# PRODUCER GAS AS A FUEL FOR PETROL DRIVEN VEHICLES*

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SUMMARY

The use of indigenous fuels for automobile units is of national importance on account of the meagre petroleum resources. Abundant supplies of wood suitable for conversion into charcoal and low grade coal are available in this country. Producer gas derived from these materials is a suitable alternate fuel to petrol.

The technical and economic obstacle for the wide use of producer gas has been the poor performance of the producer gas vehicle; and reasons have been given in detail in the form of a general comparison between petrol and producer gas as fuel for internal combustion engines.

The technical difficulties for improving the performance of the vehicle are known and are not insurmountable, and means to overcome them are given and work in the I.C.E. Department is outlined briefly.

Besides the technical side, other obstacles are met when trying to introduce producer gas driven vehicles; the Government has to alter the existing regulations so that the user of the producer gas vehicle is not penalised, as is the case now. On the contrary he should be given a relief in taxation and the cost of conversion should be subsidised proportionately. With these facilities the use of producer gas vehicles can be made attractive and even compulsory if circumstances demand.

## 1. INTRODUCTION

1.1. Petrol is required as a fuel for spark ignition engines and India imports about 90% of its petrol requirements. The development of indigenous fuels for spark ignition engines is vital to the economic conditions of the country. The country's resources in vegetable matter and low grade coal are vast. Producer gas developed from these sources can be a partial

* The investigation has been initiated by Dr. H. A. Havemann at the Department of Internal Combustion Engineering, Indian Institute of Science, Bangalore, in course of planning the development of Engines to run on indigenous fuels. This report is a prelude to the experiments that are to be carried out with a converted automobile engine to accept producer gas.

substitute for petrol. Production of synthetic petrol from low grade coal, and power alcohol from molasses can reduce further the demand on petrol.

1·2. The paper deals with the main drawbacks of producer gas as a fuel for petrol engines and how this can be overcome by suitable alterations to the engine.

## 2. Disadvantages of Conventional Types of Producer Gas Driven Vehicle

2·1. The technique of using producer gas as a fuel for motor driven vehicles has made considerable progress during the last few years, but it is not generally accepted as fuel except in times of emergencies.[1,2] This is so due to the disadvantages of producer gas driven motor vehicles. The disadvantages can be listed as:

(1) Loss of power

(2) Increase in weight

(3) Increase in bulk

2·2. There are two aspects to the problem of using producer gas as a fuel for transport vehicles; one is the design of a complete unit comprising gasifier and a special engine to co-operate with it; and the other is the conversion of the existing petrol driven power plants; *viz.*, as used in vehicles for road transport. There is no fundamental or technical difficulty in developing producer gas driven vehicles whose performance will be equal to that of petrol vehicles; this can be achieved as explained later by using on the vehicle an engine of about double the cubical capacity or an engine working on a modified cycle. These developments take time and as such do not solve the problem immediately. It can be solved, however, by modifying the existing vehicles so as to accept producer gas and at the same time having the performance not far from that of the petrol driven vehicles. As already mentioned the use of producer gas on petrol driven vehicles has the main disadvantage of loss of power.

## 3. Power Output

3·1. Before calculating the loss of power and efficiency it would be better for the sake of comparison to introduce a brief note on the theoretical cycles used. The four stroke internal combustion spark ignition engine is assumed to work on the constant volume cycle (Fig. 1) in which the gaseous or vaporized fuel and air mixture is compressed adiabatically to a pressure

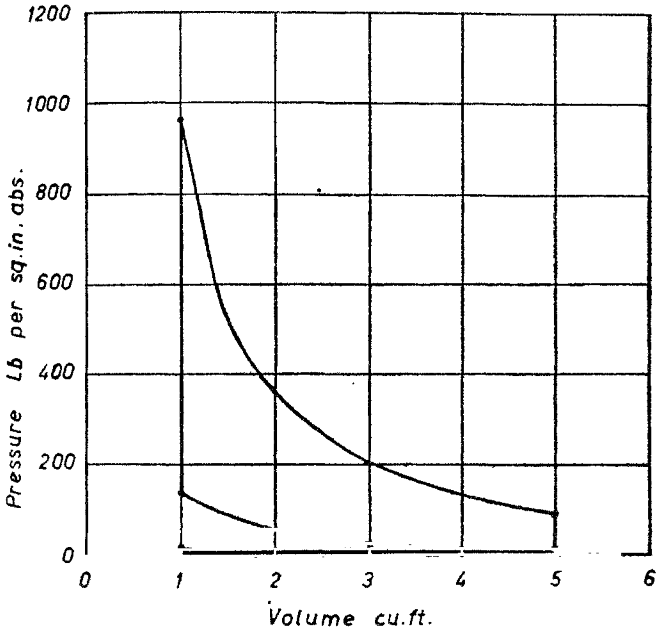



FIG. 1

depending on clearance volume, and exploded at constant volume; the gases are then expanded adiabatically, and the final residual gases are rejected at constant volume. The thermal efficiency for the cycle is given by:

$$\eta_{th} = 1 - \left(\frac{1}{r}\right)^{\gamma-1},$$

where $r$ = Expansion or compression ratio.

$\gamma$ = Ratio of specific heats for air.

Table I gives the air standard efficiency for different expansion ratios.

TABLE I

*Air Standard Efficiencies*

| Ratio of expansion "r" | Thermal efficiency $1 - \frac{1}{r}^{\gamma-1}$ |
|---|---|
| 2 | 0·240 |
| 3 | 0·353 |
| 4 | 0·423 |
| 5 | 0·471 |
| 6 | 0·508 |
| 7 | 0·537 |
| 8 | 0·561 |
| 10 | 0·598 |
| 12 | 0·626 |
| 14 | 0·648 |
| 16 | 0·666 |
| 18 | 0·682 |
| 20