chamber lined with refractory material which rests upon an annular chamber. Within this chamber is a slide grate of which modified forms are available in order to enable different kinds of fuel to be used. The chamber is provided with slots in the side wall, through which air may be admitted for supporting the combustion when up-draught is employed or for gas withdrawal when down-draught is used. A pipe connection is made to the chamber for the passage of air or gas.

A fuel hopper is arranged over the combustion chamber and at the bottom is fitted with an inclined base which is provided with a tubular dependence or spout made of a special non-corrosive heat-resisting steel. This spout extends some distance into the combustion chamber and is of such diameter that a narrow passage is left between it and the refractory liner. The tubular spout acts as an upper or auxiliary furnace and is provided with a controlled air feed tube which passes through the hopper wall. The passage between the spout and liner communicates with a chamber surrounding the inclined base of the fuel hopper, and to this chamber there is connected a pipe



FIAT COOLER

FUEL INST 624

Fig. 20.

which serves for air entry when running double down-draught or as the gas exit when operating the plant on the combined up- and down-draught method.

Points of importance in regard to the design of double-draught producers are:—

1. The fire areas and depths;
2. The relationship of the fire zones to each other;
3. The positions of air entry and method of distribution;
4. Position of gas exit and its relation to the air feeds.

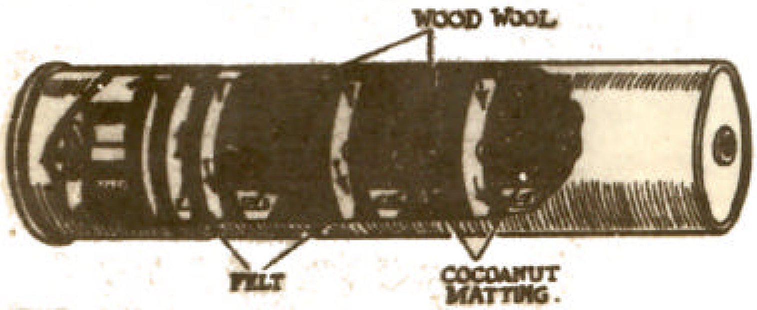
VI. Gas Purification

The composition and quantity of dust drawn from a producer depends upon the type of producer employed and the fuel used. At first attempts were made to employ the same types of cleaning apparatus as have been used with stationary plants. This was not altogether successful. Modern gas cooling and purifying plant as used with portable gas-producers is very varied, but comprises the following units (Figs. 20 to 24):—

(*a*) An expansion box or first dust separator;
(*b*) One or more cyclone or centrifugal separators;
(*c*) Cooling tubes or boxes;
(*d*) Baffle separators;
(*e*) Filtering and purifying apparatus.

(*a*) and (*b*) An expansion box is self-explanatory. The construction of cyclone or centrifugal separators is well known. This type of separator can be arranged singly or a number of cyclones can be built over a dust collecting chamber.

(*c*) Cooling tubes may be arranged as a battery with headers at each end, or built up vertically with several tubes provided with flanges or gills for air surface. Cooling boxes are circular or oblong in construction and are arranged with tubes passing through the box from end to end. Gas is led through the box, for which the tubes provide cooling. In some cases air can be drawn through the cooling box by connection to the exhaust. Another type consists of several D-shaped tubes set on their sides and superimposed over dust-collecting chambers provided with doors.

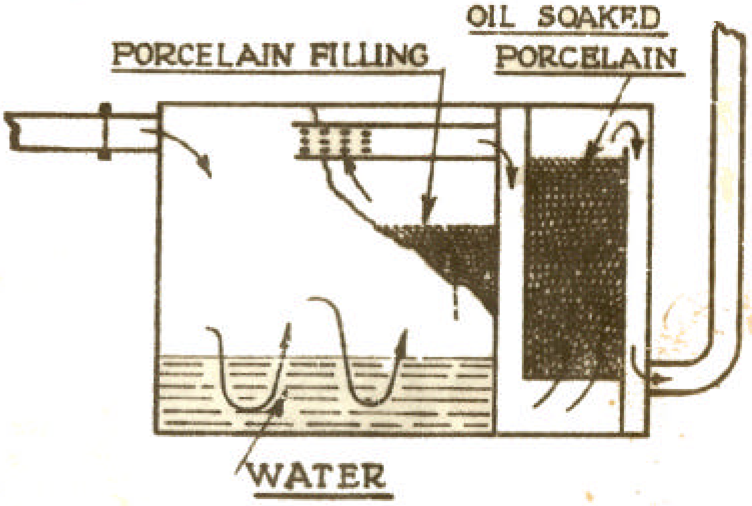


FUEL INST.651

Koela Dry Cleaner

Fig. 21.

(*d*) Baffle separators are still largely employed, although Hartner-Seberich ([17]) states that this type has lately lost some ground. This type comprises an oblong box or cylinder which can be arranged either vertically or horizontally. Plates are arranged within the box which causes the path of the gas to be frequently and suddenly changed, which results in the deposition of the larger solid particles. A particular type of construction resembles two venetian blinds set closely together, while others have vents so arranged in bulkheads that the gas has to follow a zigzag course.



WISCO CLEANER

FUEL INST. 628

Fig. 22.

(*e*) This type is varied and can be divided into four sub-sections:—

(i) Filtration in a scrubber moistened with water or oil;
(ii) Washing;
(iii) Light petroleum washing;
(iv) Dry filtration.

(i) Such scrubbers are filled with gravel or coke moistened with water; or sisal tow, wood wool, metal turnings or cork moistened with oil.

(ii) In such apparatus the gas on its passage to the engine is bubbled through oil or water, or passes over an oil or water chamber.

(iii) In such apparatus the gas passes through a scrubber filled with metal shavings moistened with light petroleum. Some of this is carried to the engine.

(iv) In such apparatus scrubbers are partly packed with coke, wood-wool, or wire-wool. They are cylindrical and about the size of the producer itself, and in the upper part, filtering cloth is stretched over frames in the form of filter bags or filter trays. An alternative arrangement is to have special filters built up of filtering cloth and wire gauze.

Complete portable gas-producers embody gas cooling, purifying and filtering equipment selected from among the types mentioned above in a variety of combinations. Two or more methods of purifying and filtering the gas can be embodied in a single plant—*e.g.*, the coke scrubber for primary, and cloth filter as secondary purifiers.

TABLE II

METHODS OF GAS PURIFICATION

Plant*	Expansion box.	Cooler.	Centrifugal or Cyclone Separator.	Baffle Separator.	Gas Reservoir.	Scrubber, Moistened.	Filtering and Purifying		No. of Units.	Final Filter.
							Washing, oil or Water.	Dry Filtration.		
Brandt	Yes, also acts as water separator (1)	Yes, tube, (2) gilled type.		Yes (3)	—	—	Yes, water combined with dry unit (4).	Yes, wire wool and cork (4)	Four.	
Fiat	Yes (1)	Yes (2)	—	—	—	—	—	Yes, cloth (3)	Three.	—
C.G.B.	—	—	—	Yes (1)	—	—	—	Wood wool, wire wool and cloth (2)	One.	—
Gohin-Poulenc ...	—	—	—	Yes (1)	—	—	—	Yes, cork and cloth.	One.	—
Hansa	—	Yes (3)	—	Yes (1)	—	—	Yes, water. (2)	—	Two or three.	—
Humboldt-Deutz...	—	Vertical tube with condensed water box.	Yes, one or two. two.	—	—	—	—	Yes, cloth.	Three.	—
H.S.G.	—	Yes, tube (2)	—	Yes (1)	—	Yes, Sisal tow may be moistened oil. (3)	—	—	Four.	Final oil washer.
Imbert	—	Condenser (2)	—	Yes (1)	—	—	—	—	—	—
,, Berliet ...	—	Yes, tubes which also serve as dust boxes.	—	—	—	—	—	Yes, cork material washed out with water.	Two.	—
,, Westwaggon	—	Yes, tube, flanged.	Yes, one.	—	Yes.	—	—	Yes.	Four.	—
,, Hardrich ...	—	Yes, tube, flanged.	Yes, in producer unit.	—	—	—	—	Yes, cloth.	Incorporated in producer unit.	
Koela	Yes (2)	Heat interchange device (1)		Yes (3)		Yes, but depends on fuel. (4)	Yes, but depends on fuel (4)	Yes.	Two or three.	Final oil washer or cloth-wire filter.
Malbay	Yes (2)	Yes, tube (1)		—	—	—	—	Yes, cloth.	Two.	—
Panhard	—	Yes, tube (1)	—	—	—	—	—	Yes, coke (2) and cloth (3)	Two.	Wire.
Sabatier-Décauville	—	Yes, tube (1)	—	—	—	—	—	Cloth (2)	Two.	—
Svedlund	—	Yes, tube (1)				—	—	Yes.	Two.	—
Wisco : Charcoal ...	—	—	—	—	—	Yes, porcelain chipping and moistened oil (3)	Yes, water (1)	Yes, porcelain chipping (2)	One.	—
Anthracite ...	—		Yes (1)	—	—	Yes, ditto.	Yes, ditto. Level automatically maintained.	Yes, ditto.	Three.	—

NOTE : The numbers indicate the sequence of units.

In certain cases, the required quantity of air necessary for combustion in the engine is mixed with gas before passing through a final filter close to the engine. Such filter may take the form of oil wash or be of the dry type, including filtering cloth or wire gauze. This ensures a clean air-gas mixture and also encourages an intimate mixture of air and gas before the engine is reached.

As regards dust separation, Rosin (25) points out that the velocity of free fall of particles is of significance for the separation of dust from gas, whether in cyclone or settling chambers.

A particular arrangement can be made in which the producer and purifier is combined. Such a unit is the Härdrich plant. This plant is built in one unit with the purifying apparatus concentrically around the fuel hopper. The purification is in two stages, first, a centrifugal separator, and secondly, a cloth filter.

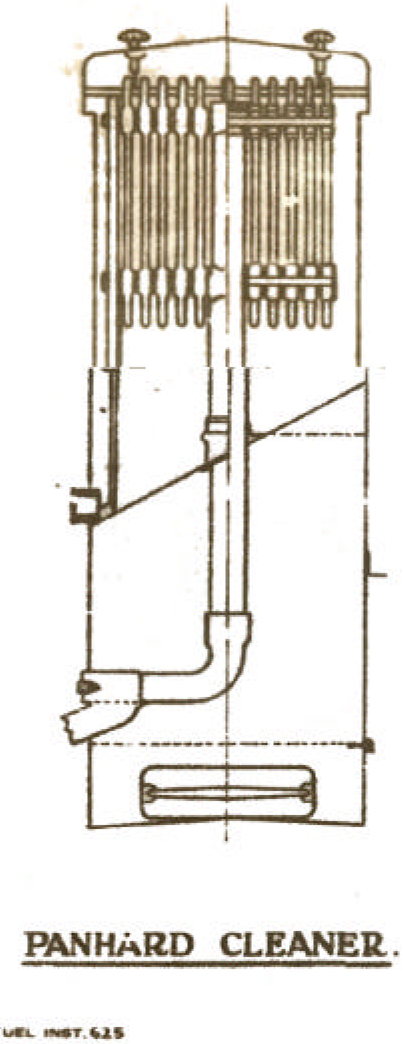


FIG. 23.

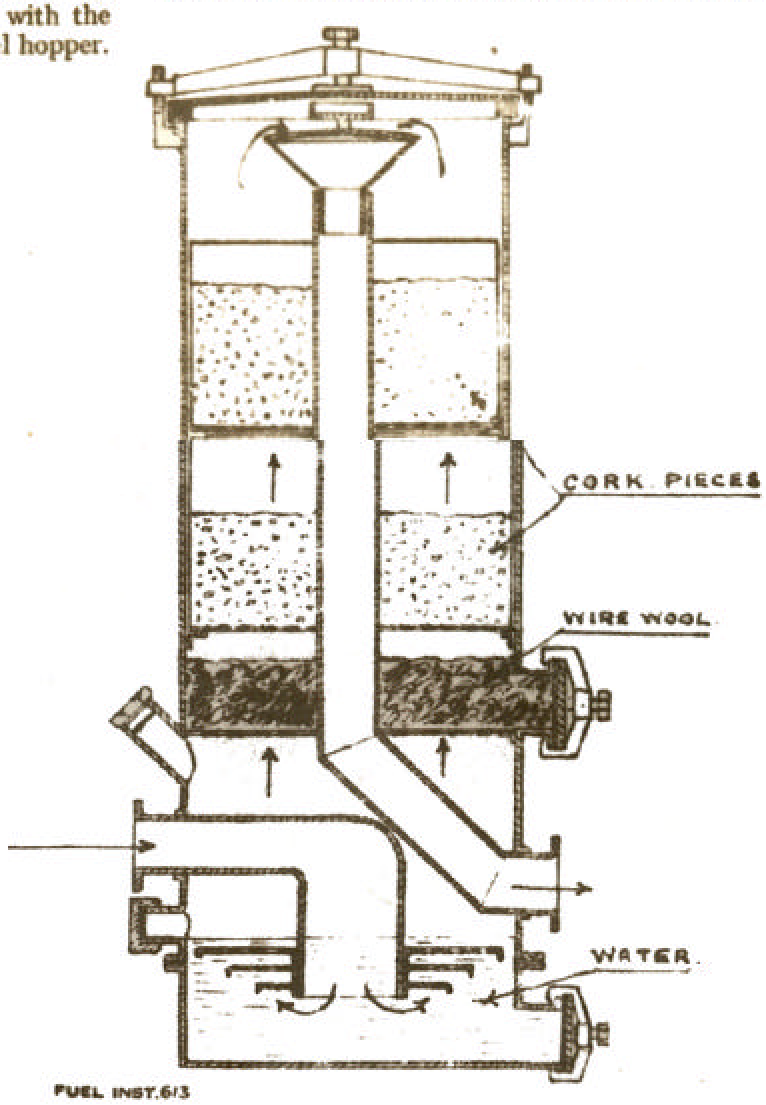


FIG. 24.—*Brandt Gas Purifier.*

In general, it can be said that the time required for cleaning out these filters has been reduced, while cooling is improved and purification made more effective, during the last few years.

It is noticeable that cloth filters are rarely employed in cases where water or steam is used for gas generation. Dust in the presence of moisture tends to form a paste on cloth filters and so they quickly clog. It is consequently desirable that the gas should be dry before a cloth filter is employed in the system.

Gohin states his opinion that the use of water for gas production is undesirable on account of silica formation, according to the following reactions :—

$$Si + 2H_2 \longrightarrow SiH_4$$
$$SiH_4 + H_2O \longrightarrow SiO_2 + 4H_2$$

Gohin points out that the removal of silica is especially troublesome and throws heavy work on the purification system.

The Sabatier-Decauville cloth filter and a Koela filter are of particular interest, since they can be very readily cleaned. In the Sabatier filter it is possible to clean the cloths by means of brushes carried about them on a shaft which can be moved from outside the filter without opening it. In the Koela purifier, the baffle separators and filter media are built up on a central shaft. By releasing two wing nuts the entire filter assembly can be drawn from the shell, sweeping out dust deposit, etc., the filtering medium dedusted and the whole assembly replaced in a few minutes.

It is desirable for the gas to be as cool as possible, so that each charge of a cylinder may contain the maximum heat value, since the loss of volumetric efficiency on an engine using producer-gas would be increased if the air-gas mixture were at a high temperature. Moreover, cooling devices are of particular importance when high water/solid fuel ratios are used, as they then act as condensers for any undecomposed steam. Table II summarises the gas cleaning equipment employed in conjunction with various types of gas-producer.

VII. Fuels : Characteristics and Distribution

The fuels used with portable gas-producers are as follows: wood charcoal, raw wood, peat charcoal, lignite or brown coal, low temperature coke (semi-coke), and anthracite. Mixed fuels are also used, *e.g.*, a mixture of anthracite and charcoal is employed in the Gohin-Poulenc. Other materials tested for the purpose include raw coal, waste hops, cotton seed, waste tan and bagasse.

Rämmler (20) draws attention to the advantages coke and anthracite have on account of their high weight for unit volume. (See Section IX.)

Factors in connection with fuel which influence performance and are therefore of considerable importance are:

(i) reactivity
(ii) size and grading
(iii) moisture content
(iv) ash
(v) volatile content

Performance on different fuels is shown in Fig. 26.

(i) *Reactivity.*

Reactivity is an important factor in the rate of conversion of carbon dioxide to carbon monoxide, during the chemical reactions which take place in a gas-producer. This rate of conversion decides the size of generator and depth of fuel bed for a given output or specified fuel and has a direct bearing on the flexibility of the plant. Reactivity also affects the temperature and consequently the gas composition when steam is used. It is not without interest to note that only the Koela designs make provision for different depths of fuel bed for use with various fuels. The authors are unable to find any comparative records of determinations of the reactivity of low temperature coke, but tests have, however, been carried out with various beehive and metallurgical cokes (26)—the reactivity value being taken as the number of ml. of carbon monoxide formed from 100 ml. of carbon dioxide. The test temperature employed was 950° C.

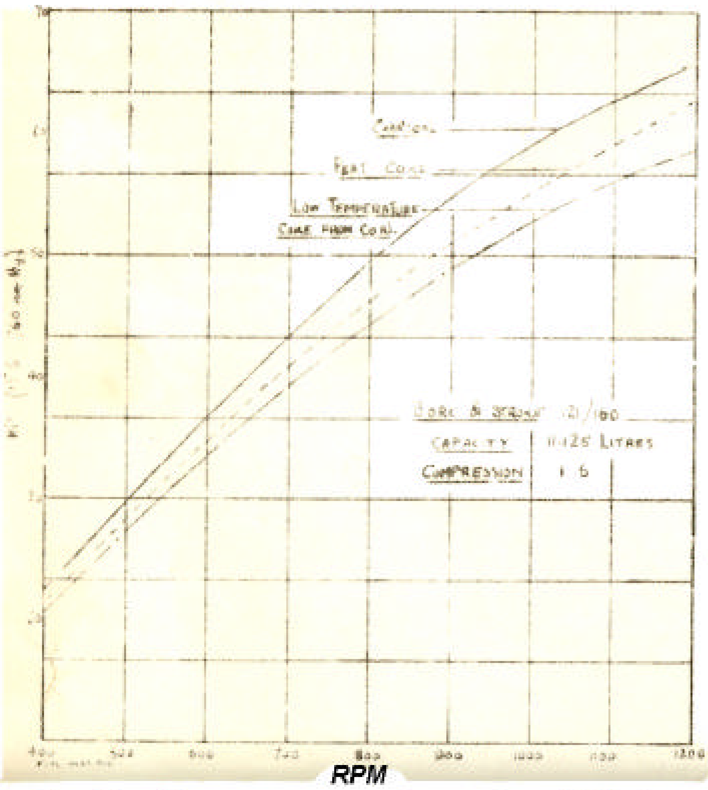


FIG. 26.—*Power curve, comparing various solid fuels.* (*Wisco.*)

Reactivity can be expressed as the solvent resistivity to carbon dioxide.

Koppers and Jenkner (27) take charcoal as a standard for reactivity and give the comparative figures as 180 for charcoal and 80 for gas coke.

Rämmler (20) states that reactivity, generally speaking, goes with the age of the fuel. Thus wood is highest and anthracite lowest. This also obtains for coke derived from particular coals, but there may be variations in detail due to driving off part of the volatile constituents.

It has been observed that reactive cokes removed from a generator after use are blackened to a greater extent in the case of the more reactive kinds. This has been found to be a surface phenomenon, but is worthy of note.

Tests on beehive cokes (26) indicate that reactivity value is not materially influenced by the size of fuel. Mezger (28) asserts that structure of surface (which is dependent on the number of grains) influences reactivity. He also states that the character of coal and the carbon modification, whether amorphous or graphitic, are most important.

In regard to reactivity, this is capable of improvement, and various processes have been used for the purpose, including treating with lime and sodium carbonate and heating up to 600° C. and treating with steam. Other methods include increasing reactivity by heating the carbonaceous substance with a potassium salt such as potassium phenolate. Potassium is better than sodium. Treatment with zinc chloride is also suggested.(29)

(ii) *Size and Grading.*

Size of fuel plays a part because it has an influence on the velocity and the course of the chemical reactions which take place in the gas-producer. Uniform sizing is desirable, but if limits are given not more than 10 per cent. of under or oversize should be present.

The fuel size must also be considered because the resistance of the fuel bed should be as small as possible in view of the fact that producers work by engine suction. Small fuel increases the resistance.

The character and size of fuel are stated by Baume and King (30) to affect the fire depth required for the best results.

Grading is also of importance because even-sized fuels overcome channelling and inequalities of draught resultant from uneven fuels. Channelling allows air to traverse the fuel bed without contact, and this air is liable to burn part of the carbon monoxide in the upper section of the generator, resulting in carbon dioxide and poor quality gas. Rosin (25) states that with high velocities and decreasing particle size the single grain is lifted by the stream and carried away—the fuel bed becomes unstable and the finer particles are blown out.

The influence of fuel size on gasification efficiency is worthy of investigation, and according to Rosin (25) little is known of the physical aspects involved in the heating of a particle of coal or a layer of particles and still less of the influence of particle size.

(iii) *Moisture.*

It is generally understood that for gas-producer fuels it is advisable to keep the moisture content as low as possible, and one company suggests 5 per cent. maximum as a standard; but this figure is not hard and fast.

High moisture content reduces the thermal efficiency of the up-draught producer, since heat is used to drive off the water. In down-draught plants the moisture in the fuel is converted into steam, and drawn down through the fuel bed where it is wholly or partially split up into its constituents. Since the moisture content is variable and not controllable, uneven operation and varying gas quality often results.

According to Rosin,(25) voidage—that is the interspaces not filled with solid fuel—is always larger with wet fuel than dry, the reason being that moisture loosens the packing density.

When using raw wood as fuel the greater part of the steam is evolved without taking part in the reaction with consequent thermal losses. It therefore follows that the mobile producer using wood is an apparatus with an uneven thermal balance and a low working temperature which favours the formation of carbon dioxide (31).

The facts stated above indicate that reasonable care must be taken to ensure that the moisture content of a fuel used with portable gas-producers should approximate to a standard if consistently good results are to be achieved.

(iv) *Ash.*

The Inter-Departmental Committee Report of 1919 on "Gas as a Source of Power" laid it down that coke for use in gas-producers should not contain more than 12 per cent. of ash and 6 per cent. of moisture.(32)

Since 1919 considerable progress has been made in the process of washing and cleaning coal before carbonisation, with the result that cokes with guaranteed ash content of less than 5 per cent. are available for use in portable gas-producers.

In the gas-producer field low ash content assists easy operation, increases the vehicle range without cleaning, and makes possible a greater mileage per hopper charge. The fusion characteristics of the ash are also of importance.

For gas-producer purposes suitable fuel is necessary, and the efforts made by certain carbonisation concerns (33) to achieve this are highly commendable.

In so far as ash content is concerned, raw wood and wood charcoals have a decided advantage, the ash being normally from 0.75 per cent. to 2.5 per cent. Clinker formation is rare. In the case of certain Indian woods—*e.g.*, Dindigo, Beete, etc.—ash contents of these charcoals are high, and such timbers are not suited for charcoal manufacture.

The ash from mineral fuels may be troublesome, and in up-draught producers provision is made to overcome clinkering by means of special types of grate. Provision is also made in some plants for the easy removal of clinker, the formation of which depends to a great extent upon the composition of the fuel and the system upon which the generator is operated. It is obvious that generators like the cross-draught which claim to work at the very high temperatures, up to 2000° C., will require greater clinker safeguards than a plant working under more normal maximum temperature conditions of 1000° C. to 1350° C. for mineral fuel.

In this connection it may be of interest to record that the ash of an important low temperature coke slags at 1300° C. to 1400° C.

(v) *Volatile Matter.*

The volatile content is of considerable importance because of its influence on the time required for starting up and the gas quality obtained from the fuel. Consistent with the elimination of tarry matter volatile content can be as high as possible. The low-temperature cokes available on the market are usually consistent and have volatile matter ranging from seven to as high as 18 per cent.—the latter figure being that given by a coke made by rotary retort process from soft coal. High volatile content implies a tar content. If more than 1 gm. of tar per kg. of fuel is present, special tar-extractors should be incorporated in the producer equipment.

The volatile matter in wood charcoals covers a wide range and may be anything from 3 to 30 per cent. and over.(34) In general, fuels containing over 20 per cent. should be used in down-draught producers, but even in this case the method of manufacture should be taken into consideration. Modern stationary retort fuel, for example, is fairly consistent in regard to volatile matter, but the same thing cannot be said about heap burnt or portable retort fuels.

(vi) *Natural Fuels : Wood.*

Composition: of air-dry wood used in portable gas-producers :—

	Per cent.
Carbon	40
Hydrogen	4.8
Oxygen	34.4
Ash	0.8
Water	20
Calorific value	8250 B.Th.U.s per lb.

Size of fuel used : 2 cm. × 2 cm. × 3 cm. up to cubes 60 cm. × 60 cm. × 60 cm. roughly chopped.

Characteristics: Raw wood varies to a considerable extent and moisture content is uncertain. There can be no fixed standard for the moisture content of freshly felled wood, but that after the wood has remained in store for a certain time—about 12 months after felling—the moisture content of the different species becomes adjusted to a fairly constant figure—approximately 20 per cent. Schubler and Hartrey found the moisture content of freshly cut wood varied from hornbeam, 18.6 per cent., to black poplar, 51.8 per cent.(35) For producer operation oak is preferred.

Starting up with raw wood takes longer than with other fuels and vehicles have low range per producer charge or large hopper capacity is necessary.

(vii) *Natural Fuels : Anthracite.*

The principal deposits are in South Wales and the fuel is of high quality. This fuel is now graded and classified for industrial purposes. Typical approximate analyses of anthracite, as used for portable gas-producers :—

	Anthracite peas, $\frac{3}{8}$ in.–$\frac{1}{4}$ in. Per cent.	Anthracite A.1 $\frac{1}{4}$ in.–$\frac{3}{16}$ in. Per cent.
Volatile matter	7.2	5.3
Ash	4.2	3.5
Moisture	2.5	5.0
Fixed carbon	86.1	86.2
Calorific value, B.Th.U.s (dry basis)	14,450 per lb.	14,850 per lb.

Size of fuel usually employed : $\frac{1}{4}$ in. to $\frac{1}{2}$ in.

Characteristics : Usually takes longer to start up than charcoal or coke, but gives good results when in operation. Has the great advantage of enabling a producer to run for about three times as long per charge as the other fuels owing to the quality of heat available per unit volume.

In the case of anthracite up- or cross-draught producers are generally used. The high temperatures necessary with this fuel induce slagging, which is reduced in the up- as compared with the cross-draught.

(viii) *Manufactured Fuels : Charcoal.*

The manufacture of wood charcoal is an ancient industry. This fuel is still manufactured by burning wood in forest heaps and it is also produced by means of portable charcoal kilns or in large stationary retorts with by-products recovery plant. Charcoal is largely used on the Continent in the form of briquettes, which have the advantages of even size, low moisture content (3 per cent.), resistance to crushing, cleanliness and even quality.

Clarke Jones (36)—recently reviewed the subject of charcoal manufacture.

Typical approximate analyses of wood charcoals as used for portable gas-producers :—

1. *Native burned.*—Mixed forest wood, Kenya.

	Per cent.
Volatile matter	5.38
Ash	2.53
Moisture	6.67
Fixed carbon	85.42

Calorific value, B.Th.U.s per lb., 13,464.
Weight per cub. ft. loosely packed, 17.8 lb.

2. *Heap burned.*—Yaruru wood, British Guiana.

	Per cent.
Volatile matter	19.3
Ash	1.82
Moisture	5.58
Fixed carbon	73.3

Calorific value, B.Th.U.s per lb., 12,960.
Weight per cub. ft. loosely packed, 24.25 lb.

3. *Stationary retort* (modern).—English mixed hardwoods.

	Per cent.
Volatile matter	18.6
Ash	2.0
Moisture	4.4
Fixed carbon	75

Calorific value, B.Th.U.s per lb. 13,860.
Weight per cub. ft. loosely packed, 16 lb.

Size of fuel usually employed : ⅜ in. to ¾ in.

Characteristics : This fuel is highly reactive and gives easy starting, satisfactory flexibility and excellent power. Quality, however, is not very consistent and varies according to the method of manufacture and the soil in which tree is grown. The fuel is best prepared from one kind of wood only per batch. Hardwoods are most suitable because the charcoals are not so friable and being heavier give more miles per charge. The range of a vehicle per fuel charge varies considerably because the weight per cub. ft. of charcoal ranges from 14 to 26 lb.

(ix) *Manufactured Fuels : Low-Temperature Coke.*

This fuel is manufactured by the carbonisation of coal at temperatures ranging from 425° to 600° C.[37] Various systems are employed to carry out the process of carbonisation, which include the use of vertical static, horizontal layer type, and rotary (internally and externally) heated retort processes.

Typical approximate analyses of low-temperature cokes as used for portable gas-producers :—

Internally heated rotary retort.	Per cent.	Externally heated vertical retort. (Gaspro)	Per cent.
Volatile matter ...	16.6	Volatile matter ...	8.32
Ash	3.7	Ash	5.08
Moisture	4.5	Moisture	4.12
Fixed Carbon ...	75.2	Fixed carbon	81.6
Calorific value, 13,224 B.Th.U.s per lb. (dry basis).		Calorific value 14,200 B.Th.U.s per lb.	

Size of fuel usually employed : ⅜ in. to ⅝ in.

Characteristics : Gives more miles per charge than charcoal, but starting up takes longer. In general, the higher the volatile content the better the result. The limit is reached at 1 gm. per kg. Cokes made from soft non-coking coals usually give the best results. Low-temperature cokes are best used in up- or cross-draught producers. High temperatures induce slagging and this is reduced in up-draught generators as compared with the cross type.

(x) *Manufactured Fuels : Brown-coal and Peat-char.*

(a) *Brown coal.*—This fuel can be used as char or briquettes. In the form of char the fuel is reactive and gives easy gasification, but has a high ash content which is subject to clinkering. Brown-coal char is, therefore, best gasified in an up-draught generator with horizontal grate provided with shaking mechanism to handle the high ash content. A generator used with this fuel is the "Voigt," which is an up-draught type, but is also provided with a water-jacket surrounding the combustion chamber so that an ample supply of steam can be passed to the generator in accordance with the practice much favoured in Germany. In order to use brown coal briquettes a modified Gohin-Poulenc plant has been employed with two water-cooled tuyeres placed side by side. The gas, however, requires careful condensation and washing before use. The following is an approximate analysis of brown-coal char :—

	Per cent.
Volatile matter	12.47
Ash	10.30
Moisture	3.02
Fixed carbon	74.21

Calorific value, 12,040 B.Th.U.s per lb.

(b) *Peat.*—This fuel in the raw state contains a large percentage of water. It can be carbonised—*e.g.*, by the Ziegler process—and the residual solid used as fuel for gas-producers. For use in portable gas-producers peat charcoal is usually converted into briquettes.

The following is an approximate analysis of peat charcoal briquettes :—

	Per cent.
Volatile matter	7.6
Ash	4.8
Moisture	3.6
Fixed carbon	84.0

Calorific value, 12,800 B.Th.U.s per lb.

(xi) *Distribution of Fuel.*

It will be appreciated that there are ample suitable fuels available in Great Britain. However, the utilisation of solid home-produced fuels is to some extent held back in this country by the relative difficulty of obtaining supplies by comparison with liquid fuels already in great demand. The users of electric battery and compressed gas vehicles have to face this problem also, but by reason of the restricted sphere of usefulness of these types the problem is more easily solved.

In the case of gas-producer vehicles, the economy effected is so great that the oil and coal companies should certainly take advantage of the demand for solid fuel. The oil companies have a most extensive and efficient organisation for reaching their customers on the road. The coal industry also has a widespread distributing organisation, though it cannot serve a customer on the road with quite the same ease. Since the fuel is primarily coal, some form of co-operation is desirable both from the standpoint of the user and the gas-plant manufacturers. Moreover, it is likely to be increasingly profitable to both as the utilisation of gas-plants for road transport and power agriculture develops.

The fuels involved in Great Britain are principally anthracite and low-temperature coke ; also possibly in the future dry steam coal, carbonised peat and charcoal. It has been estimated that 700,000 tons of low-temperature coke and 500,000 tons of anthracite can be made available annually for use in gas-producers without disturbance of supplies to other users. It should be emphasised that this would be an entirely new outlet for both of these fuels.

The standardisation as regards analysis, reactivity, size and size ratio of fuels should also be undertaken, and in principle the desirability of standardising the most suitable gas-producer should be recognised by the producer manufacturers. In both these respects the formation of the Transport Producer-Gas Plant Makers' Association is to be welcomed by users and fuel interests alike.

On the Continent the distribution of standardised fuels is undertaken. In Sweden it is undertaken under the supervision of the State; in France the State is interested in the production of "carbonite," a standardised fuel, and the report by M. Baron (38) emphasised its importance. The Gohin-Poulenc organisation, through existing distributors, supply a standardised fuel (a mixture of charcoal and anthracite) in suitable containers. In Germany dried wood of suitable size is available at numerous filling stations.

In Great Britain, by reason of the control exercised over road transport by the Traffic Commissioners, a small number of solid fuel filling stations would suffice for the majority of users in this country. Most vehicles either operate from a given base on known runs or within a circle of known (and often small) radius. The percentage of vehicles liable to go to any part of the country at short notice is therefore small.

VIII. Gas Produced in Portable Plants

(i) *Analyses of the gas generated* by various plants are given in Table III.

As the result of tests carried out with producer-gas plants, the U.S.A. Bureau of Mines (39) gave the average calorific value as follows:—

Up-draught	151 B.Th.U.s cub. ft.
Down-draught	123 B.Th.U.s cub. ft.

Finkbeiner (40) gives the following interesting figures relating to the gas quality from various fuels with up- and down-draught producers:—

	CO	H_2	CH_4	CO_2	O_2	N_2
Charcoal						
Up	30.8	12	0	3.6	0.4	53.5
Down ...	23	14	0.9	7.0	0.2	54.9
Anthracite						
Up	29.3	6.8	1.6	1.4	0.3	60.6
Down ...	22	12.0	1.1	6.0	1.0	57.9

In this connection the views of Rämmler (20) are that with charcoal on the up-draught system a somewhat higher power is obtained than with down- or cross-draught generators. The result (of up-draught) is better gas formation and there is smaller resistance in the producers and cleaners.

The factors which influence quality of gas produced are dealt with in Section III.

The gas generated by an Imbert producer from raw wood consists of 23 per cent. CO, 17.5 per cent. H_2, 1.5 per cent. CH_4, 7.5 per cent. CO_2, and 50.5 per cent. N_2, the calorific value of which is given as 1,200 to 1,350 K.cal.m^3. A test carried out with a Koela producer on a brown-coal char gave a gas of the following composition:—

	Per cent.		Per cent.
CO_2	3.3	H_2	10.8
O_2	0.8	CH_4	2.8
CO	27.2	N_2	55.1

Water fuel ratio employed, 0.31 lb./1.0 lb. fuel.

(ii) *Exhaust Gases.*

The exhaust of a petrol operated internal conbustion engine may contain upwards of 10 per cent. of CO, the exact figure depending upon the completeness of the combustion. Sample figures for three fuels (petrol, diesel oil and producer-gas) are set out below:

	PETROL.		DIESEL OIL		PRODUCER-GAS.	
	Complete combustion	Incomplete combustion	Light load.	Full load.	Anthracite.	Charcoal.
CO_2	12%	7.8%	5.8%	13.2%	14.6%	17.3%
CO	0.6%	10.5%	—	0.6%	0.6%	0.5%
O_2	0.2%	0.2%	12.4%	1.4%	0.4%	0.8%

In dense traffic or when stationary, the exhaust of a petrol vehicle will contain more carbon monoxide than it would when running steadily on the open road. Thus, in circumstances where there is the greatest danger to public health—*i.e.*, in towns, there is the greatest proportion of carbon monoxide present.

In the case of the diesel vehicle, rapid changes of load may result in a very dirty exhaust causing an unpleasant rather than a dangerous atmosphere.

In the case of producer-gas the exhaust is always clear, and in no case contains more than 1 per cent. of carbon monoxide.

Harmful concentrations of carbon monoxide exist when more than 0.3 per cent. is present in air. The capacity of the petrol engine fitted to the average 1½ to 3 ton chassis is about 200 cub. in. Thus at 2,000 r.p.m. (if the exhaust contains 10 per cent. CO), as much as 3,850 cub. ft. of air per minute would be rendered dangerous to human health. This figure in terms of the growing traffic in city streets might well become serious, especially in dense traffic stops.

IX. Fuel Consumption

Figures in Table III and from other sources show that the consumption per b.h.p.-hour of solid fuel differs according to the type used and the design of generator in which that fuel is gasified. In general it can be said that the consumption by weight varies inversely as the calorific value per unit weight of a particular fuel, the specific consumption being decreased to a greater or lesser degree by the addition of steam according to the thermal efficiency of gasification in a particular producer. The engine design also influences the specific consumption.

The consumption is, as a rule, about 1 lb. per b.h.p. hour.

The importance of a low solid fuel consumption lies not so much in the additional monetary saving thus possible, but rather in the saving of space and weight of one particular fuel by comparison with another against that of a petrol or diesel vehicle of the same capacity and radius of operation. The consumption depends upon the fuel; and, similarly, the size and weight of a producer, for a given output, on the fuel. In most cases of low specific fuel consumption the size and weight of the producer equipment is correspondingly small. In this connection Rämmler (20) states that anthracite occupies only 1.5 times the space of the corresponding amount of petrol, low temperature coke 2.6 times, and wood 10 times. The ratio of weights are: petrol, 1; wood, 3.3; charcoal and anthracite, 1.5; low temperature coke, 2.4.

The following figures give some examples of the consumption of producer gas vehicles:—

TABLE IV.

Vehicles.	Unladen Weight.	Gross Weight.	Fuel.	Consumption per 100 miles.
Lorry ...	6.9 tons	13.8 tons	Wood	400 lb.
,, ...	5.8 ,,	10.7 ,,	Charcoal	162 lb.
,, ...	4.2 ,,	6.7 ,,	Anthracite	118 lb.
Omnibus	6.7 ,,	27 passengers	Charcoal	230 lb.
Lorry ...	1.75 ,,	3.25 tons	Charcoal	99 lb.
,, ...	1.45 ,,	3.0 ,,	L.T. coke	108 lb.
,, ...	2.2 ,,	4.55 ,,	L.T. coke	98 lb.

Tested with a Koela producer on a light tractor showed that where consumption had previously been 3½ gallons of petrol, 43 lb. of low temperature coke were used per acre.

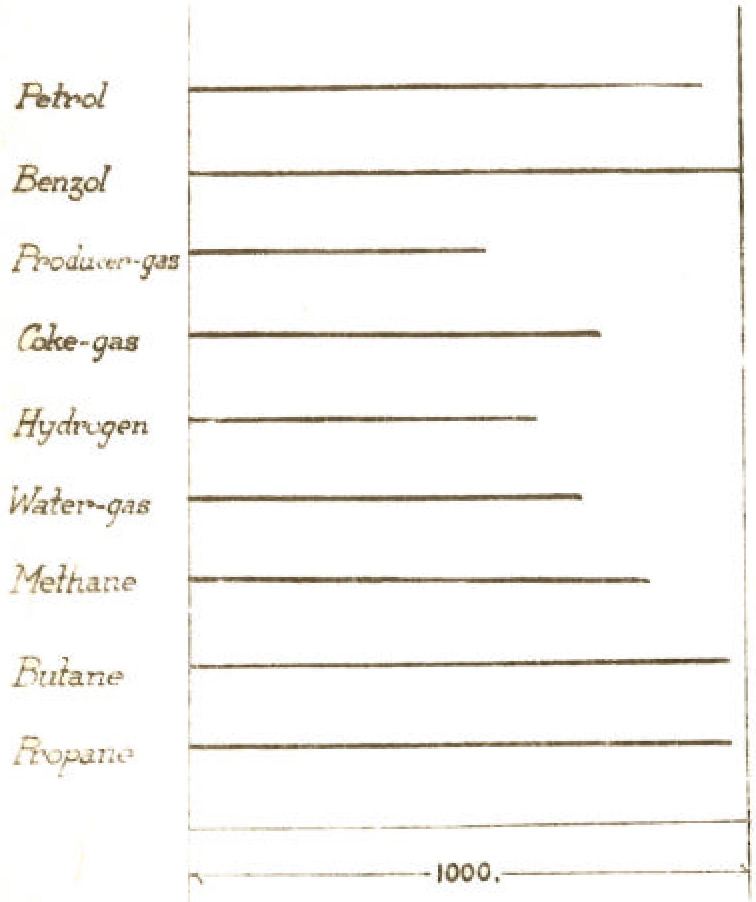
The Interdepartmental Committee on Gas Traction in 1919 gave figures of 2.2 ton-miles per lb. of anthracite and 1.8 ton-miles per lb. of coke. Comparison of these with those above is some indication of the progress which has been made.

X. Engine Design

(i) *The Significance of Power Loss.*

Main (41) and Fiebelkorn (42) have drawn attention to the generally admitted loss of power of an unmodified petrol engine using producer gas. This loss theoretically amounts to some 30 per cent., and in practice in some cases goes as high as 50 per cent. Fiebelkorn illustrates this by a sketch showing calorific value of the mixture in the induction manifold, derived from various fuels. There are, of course, also differences between various solid fuels (Fig. 26).

TABLE V



In estimating the importance of this power loss to the lorry operator, the reserve of power now provided by most vehicle manufacturers in their own engines at the present time should be borne in mind. This in part at least provides against the power loss otherwise associated with producer-gas. Moreover, in Great Britain, the speed limit does away with the necessity for a lorry engine's maximum output, save for climbing the steepest hills. Lastly, the good surface and careful grading of most British roads further tend to reduce the significance of power loss from the operator's standpoint. The performance now obtained is described in Section XI and is illustrated in Fig. 25.

The power loss can be reduced to less than 15 per cent. of the maximum h.p.

Nevertheless, both to overcome the prejudices occasioned by the power loss, and to encourage the operation of producers overseas, where more arduous conditions obtain, producer-gas plant manufacturers have also to study many points of engine design.

The authors have to consider the immediate future in terms of cheap and practical modifications to existing engines; and further ahead, the possibility of a special engine being designed in conjunction with the automobile industry as a whole.

(ii) *The Immediate Future: Engine Modifications.*

It is well known that the power output of an engine mainly depends upon its volumetric efficiency and compression ratio, and its fuel consumption principally upon the latter.

The scantlings of the majority of engines would permit an increase of compression ratio, and, indeed, even more rapid rates of change of pressure than now take place on petrol. Consequently one of the authors first worked in this direction. Clarke Jones (43) patented methods of increasing the compression ratio, which also had in view an improvement in the turbulence and scavenging of cylinders when using producer-gas. As regards increasing the compression ratio, it is possible that a limit beyond which detonation or pre-ignition would take place has been reached at about 9 : 1 (as used by a Panhard lorry in the 9th Rallye, organised by the Automobile Club de France in 1935). It should be emphasised that these high compression ratios for producer-gas do not adversely affect the operation of life of an engine as might well be the case on petrol. On the other hand, it is possible that further progress may still be made under this head by those who achieve a more successful solution of the problems of heat distribution in high compression cylinder heads than have yet been made. The authors, among others, are engaged upon developments of this character. Any further developments in this direction would probably involve reconsideration of the Highest Useful Compression Ratio values established by Ricardo.(44)

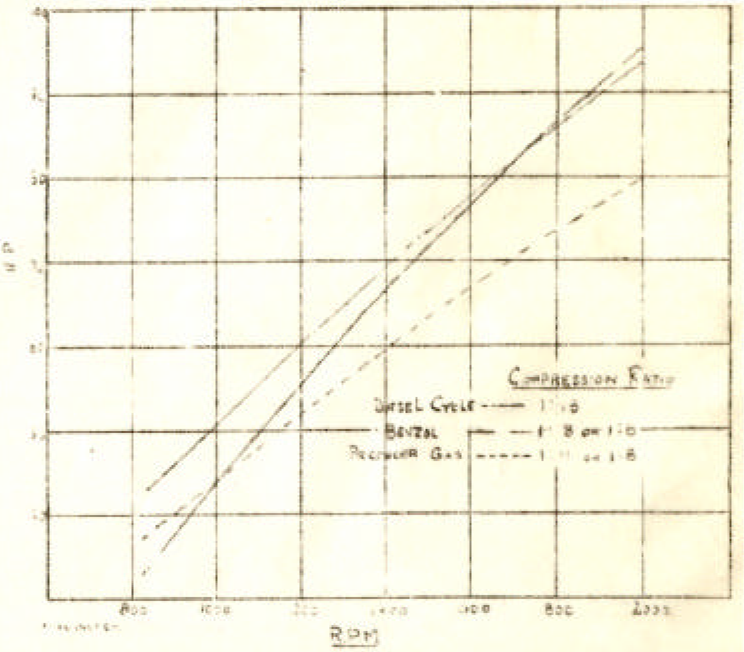


FIG. 25.—*Power curve, comparing liquid and solid fuels. (Gohin Poulenc.)*
Ratio 1 : 6 *Benzol*, 1 : 8 *Producer Gas*.

As regards special pistons, the authors have in mind further development in this direction, since these offer a practical method of achieving improved performance without undue or expensive alterations to existing engines. However, realising that with the gradually increasing compression ratios now generally adopted by the automobile industry, the value of increasing the compression ratio is diminishing, the authors have other lines of development in hand.

Beale (45) points out that there is a gain of 8 per cent. in power in raising the compression ratio from 5 : 1 to 6 : 1 ; 6 per cent. from 6 : 1 to 7 : 1 ; and only 4 per cent. from 7 : 1 to 8 : 1 (incidentally the efficiency falls off in the same way). Moreover, on petrol maximum cylinder pressure is about 500 lb. per sq. in. at 5 : 1 compression ratio ; 650 lb. at 6 : 1 ; 800 lb. at 7 : 1 ; 950 lb. at 8 : 1. This shows that the maximum pressure has been nearly doubled while increasing the power by only 18 per cent.

In contrast, if the anti-knock value of the fuel is taken advantage of to use supercharging, greater benefit results. In the case of a 6 : 1 compression ratio engine, supercharged by 4 lb. per sq. in. above atmospheric pressure instead of raising the compression ratio to 7 : 1, the gain in power is 36 per cent. instead of 6 per cent., not taking into account the power to drive the supercharger. Moreover, in the one case the maximum pressure rises by 120 lb. to 150 lb. per sq. in. for 6 per cent. increase in power, whereas in the other it rises by only 260 lb. per sq. in. for increase of 36 per cent. in power.

The authors are therefore working on the fact that for a given fuel supercharging is to be preferred to increasing the compression ratio, although other factors have to be borne in mind. Kühne also draws attention to these facts, particularly in relation to producer-gas (46). He shows that with a compression ratio of 7 : 1 and a boost of about 5 lb. per sq. in. a power output equal to benzol at 5 : 1 compression was obtained. Walter (47) states in regard to coal gas used for vehicular propulsion that supercharging shows a higher gain than is the case with petrol.

Another interesting development is described by Wawrziniok, (48) who gives the following table to show the improvement in performance gained by carburetting producer-gas with alcohol :—

Compression ratio	4.02	5.75	8.29
Power loss, producer-gas only	35.1%	15.8%	5.6%
Power loss, producer-gas plus alcohol	12.8%	—	+22%

The authors have in view another solution which does not involve the same complication as carburetting with alcohol. This the authors hope to apply to a standard producer-gas plant on a standard vehicle as supplied to-day by any of the leading manufacturers.

There remains one important line of development. It is known that various arrangements of an exhaust manifold can be made to improve power output. In the case of a transport vehicle an increase of 10 per cent. in the power output on petrol is only of value (and even then it is small) to the operator if the back axle ratio is altered accordingly. On the other hand, if developments of this character could be used to increase the power obtainable on producer-gas from a petrol engine, not only would the petrol power be once more available, but a 70 to 80 per cent. economy in fuel costs would be obtained. The authors are following this matter also with the closest attention.

Owing to the fact that producer-gas-air mixture burns more slowly than petrol-air it is generally necessary to advance the ignition beyond the petrol setting, and tests made by the authors indicate that the correct figure is of the order of 8°. At the higher compression ratios in use with producer-gas, suitable mica insulated plugs can be fitted with advantage, as can dual ignition. With regard to the latter, it is known that the performance of an engine is to some extent dependent upon (among other factors) the distance from the point of ignition to the furthest part of the combustible mixture. With slower burning mixtures than petrol-air, the importance of this factor increases. The proportion of hydrogen in the mixture is important. Hydrogen is of value in propagating flame through the relatively slow burning carbon monoxide. There is, however, an optimum value beyond which a further percentage may give rise to knocking, the precise figure depending upon the compression ratio employed, but influenced by the amount of nitrogen present in the mixture.

(ii) *Further Ahead : Specially Designed Engine.*

In the more distant future, other modifications could with advantage be made for gas operation aiming at improved volumetric efficiency. Apart from increasing the swept volume, a square bore to stroke ratio is desirable ; also larger inlet valves and different lifts, modified induction design, altered arrangement of valve passages, and retiming of the valves. This last has an important influence on the scavenging of the burnt gases.

It is now generally recognised that an engine using producer-gas operates at higher thermal efficiency than on petrol. In this connection the lower flame temperature has some influence.

A further method of making good the power loss otherwise associated with the conversion of petrol engines might lie in further improvement of the thermal efficiency. Erren (49) has perhaps pointed to a line of research in this direction. By injection of hydrogen through a separate inlet valve into a cylinder charged with air just before the top of the compression stroke a brake thermal efficiency of 45 per cent. has been achieved. Moreover, this figure is reached irrespective of the load factor. At present the thermal efficiency of a petrol engine is accepted as about 25 per cent. in optimum conditions, while the corresponding figure for producer-gas is about 28 per cent.

These questions, such as valve lifts, improved thermal efficiency, etc., are at present somewhat academic, since they postulate considerable alterations of a standard engine design. Consequently the authors reserve their views upon this subject until the design of producer-gas engines becomes of interest to the automobile industry as a whole.

XI. Performance and Utilisation

(i) *Performance.*

Gas-producers are applied either—

(1) To existing vehicles, modifying the existing engine ;

(2) To new standard vehicles, a larger engine being installed ; or

(3) Incorporated into a chassis specially designed around the producer, including a larger engine.

Methods (1) and (2) are in the greatest use. The performance of vehicles in these classes is a matter of outstanding importance, since the economy and reliability of gas-producers are now accepted. An independent report comparing the performance of the Bedford 30-cwt. vehicle on petrol and equipped with a Koela plant is of interest.(50) The total weight of the vehicle was 3 tons 4 cwt., made up as follows : chassis 25 cwt., ballast 25 cwt., body 6¼ cwt., personnel 3¾ cwt., gas plant 2⅜ cwt. The only difference in the vehicle on the two tests was that a special cylinder-head was fitted, raising the compression from 5.6 to 6.9.

The climbing of two test hills was timed, the first 1,595 ft. in length with a maximum gradient of 1 in 11 and an average of 1 in 18, the second 960 ft. long with a maximum gradient of 1 in 9 and an average of 1 in 12. The times on these hills on gas and petrol were as follows : 118 and 109 seconds ; 126 and 105 seconds, respectively.

The acceleration from 0 to 30 m.p.h. through all gears is shown in Fig. 27. The acceleration from 5 to 23 m.p.h. in third gear was better on gas, while the acceleration from 10 to 30 m.p.h. in top gear was better on petrol.

The importance of the extra service etc., detailed in Table III can be estimated in relation to cost from Table VII. It can be said, however, that the conversion of vehicles to use solid fuel is perfectly sound if the standard of performance described above is reached.

An important point in connection with the power obtained from an engine running on producer-gas as compared with petrol is that maximum power on gas is obtained at a mixture strength slightly weaker than that theoretically needed for maximum power. On petrol maximum power is obtained at an appreciably richer mixture strength than that theoretically needed. Thus the air setting for maximum power on gas approximates to the maximum economy. This is a great advantage, since the average truck driver is less concerned with economy than with power.

Performances of various types of producer are compared in Table III.

(ii) *Reliability.*

Interest in this connection is twofold : the length of time (or distance) individual producers have been in operation, and the number in use in different countries.

Individual Koela units have been in use for upwards of seven years. A unit originally fitted to an old lorry has been transferred to a new lorry and still continues to give satisfaction in regard to performance and costs.

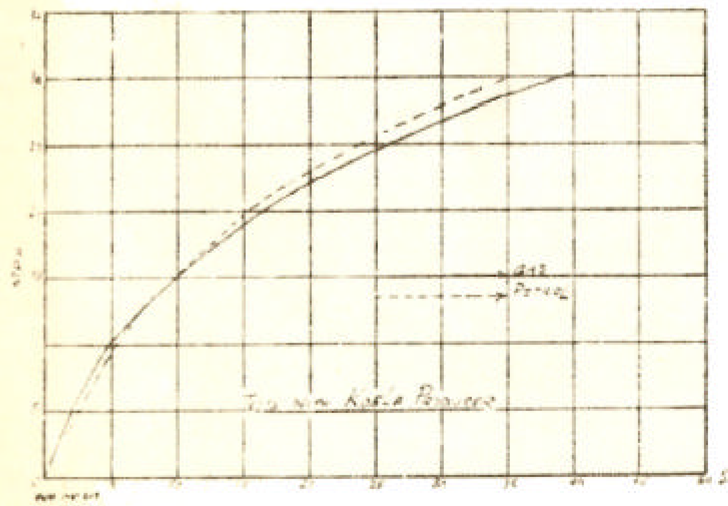


FIG. 27.—*Comparative acceleration on petrol and solid fuel. (Koela.)*

An old type of Svedlund producer fitted to a Scania-Vabis truck of 6.2 tons load capacity covered more than 350,000 kilometres between May, 1933, and November, 1937. The owner remarks on the improved performance of the vehicle using the new Svedlund producer in which steam is used, and also on the reduction in engine wear by comparison with petrol operation.

Many other examples could be quoted, but these suffice to show the reliability of modern portable gas-producers. Reisch (51) gives these figures for comparative bore wear using different fuels, based on tests with 46 vehicles:—

	In. per 1,000 miles.
Wood	0.000185
Charcoal	0.000368
Anthracite	0.0006
Lignite coke	0.0014
Coal coke	0.00115
Peat coke	0.0012
Lignite briquettes	0.002
Methanol	0.0002
Bottle gas	0.0001

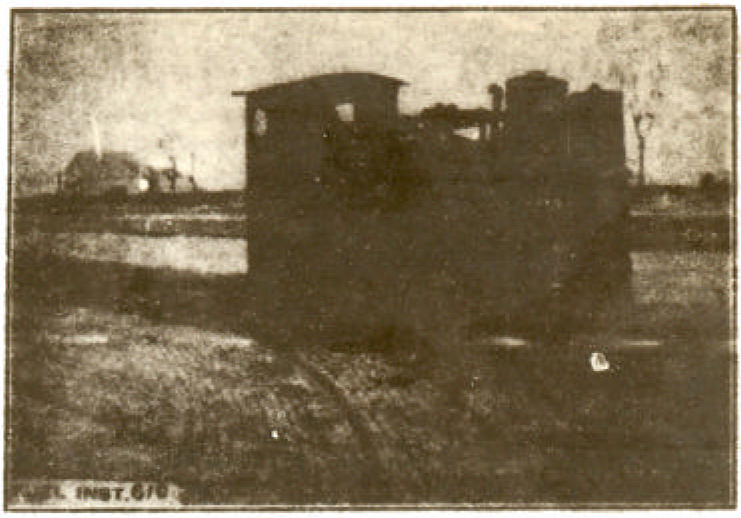


PLATE 8.—*A shunting locomotive fitted with a Hansa producer.*

(iii) *Utilisation in Great Britain and in Europe.*

British manufacturers have principally been engaged in the export market, and have only recently made progress in Great Britain. In this country only 10 or 12 producer-gas vehicles are in use. This is partly explained under the headings of taxation and fuel distribution (pp. 21 and 27). Standardisation of fuel has only recently been carried out, and the fact that special " coalite " is now marketed (33) is a considerable forward step. Another obstacle to progress has been the belief held by possible users that if any considerable number of producer-gas vehicles were to come into use, either a tax would be imposed on the fuel or an addition on the road fund licence of such vehicles would be imposed. The history of the diesel vehicle is quoted as an example in this connection.

A clear statement by the Government of their intentions would remove this objection, and might usefully take the form that there was no intention to discriminate between home-produced solid and liquid fuel, the future of the latter having been assured for 12 years at least by the acceptance of the Falmouth Report.(3) Remaining obstacles are the still high price of conversion in relation to the price of a standard petrol vehicle, and the reluctance of an operator to pay down capital to save over a period ; also prejudice still persists among many who regard producer-gas as a new invention. In due course users'

PLATE 7.—*The installation of a Koela generator on a Humber car.*

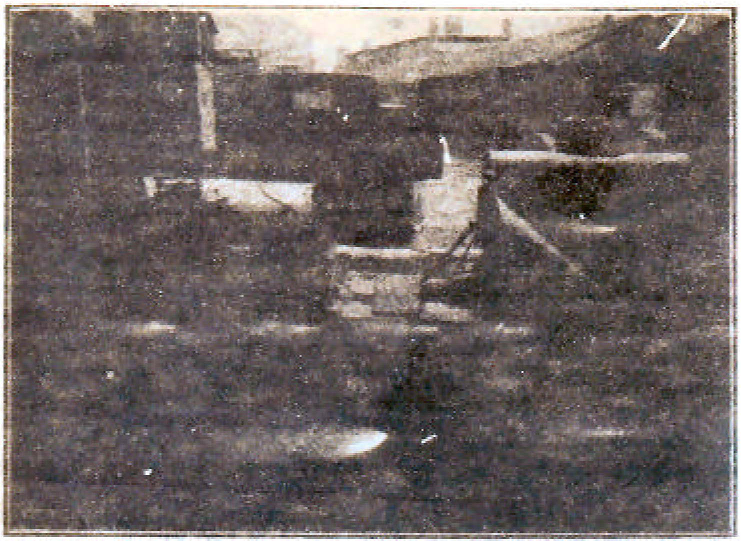


PLATE 3.—*Koela plant installed on a Carden-Lloyd tractor.*

PLATE 10.—*A tractor in operation fitted with a Koela producer.*

reports, demonstrations, and tests such as those organised by the Automobile Club de France between 1926 and 1935 will overcome much prejudice, since the standard of performance of a modern gas-producer is agreed by all who have to do with them.

In Germany liquid or compressed gas has progressed more rapidly than producer-gas, but in 1937 there were 1,207 producer-gas vehicles out of a total of 377,547. Another source gives the number as 1,000 using wood fuel and mentions others using peat, lignite, and low temperature coke.(53)

In Italy about 500 out of 10,000 buses, and 1,000 out of 110,000 goods vehicles, are producer-gas propelled.

PLATE 4.—*A boat operated by a Hansa producer.*

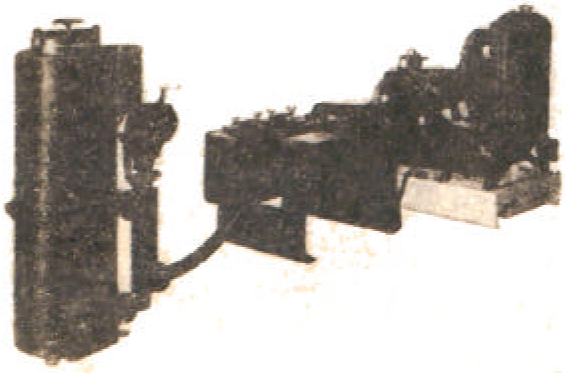


PLATE 5.—*Stationary engine operated by a Koela producer.*

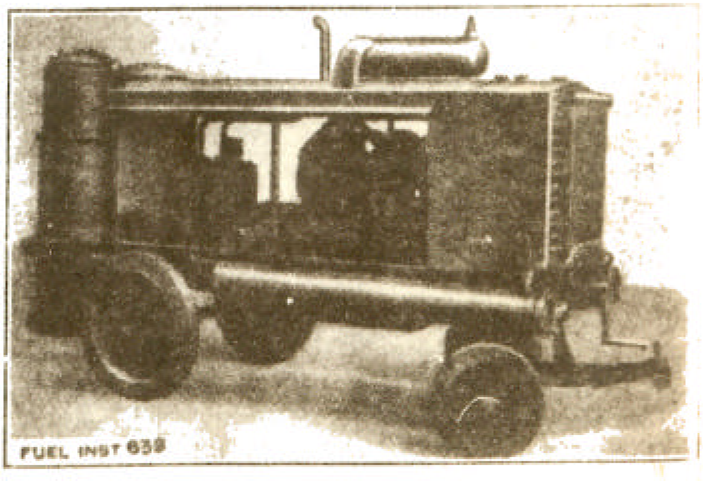


PLATE 11.—*A Flottman compressor equipped with an Imbert producer.*

In France 6,000 out of 500,000 goods vehicles are said to be equipped with producers.

Producers are also considerably used in the U.S.S.R., and in the Scandinavian and Baltic countries, but the authors have no figures.

(iv) *Other Applications.*

The portable gas-producer has other applications besides vehicles and tractors (Plates 3 and 10). For instance, Koela producers using various fuels are in use in tugs, rail-cars, and to drive compressors, stationary units (Plate 5), and electric generating units. Further applications of a different sort are in view. Continental manufacturers, in addition to the above applications, illustrate a producer driving a crane, shunting locomotives, and cars (Plates 4, 8 and 11).

XII. Taxation and Official Encouragement.

(i) *General.*

Both here and throughout Europe as a whole home-produced solid fuel is not liable to excise or other duty, whereas petrol if imported pays heavy duty. Apart from this indirect taxation, commercial vehicles are also liable to direct taxation assessed on various systems. The authors do not propose to give full data relating to the direct taxation (or rather lack of it) on producer-gas propelled vehicles on the Continent. However, the remarks below suffice to show that preferential treatment is given there, whereas in this country such vehicles are handicapped. This is the more unfair, since the regulations were framed prior to producer-gas being seriously considered here, and although modifications in regard to other forms of propulsion have already been made.

(ii) *Great Britain.*

With the object of bringing into line taxation on vehicles using various fuels a deputation under the leadership of the Low Temperature Coal Distillers' Association of Great Britain waited on the Minister of Transport in April, 1938. The deputation asked that modifications should be made in the existing regulations to place the producer-gas-propelled vehicle on a similar footing with other alternative fuels such as steam and electricity. This involved the weight of the gas-producer and auxiliary equipment being disregarded in arriving at the unladen weight for speed limit and taxation categories. The request was refused.

To consider one example from among tractors, buses, and goods-carrying vehicles, the annual road fund licences payable on various classes of lorry are to be found in Table VI.

As regards speed limit categories, vehicles up to 2½ tons unladen are allowed a maximum legal speed of 30 m.p.h.; above that 20 m.p.h.

It should be understood that the manufacturers of motor vehicles for the carriage of goods in pursuit of maximum strength and carrying capacity naturally tend to design their various models in such a way that they in fact nearly always reach the maximum size and weight which will allow these vehicles to fall within a given taxation or speed limit class. This follows from the fact that purchasers are naturally anxious to have as much space as they can for the money they pay in taxation, and to be in a position to transport as much as they can at the quickest pace allowed by the law. Thus in many cases the additional weight of the gas producer may carry the producer-gas propelled vehicle into the next higher taxation category. In the case of the 2½-ton unladen vehicle the maximum legal speed is likely to be reduced from 30 to 20 m.p.h. by fitting it with a producer-gas plant, an effective deterrent to the potential user. The 2 to 2½-ton category comprised 96,560 out of 452,438 goods vehicles licensed in 1937. The same reduction in speed prevents the whole producer unit being carried in a light trailer, a most convenient way of providing for the rapid conversion of a considerable number of vehicles from petrol to producer-gas. It is of interest to recall that the Inter-departmnetal Committee of 1919 dealing with gas traction (32) recommended that the war-time provisions favouring the use of light pneumatic-tyred trailers carrying compressed gas cylinders should be made permanent.

Table VI

Goods Vehicles

Unladen weight.	Tax on electrically propelled vehicle.	Tax on oil burning vehicle.	Tax on vehicle using steam-compressed gas or producer-gas (if weight of generator, etc., is not included in unladen weight).	Tax on vehicle using producer-gas if weight of generator, etc., is included in unladen weight as at present.
Not exceeding 12 cwt. unladen	£ 10	£ 10	£ 25	£ 25
Exceeding 12 cwt. but not 1 ton unladen	15	15	25	25
Exceeding 1 ton but not 1½ ton unladen	20	20	25	25
Exceeding 1½ ton but not 2 tons unladen	20	25	25	30
Exceeding 2 tons but not 2½ tons unladen	25	30	30	35
Exceeding 2½ tons but not 3 tons unladen	30	35	35	50
Exceeding 3 tons but not 4 tons unladen	35	50	50	70
Exceeding 4 tons but not 5 tons unladen	40	70	70	90
Exceeding 5 tons but not 6 tons unladen	45	90	90	105
For each additional ton or part thereof over 6 tons add ...	10	20	15	15

In connection with Table VI, it should be pointed out that not only is the weight of the batteries excluded from the unladen weight of electrically propelled vehicles but also that the Road Fund licence duty in each category above the 1 to 1½-ton class is very much less. The deputation previously referred to only asked that the weight of the gas-producer should be omitted in arriving at the unladen weight and not for special consideration equal to that given to the electric vehicle. Corresponding modifications to those asked for by the deputation have already been made in the case of steam vehicles.

(iii) *On the Continent.*

In Germany, since 1935 the taxation of vehicles using producer-gas and other indigenous fuels has been halved. Also there was from 1936 to 1938 a State subsidy of 300 marks and upwards for converted vehicles, amounting to 600 marks in the case of new vehicles.

In France, as in August, 1938, goods vehicles paid taxation on account of horse-power, load space, and weight-carrying capacity. As regards the first two, producer and compressed gas vehicles are exempt. As regards the fee per ton of load, producer-gas vehicles are exempt until July, 1939, after which 50 per cent. under this head will be payable. Moreover, by decree of June, 1938, 10 per cent. of vehicles belonging to concerns owning 10 or more vehicles have to be operated on home-produced fuel.

In Italy a decree is in force stating that all passenger vehicles have to use home-produced fuel by the end of 1938, but it is considered unofficially that the time will

TABLE VII

COMPARATIVE OPERATING COSTS FOR 1¼, 3 AND 5 TON VEHICLES BASED ON THE "COMMERCIAL MOTOR" TABLES OF OPERATING COSTS AND THE RECORDS OF THE KOELA PRODUCER GAS PLANT CO., LTD.

Standing Charges (per week)		1¼ ton			3 ton					5 ton				
		Petrol.	Producer Gas.	Difference	Petrol.	Diesel.	Difference	Producer Gas.	Difference Petrol/ Gas.	Petrol.	Diesel.	Difference	Producer Gas.	Difference Petrol/ Gas.
Licences		10.0	10.0		12.0	12.0		12.0		12.0	12.0		12.0	
Wages		61.6	65.0		66.0	66.0		70.0		69.0	69.0		74.0	
Rent and rates		6.0	6.0		7.6	7.6		7.6		10.0	10.0		10.0	
Insurance		6.0	6.0		7.6	7.6		7.6		8.3	8.3		8.3	
Interest		3.6	4.6		4.7	7.7		5.10		5.9	8.9		7.3	
Total		87.0	91.6	+ 4/6	97.7	100.7	+ 3/-	102.10	+ 5/3	105.0	108.0	+ 3/-	112.6	+ 7/6
400 Miles per week—														
Fuel	(pence per mile)	1.21	0.29	— 0.92	1.42	0.69	— 0.73	0.33	— 1.09	1.70	0.83	— 0.87	0.40	— 1.30
Lubricants	(,,)	0.06	0.05		0.10	0.12		0.09		0.12	0.14		0.11	
Tyres	(,,)	0.33	0.33		0.42	0.42		0.42		0.60	0.60		0.60	
Maintenance (*d*) ...	(,,)	0.26	0.26		0.29	0.29		0.29		0.31	0.31		0.31	
,, (*e*) ...	(,,)	0.45	0.45		0.62	0.68		0.65		0.70	0.77		0.73	
Depreciation	(,,)	0.80	1.04		0.79	1.34		1.04		0.94	1.49		1.19	
Total running costs	(,,)	3.11	2.39		3.64	3.54		2.82		4.37	4.14		3.34	
Total operating costs	(,,)	5.72	5.17	— 0.55	6.57	6.56	—	6.01	— 0.56	7.52	7.38	— 0.14	6.91	— 0.61
,, ,, ,,	(£ per week) ...	£9 11	£8 12	— 19/-	£10 19	£10 19	—	£10 0	— 19/-	£12 11	£12 6	— 5/-	£11 11	— £1 0
600 Miles per week—														
Fuel	(pence per mile)	1.21	0.29		1.42	0.69		0.33		1.70	0.83		0.40	
Lubricants	(,,)	0.06	0.05		0.10	0.12		0.09		0.12	0.14		0.11	
Tyres	(,,)	0.33	0.33		0.42	0.42		0.42		0.60	0.60		0.60	
Maintenance (*d*) ...	(,,)	0.17	0.17		0.20	0.20		0.20		0.21	0.21		0.21	
,, ( ) ...	(,,)	0.45	0.45		0.62	0.68		0.65		0.70	0.77		0.73	
Depreciation	(,,)	0.64	0.84		0.63	1.07		0.83		0.75	1.19		0.95	
Total running costs ...	(,,)	2.86	2.13		3.39	3.21		2.52		4.08	3.74		3.00	
Total operating costs	(,,)	4.60	3.96	— 0.64	5.34	5.19	— 0.15	4.58	— 0.76	6.18	5.90	— 0.28	5.26	— 0.92
,, ,, ,,	(£ per week) ...	£11 10	£9 17	— £1 13	£13 7	£13 0	— 7/-	£11 10	— £1 17	£15 9	£14 15	— 14/-	£13 4	— £2 5
800 Miles per week—														
Fuel	(pence per mile)	1.21	0.29		1.42	0.69		0. 3		1.70	0.83		0.40	
Lubricants	(,,)	0.06	0.05		0.10	0.12		0.09		0.12	0.14		0.11	
Tyres	(,,)	0.33	0.33		0.42	0.42		0.42		0.60	0.60		0.60	
Maintenance (*d*) ...	(,,)	0.17	0.17		0.15	0.15		0.15		0.16	0.16		0.16	
,, (*e*) ...	(,,)	0.45	0.45		0.62	0.68		0.65		0.70	0.77		0.73	
Depreciation	(,,)	0.64	0.84		0.63	1.07		0.83		0.75	1.19		0.95	
Total running costs ...	(,,)	2.86	2.13		3.34	3.13		2.47		4.03	3.69		2.95	
Total operating costs	(,,)	4.16	3.50	— 0.66	4.80	4.64	— 0.16	4.02	— 0.78	5.61	5.32	— 0.29	4.64	— 0.97
,, ,, ,, ...	(£ per week) ...	£13 17	£11 14	— £2 3	£16 0	£15 8	— 12/-	£13 8	— £2 12	£18 14	£17 14	— £1 0	£15 10	— £3 4

NOTES.—(i) Petrol, 1/5 per gallon.
(ii) Diesel Oil, 1/3 per gallon.
(iii) Solid Fuel, £3 per ton.
(iv) Maintenance (*d*) includes washing, polishing, painting, etc.
(v) Maintenance (*e*) includes greasing, decarbonising, brake adjustment, etc.

Prepared by :
GOLDMAN LAMBERT & PARTNERS,
Aldwych House

have to be prolonged. The State pays two-thirds of the costs of conversion up to 18,000 lire (the actual cost is given as about 22,000 lire), but there is no rebate in taxation.

Various forms of encouragement are also in force in other countries, particularly in the Baltic and Scandinavian States, but the authors have no details.

By way of contrast, in certain parts of the world where petrol is indigenous, or a large source of local revenue, special taxation penalising the gas-producer vehicle has been put into force—perhaps an even greater tribute to the efficiency of the modern portable gas-producer.

(iv) *Desirable Encouragement in Great Britain.*

Attention has been drawn in Section XI and in this section (pp. 25 and 27) to the desirability of a statement on the fiscal future of home-produced fuel, similar to what has been said in regard to home-produced liquid fuel, and the desirability of bringing into line the taxation on vehicles using various fuels.

These are purely questions of equity. The Transport Producer-Gas Makers' Association has urged upon the Government the importance of further and more positive action as a defence measure, positive action being necessitated in order to reach at least the proportion of vehicles fitted in other countries during the period of handicapping in Great Britain.

The Association suggested that the Government should have available a reserve of plants for immediate application on a state of emergency being declared. Moreover, if a portion of this reserve could be fitted forthwith, time would be saved and experience gained. Thus, if the reserve were established now, its price would be low, whereas in war both labour and materials would be scarce; and if units from the reserve were hired to operators at a charge per mile or month all objections would be met. The charge could be such as to provide both interest and sinking fund on the capital involved while still showing the operator a saving. So, in due course, the expenditure would be justified in war, or recovered in peace, securing meanwhile an increased independence of imports, increased employment of miners, and a strengthening of the automobile industry's competitive position overseas due to the reduction in fuel costs thus possible.

The authors are in complete agreement with the suggestions of the Association, which has offered to prepare detailed proposals in collaboration with the various bodies concerned.

XIII. Comparative Operating Costs

Producer-gas can be shown to be the most economical form of power. As an example, Table VII shows comparative operating costs of various sizes of lorry over various weekly mileages on petrol, diesel oil, and producer-gas.

The following points are noteworthy :—

1. The price of a standard vehicle designed for petrol operation but equipped with a gas-producer is less than that of a diesel-engined vehicle of similar capacity.

2. On producer-gas the wages, maintenance and depreciation are more than for a petrol vehicle, while fuel and lubricating oil costs are less. Again, the wages are more than for a diesel vehicle, while fuel and oil costs, maintenance and depreciation are less than for a diesel vehicle.

3. The amount of the nett savings of a producer-gas vehicle depends upon the mileage run. Thus there is a minimum annual mileage below which the equipping of a vehicle would not be economically justified. However, the mileage at which net savings begin is lower than for a diesel vehicle and the savings are greater.

The table is based upon the unladen weight of the vehicle fitted being such that the weight of the plant will not affect its speed limit or taxation categories. Otherwise, allowance would have to be made for the extra road fund licence duty payable (this would slightly increase the mileage figure at which the attachment showed a net saving). In the particular case of a vehicle being raised from the 2 to 2½ tons to the 2½ to 3 ton category, it will probably prevent any nett saving on account of the reduction in maximum legal speed (Section XII).

XIV. Tendency and Development

(i) *Tendency.*

In Great Britain all types of producer are available, but the up-draught has predominated until recently, when cross-draught types have increased in number under the influence of French design. Water is used with plants of British design originally developed for charcoal but now able to use low-temperature coke and anthracite equally well. Conversion is the line generally followed both with trucks and tractors, but a new vehicle specially designed for producer-gas has been built and its development is proceeding.

In Germany standard practice is more closely adhered to, though considerable progress has been made with the Imbert down-draught producer using raw wood as fuel. Otherwise up-draught principles obtain, with moderate temperatures and low gas velocities. There is, however, a tendency to use the highest possible proportion of water in direct contrast to the methods employed in France. Conversion, with and without a larger engine, is the method followed, and apart from ordinary fuels plants are being developed to use lignite and certain classes of anthracite.

In France the down- and cross-draught producers are now in favour. The tendency is no longer to use water or steam in the producer. Many vehicle manufacturers fit standard gas-producers to their vehicles. Panhard fit their own down-draught producer and employ their well-known sleeve-valve engine by giving it a larger bore than with petrol. Generators are also in use on private cars.

Plants are primarily designed for wood or charcoal, since France has considerable resources of this kind. Attempts have been made to agglomerate charcoal, and these experiments are being repeated with certain low-temperature cokes.

In Italy the utilisation of wood and charcoal is the objective, and down- and up-draught plants are manufactured for the conversion of standard vehicles.

In Sweden the down-draught principle predominates with wood and charcoal as fuel, both of which are readily available.

(ii) *Development of Generator Design.*

Before considerable progress can be made a supply of classified and standardised fuels must be known to be available. In due course a decision will be necessary in regard to the utilisation of lower grades of fuel, *i.e.*, whether to design the producer to use them, or to up-grade these fuels in order that they can be used in existing producers.

The Fuel Research Station is engaged upon the comparison and classification of various fuels, as well as the utilisation in particular of low-grade fuels. The publication of this work and the decisions attending upon it will enable further design steps to be taken with regard to specific fuels.

The most important development now in hand by the authors is that of relating the maintenance of the most favourable gasification conditions in the generator to the varying demand of the engine. Also important is the optimum composition which gives the best engine performance considered in terms of a greater or lesser degree of fuel economy.

On the mechanical side, the authors' attention is being given to making the complete plant easier and cheaper to produce and operate; and to making the plants lighter and smaller.

(iii) *Cleaners and Filters.*

The purification of gas derived from selected fuels is now adequate, but fresh methods will have to be devised if lower-grade fuels are to be used. On the mechanical side the same objectives as in the case of generators are in view.

A reduction in the resistance of the whole system to the flow of gas is also an object of further work.

(iv) *Mixture.*

If a more intimate air-gas mixture could be obtained without increasing resistance to flow, advantage would accrue.

(v) *General.*

The authors consider that the requisite technical knowledge exists in this country for the development work to be completed, but suitable facilities are lacking to those who possess the knowledge. Development beyond the present stage would be much facilitated by a more general co-operation not only among producer-gas plant manufacturers themselves, but with the suppliers of fuel and the automobile industry. As regards the refining of performance without the increased cost of a special vehicle, much depends on the automobile industry. The automobile industry should give attention to this development on account of the improved position in the overseas market that the British industry would enjoy if able to offer as optional the inclusion on a standard vehicle of a standard producer-gas plant.

XV. Acknowledgments

The authors are indebted for assistance of various kinds to the following gentlemen: Dr. P. O. Rosin, James C. MacPhee, Esq., and Oliver Gatty, Esq.

They are also indebted to the following firms:—

Marks and Clerk, 57, Lincoln's Inn Fields, W.C.2
Bureau d'Etudes Techniques et Industrielles, 72, Rue la Boetie, Paris (*e*).
Koela Producer Gas Plant Co., Ltd., Aldwych House, London, W.C.2.
Compagnie des Procedes Gohin-Poulenc, 6, Rue Thiers, Choisy-le-Roi (Seine), France.
Hansa-Gas-Generatoren, Berlin-Reinickendorf, Verlängerte Koloniestrasse, 1–2. Germany.
Humboldt-Deutzmotoren A.G., Koln-Deutz, Deutz-Mulheimer-str. 149–155.
Wisco (Grau, Isendahl & Co., K.G.) Berlin-Halensee, Paulsbornerstr. 27, Germany.
Soc. An. d'Exploitation des Procedes Malbay, 57, Rue Pierre-Charron, Paris, (8e).
Ets. Edgar Brandt, 101, Boulevard Murat, Paris (16).

and to other producer-gas plant manufacturers who only sent their literature.

The authors also wish to express their gratitude for other assistance to:—

The Coal Utilisation Council.
The Institution of Automobile Engineers.
The Institution of Mechanical Engineers.
London and Counties Coke Association.
Automobile Club de France.

References

1. V. R. Garfias and R. V. Whetsel: "Proved oil Reserves. Science of Petroleum." Oxford, 1938.

2. Oil in War: Leading and special articles; The *Times* Dec. 7 and 31, 1937.

3. Appendix I, Table 4, Report of Sub-committee on Oil from Coal. Cmd. 5665. 1938.

4. W. R. Ormandy: "Fuels—Alternative or Supplementary to Petrol," *Journal Institute of Fuel*, No. 6, Vol. II, 1929.

5. B. E. M. Goldman: "Oil and other Fuels." London, 1938.

6. B.P. 23476—1901.

8. B.P. 164548—1920.

9. Robert Vaultrin: "L'Utilisation du Bois comme Carburant." Bulletin de la Société d'Encouragement pour l'industrie Nationale September to October 1937, p. 409.

10. B.P. 222849—1924.

11. Rallye des Carburants Nationaux, 1927 and subsequent years. Automobile Club de France.

12. J. Dowson and A. Larter: "Producer Gas." London, 1920.

13. N. Latta: "American Producer Gas Practice." New York.

14. R. V. Wheeler: "Producer Gas and Producer Gas Practice." London, 1937.

15. D. J. Smith: "Producer-Gas for Motor Vehicles," *Proc. Inst. Aut. Eng.*, XIV, 1920, pp. 169–239.

16. Clements and Adams: Bull. Bureau of Mines, U.S.A., 1911, No. 7.

17. R. Hartner-Seberich: *Brennstoff-Chemie*, 1936, 17, 1–11.

18. H. Guillon: *Journal des Usines à Gaz*, 1930.

19. B.P. 183219—1921.

20. E. Rämmler: *Motor*, Berlin, June 1937, p. 32.

21. M.P. Guillaume: "Utilisation dans la Domaine Ferroviaire des Bois Créosotes comme Carburant de Gazogènes," Memoires de la Société des Ingénieurs Civils de France, p. 777, 1937.

22. B.P. 323147—1929, 361174—1930, 383980—1931.

23. B.P. 336932—1930.

24. *Automobile Engineer*, November 1936. London.

25. P. O. Rosin: The Influence of Particle Size on Processes of Fuel Technology," J. Inst. Fuel, October 1937. London.

26. "The Reactivity of Coke". Department of Scientific and Industrial Research. Technical paper, No. 18, pp. 18, 24, 13.

27. Koppers and Jenkner: Eisen Huttenwesen, 1932, p. [illegible]

28. Mezger: "Reactivity of Coke," *Feuerungstechnik*, 1927.

29. Faraday Society: "Reactions of Solids," Ref. Solid Carbon. Discussions, 1938.

30. J. S. S. Baume and J. G. King: *Fuel*, p. 314. Lond[illegible]

31. A. Metral: "Fuels—Alternative or Supplementary to Petrol," *J. Inst. Fuel*, No. 6, Vol. 2, 1929.

32. Inter Departmental Committee Report, 1919: "The Employment of Gas as a source of Power," Cmd. 263, H.M. Stationery Office.

33. Chairman's Speech: Low-Temperature Carbonisation, Ltd. July 1, 1938.

34. Journal Imperial Institute, Bulletin 28, 1930, p. 139. London.

35. M. Klar: "The Technology of Wood Distillation," p. 23. London.

36. N. Clarke-Jones: "Wood Charcoal and Portable Charcoal Kilns." *Industrial Chemist*, October 1938. London.

37. J. Roberts, and A. Jenkner: "International Coal Carbonisation," p. 197. London 1934.

38. Charles Baron: "Commission des Mines et de la force motive," No. 3784, Chambre des Députés, 16me Législature, 1938.

39. U.S.A. Bureau of Mines, Bullt. 109, 1914–1915.

40. H. Finkbeiner: "Hochleistungs Gaserzeuger fur Fahrzeu Betrieb und orfeste Kleinanlagen." Berlin, 1937.

41. F. Main: "La puissance des moteurs alimentes au gaz des Forets. Revue Internationale du Bois. Fev.–Mars, 1937.

42. H. Fielbelkorn: "Fahrzeug-Diesel Motoren und Fahrzeu Gas-Generatoren." Stuttgart 1937.

43. N. Clarke-Jones: B.P. 412, 341—1933; B.P. 292, 715 1927.

44. H. R. Ricardo: *Proc. Inst. Aut. Eng.*, 18, Pt. 1, 1923.

45. C. O. B. Beale: "The Engineering Aspects of Detonation. Science of Petroleum, p. 3072, Vol. IV. Oxford, 1938.

46. G. Kühne: *V. D. I. Zeit.*, December 2, 1933, p. 12–3.

47. C. M. Walter: Copyright publication No. 48, Institution of Gas Engineers.

48. E. Wawzinok: *Aut Zeit.*, November 10, 1933, p. 546.

49. R.A. Erren and W. H. Campbell: *J. Inst. Fuel*, **6**, 277, 1932-1933, London.

50. *The Commercial Motor*, July 15, 1938. London.

51. A. Reisch: *V.D.I. Zeit.*, December 28, 1935, pp. 1543-57.

52. *Petroleum Times*, July 30, 1938.

53. *Essener National Zeitung*, Aug. 29, 1938.

OTHER REFERENCES NOT CITED IN THE TEXT.

54. A. Lepavre and G. Septembre: "Le Gas des Forets." Paris, 1938.

55. G. Lavagnolo: "Gassogeni." Turin

56. Edizioni: "La Critica." "I Gassogeni per gli autoveicoli." Rome.

57. U. Hoepli: "Il Conducente di Autoveicoli a gassogeno." Milan.

58. G. Rouyer: "Etudes des Gazogenes Portatifs." Paris, 1938.

59. *Fuel Economist*, July, 1938.

60. *Petroleum Times*, September 17, 1938.

61. Sir David Rivett: "Oil Production from Coal from an Australian Standpoint," Govt. of Australia, 1936.

62. Royal Commission on the Coal Industry. London, 1925.

63. British Hydrocarbon Oils Production Act, 1930, together with modifications contained in Orders 119/1936 and 383/1936.

64. D. P. C. Neave: "Copper and its Alloys in Automobile Design," *Inst. Aut. Eng.*, February 15, 1937.

65. W. Rixmann: *V.D.I. Zeit.*," Tests with Gas Producers." November 20, 1937, pp. 1357-83.

66. H. Voelkel and W. Malchedeck: "Tests with a Deutz Producer," *Aut. Zeit.* June 10, 1936, pp. 285-7.

67. John Stewart: "Producer-Gas Practice," *Proc. Inst. Aut. Eng.*, XV, 1920-1.

68. *Engineering*: Description of Tulloch producer, [illegible] 24, 1929, p. 641.

69. E. A. Allcut: "Producer-Gas for Road Traction," Bulletin 6, Section 12, University of Toronto, 1926.

70. H. F. MacGillivray: "From Mine to Road." Third National Coal Convention, October 7, 1937.

71. M. W. Woods: Producer Gas Vehicles, *Journal Institute of Engineers*, Australia, March 1938.

Discussion

Mr. J. G. Bennett (Member) said that a debt of gratitude was owing to the authors for the pioneer work they had done and were doing in developing the portable gas producer. Everyone concerned in fuel transport and problems must realise that this was a subject of prime importance to the country. The authors and other investigators who were engaged on this problem had to a great extent been breaking new ground, because the conditions of producer-gas transport in this country were different from those in the continental countries where this method of traction had seen its greatest development. In France, for obvious strategic reasons, the use of charcoal and wood had been developed in preference to coal. We, on the other hand, had comparatively few forests. In Germany, 27 per cent. of the total area was covered with forests, with 0.2 hectare per head of population. In France, 18 per cent. of the area was forest, and 0.24 hectare per head of population. The British Isles came at the bottom of the scale of European countries with 4.6 per cent. of forest areas and with 0.02 hectare per head of population. Being thus largely dependent upon imported timber, we could not use charcoal to any great extent as a fuel. The authors had therefore quite rightly turned their attention to fuels derived from British coals, either natural fuels of low volatile content, such as anthracite, or carbonised fuels particularly low-temperature coke. A careful and thorough study of the characteristics which a solid fuel should possess to permit its use in a portable gas producer was, therefore, one of the most urgent of tasks, and in this respect we were fortunate in possessing, through the Coal Survey, a degree of exact knowledge of the characteristics of our coal seams probably greater than in any other country in the world. There was no doubt that we in this country had realised that the question of providing alternative fuels to replace imported oils was of real national importance. He welcomed the concluding remarks of the paper that this was a matter in which everyone must work shoulder to shoulder, affecting, as it did, the fuel and transport industries as much as those commercial concerns which hitherto had borne the greater part of the burden.

Mr. Bennett referred to the Advisory Committee set up by the British Coal Utilisation Research Association jointly with the Mining Association of Great Britain and the Coal Utilisation Council. He stated that this committee would begin its investigations at a very early date, and it was hoped that they would be able to contribute something useful towards the solution of this very important national problem.

Prof. P. O. Rosin (Member of Council) said he had been able to watch the development of portable gas producers for many years and the paper by Messrs. Goldman and Jones was the best survey on the subject that had come to his notice. It was almost 15 years ago that he came into contact with this problem when an outlet was sought on the Continent for semi-coke, and he, therefore, would like to contribute to the fuel side of this question with particular reference to low temperature coke as a fuel.

At first the oil from low-temperature distillation was considered the main product and the coke a by-product. Since, contrary to the conditions in this country, the domestic market on the Continent was much restricted due to the absence of open fires, the gas car was considered as a possible outlet. This ambition failed mainly because suitable constructions of gas-producer plant did not exist at that time. Later, the shortness of home-produced Diesel oil and motor spirit led to a revival of the idea of gas cars, and the moral and financial support granted by some Governments led to the construction of appropriate plants. It turned out, however, that too little attention had been paid to the properties of the coke necessary to give the highest efficiency with the least trouble. Very comprehensive tests, most of them carried out by his former collaborator, Dr. Rammler, proved that not only a marked difference existed between semi-cokes of different makes but also that those differences greatly influenced the performance of a gas car. It was his firm belief that in order to make the gas car a technical and economic success a certain standardisation of fuel must be agreed upon. This was not astonishing when one realised the very exacting specifications which a liquid fuel was expected to fulfil to-day. For many years the motor industry developed their constructions largely on the back of the oil industry, which only by the greatest efforts of research was able to follow up the ever-increasing demands of modern engine construction. At that time, the question was often discussed whether the internal-combustion engine had to meet the fuel or the fuel the engine. Eventually this question was decided in favour of the engine.

TABLE III.

PERFORMANCE DATA CONCERNING VARIOUS TYPES OF GAS PRODUCER

	MALBAY.			WISCO.				HUMBOLDT DEUTZ.
SIZES ...				Two.				
DRAUGHT ...	Up.			Up.				Up.
Fuel used ...	Charcoal	L.T. coke	Anthracite	Charcoal	Peat coke	L.T. coke	Anthracite	Any tar-free fuel—anthracite, coke, L.T. coke, charcoal.
Is water used? ...	No	No	No	Yes	Yes	Yes	Yes	Yes
Fuel sizes ...	Small	10/25 mm.	10/20 mm.	20/40 mm.	20/40 mm.	10/20 mm.	" Nuts 4 "	*Anthracite*
Consumption lb./h.p. hour ...	1.18	1.23	1.01	0.88	—	1.0	—	—
Gasification capacity ...	—	—	—	—	—	1785 m³/m² hr. of combustion area	—	Anthracite 1,400mm.³/m² hr.
Starting time ...	5/6 min.	5/6 min.	5/6 min.	—		5/10 min.	—	4/6 min.
Fuel Analysis—%								
Moisture ...	4.7	7.7	2.1	—	—	2.65	—	
Ash ...	—	8.8	7.9	—	—	4.81	—	—
Volatile ...	—	13.0	9.6	—	—	7.42	—	—
Carbon ...	—	70.5	80.4	—	—	83.9	—	—
Calorific value ...	—	7,056 kcal/kg.	7,750 kcal/kg.	—	—	8,057 kcal/kg.	—	7,800 kcal/kg.
Gas Analysis—%								
CO_2 ...	0.8	0.5	0.6	2.5	—	6.25	—	4—5
CO ...	30.4	30.6	24.4	31.5	—	23.15	—	24—28
H_2 ...	6.7	5.3	13.1	17.5	—	17.95	—	14—16
CH_4 ...					—	0.7	—	1.4
O2 ...	0.6	0.5	0.6	0.2	—	0.0	—	—
N_2 ...	61.5	63.1	61.3	48.3	—	51.9	—	Non-combustible = 57/50
Calorific value ...	1,124 kcal/m³	1,108 kcal/m³	1,197 kcal/m³	1,410 kcal/m³	—	1,222 kcal/m³	—	1,216/1,388 kcal/m³
Water/Solid fuel ratio ...	—	—	—	40/70%	—	68%	—	35/40%
% decomposition ...	—	—	—	98/80%	—	60%	—	70%
Clinker and ash—h.p./hour ...	1.5gm. + 8.3gm.	30gm. + 4gm.	14gm. + 6gm.	—	—	—	—	—
Temperature at Producer outlet...	180/220° C.	150/160° C.	160/175° C.	400° C.	—	—	—	280/300° C.
Suction at Producer outlet ...	70/85 mm./wg.	150/250	150/190	—	—	—	—	—
Cooler or cleaner—inlet temp. ...								350° } suction 126mm. wg.
" " outlet temp. ...	60/70° C.	70/100° C.	50/80° C.	—	—	—	—	200°
Filters:—Type ...	Dry	Dry	Dry	Wet	Wet	Wet	Wet	Wet
Inlet temperature ...				} Difference of 40° C.				180° C.
Outlet temperature ...	30/40°C.	40/60° C.	20/35° C.					40° C.
Outlet suction ...	150/190mm./wg.	250/480	425/570	Difference 150/200 mm./wg.—total suction 640-135 according to load				200mm./wg. suction on cleaner
Temperature at mixer ...	20/25° C.	20/25° C.	20/25° C.	—	—	—	—	—
Impurities removed ...	—	—	—	All down to 10 mikron (0.0 1 mm.)				80-85% in dry cleaner, remainder in wet cleaner
Convert vehicles ...	Yes	Yes	Yes	Yes	New lorries			Fit to new vehicles with special gas engine
Compression ratio ...	7.45	7.45	7.45	—	6/8			—
Larger engine ...	If possible			Yes—plus 15/20%				
Special vehicle ...	No	No	No	No	No	No	No	No
Special mixing valve ...	No	No	No	Yes	Yes	Yes	Yes	No
Thermal efficiency... ...	—	—	—	85/87%	—	80/83%	80/83	80/85%
Savings ...	Varies with locality 1.4 kg. charcoal = 1 litre petrol		—	50% against petrol, 10% against diesel				—
Weight of apparatus ...		380 kg.		450 kg. for 65 h.p., including water and fuel				800 k. for 90 h.p. gas engine, including water and fuel
Reduction in weight capacity ...	—	—	—	—	—	—	—	Corresponding reduction in maximum laden weight
Reduction in load capacity ...	—	—	—	None if fitted in cab				None
Price ...	Frs. 12,000 plus Frs. 2,000 fitting charges			1,500—1,800 RM.				2,000/2,400 RM. for 90h.p. gas engine. Producer-gas lorry at same price as diesel lorry
Service—								
Firebox—Frequency ...	½ hour per week plus 2 hours per month			Grate agitator moved every 150/200 km., cleaned out 1,000/1,500 km. Ash withdrawn daily, wet cleaner every day including topping up with new water Re-oil filling material every 1,000/2,000 km.				De-clinkered daily. Cleaned out weekly. Emptied weekly. 5 minutes Washed out daily More frequently on L.T. coke, and also necessary to agitate the grate during operation.
Firebox—Time ...								
Cleaner or cooler—Frequency...								
Cleaner or cooler—Time ...								
Scrubber—Frequency ...								
Scrubber—Time ...								
NOTES : ...	Charcoal preferred as fuel on account of high reactivity, ease of cleaning gas. Equally successful with anthracite.			Charcoal preferred because of low ash, no sulphur and high reactivity. If charcoal is briquetted, low weight/volume ratio overcome.				Anthracite preferred on account of greater radius on one filling of hopper. From the operational standpoint any tar-and-sulphur-free fuel is equally good.

	GOH		GOHIN POULEN			BRANDT.	KOELA.		
SIZES ...			Five.			Three.	Six.		
DRAUGHT ...			Cross.			Double Zone.	Up, Down and Double.		
Fuel used ...	Charcoal	L.T. coke	L.T. coke	Anthraci	Mixed anthracite and charcoal	Wood and charcoal together	Charcoal, L.T. coke, peat briquettes, Anthracite.		
Is water used? ...	No	—	—	—	—	No		Yes	
Fuel sizes ...	15/22 mm.	—	—	5/15 mm.	—	Wood 8 cm. × 4/5 cm.: charcoal 15/25	*Charcoal.* ⅜—¾ in.	*L.T. Coke.* ⅛—½ in.	*Anthracite.* 3/16—7/16 in.
Consumption lb./h.p. hour ...	—	1.04	1.04	—	—	Wood 1.5/1.6 lb., charcoal 0.09/0.1 lb.	1.0	1/1.1 according to fuel	1/1.1
Gasification capacity ...	—	—	—	—	—	—	—	1,540 m³/m³hr.	—
Starting time ...	Starting by means of e		by means of engine suction			—	5/8 min.	8/10 min.	10/12 min.
Fuel Analysis—%									
Moisture ...	—	9.5	9.5	2.67	—	Wood not more than 18/20% of moisture	4.4	4.5	5.0
Ash ...	—	—	—	6.31	—	—	2.0	less than 3.7	3.5
Volatile ...	—	—	—	6.25	—	—	18.6	16.6	5.3
Carbon ...	—	—	—	84.77	—	—	75.0	75.2	86.2
Calorific value ...	—	—	—	7,500 kcal/kg.	—	—	7,700 kcal/kg.	7,346 kcal/kg.	8,250 kcal/kg.
Gas Analysis—%									
CO_2 ...	1.7	0.8—1.0	0.8—1.0	1.7	1.4	4.5/6	2.0	1.8	1.6
CO ...	28.4	30.1—29.3	30.1—29.3	29.3	27.8	23/26	31.3	28.6	29.0
H_2 ...	11.7	5.7—5.5	5.7—5.5	8.5	9.3	15/19	8.2	11.6	15.0
CH_4 ...				0.7		3.5/4	1.3	1.8	4.1
O2 ...	0.1	0.8—0.9	0.8—0.9	0.0	0.6	2/6	0.2	0.4	0.5
N_2 ...	61.7	62.6—63.3	62.6—63.3	59.8	60.9	46/52	57	55.8	48.8
Calorific value ...	—	—	—	1,180 kcal/m³	1,125 kcal/m³	—	1,249 kcal/m³	1,221-1,288 kcal/m³	1,340 kcal/m³
Water/Solid fuel ratio ...	—	—	—	—	—	—	—	15—40%	—
% decomposition ...	—	—	—	—	—	—	—	85—80%	—
Clinker and ash—h.p./hour ...	—	—	—	—	—	—	—	—	—
Temperature at Producer outlet...	400/500° C.	400/500°C.	400/500°C.	400/500° C.	—	—	180°/230° at bottom of preheater		
Suction at Producer outlet ...	—	—	—	—	—	—	—	—	—
Cooler or cleaner—inlet temp. ...	—	—	—	—	—	—			
" " outlet temp. ...	—			—	—	—	—	—	—
Filters:—Type ...	—	Dry	Dry	—	—	—	—	—	—
Inlet temperature ...	—	—	—	—	—	—	—	—	—
Outlet temperature ...	—	—	—	—	—	—	—	—	—
Outlet suction ...	100mm./wg.	—	—	—	—	—	At final filter outlet 150/350 mm., wg.		
Temperature at mixer ...	—	—	—	—	—		20°/25° C.		
Impurities removed ...	—	—	—	—	—		Gas to engine, 1-2 mgr./m³		
Convert vehicles ...	—	Yes	Yes	—	—	Yes		Yes	
Compression ratio ...		High compres	High compression heads fitted			8.1		6.5/7.5	
Larger engine ...						+ 33% and larger inlet valves	Yes, to meet special requirements—about +20%		
Special vehicle ...	—	No	No	—	—	No		No	
Special mixing valve ...	—	Yes	Yes	—	—	—		No	
Thermal efficiency... ...	—	80/85%	80/85%	—	—	—		85/88%	
Savings ...	—	30.8% nett.	30.8% nett.	—	—	—		See Table VII	
Weight of apparatus ...	166 kg. for Ford V.8 + diff		ord V.8 + difference in engine if fitted			450/500 kg. + 40/50 kg. for larger engine	170/190 kg. for 65 h.p.		
Reduction in weight capacity ...	—	None	None	—	—	—	Corresponding reduction in maximum laden weight.		
Reduction in load capacity ...	—	None	None	—	—	—		None	
Price ...	—	£80—£100	£80—£100	—	—	Frs. 21,000, including fitting for 75 h.p. Citröen	£80/85 for 65 h.p., including special cylinder head or pist		
Service—									
Firebox—Frequency ...	Emptied and drawn daily. T door in producer base durin		rawn daily. The ash may also be withdrawn through cer base during midday hal			Before starting each day, withdraw ash, etc., agitate grate, poke down both fuels. Adjust water level in scrubber. Each evening empty special condenser tank. Every 500 km. clean out cleaner. Every 1,000 km. inspect piping, wash out cleaner completely. Every 2-3 days examine condenser for tar.	400/800 km.	300/600 km.	300/400 km
Firebox—Time ...							10 minutes (remove slide grate)		
Cleaner or cooler—Frequency...	Filtering medium changed ab Filter cloths changed every 6 ı	Every 2 or :	Every 2 or 3 days m changed about every 1,000 km. anged every 6 months				100/300 km.	200/300 km.	250/350 km
Cleaner or cooler—Time ...								10 minutes	
Scrubber—Frequency ...	—	—	—	—	—		250/450 km.	400/500 km.	450/550 km
Scrubber—Time ...								10 minutes	
NOTES : ...	Charcoal or 75/25 mixture preferred.		75/25 mixture of anthracite charcoal or L.T. coke			—	Hardwood charcoal, selected cokes and anthracites, all comparable results. (Type of generator and grate given fuel—see section V)		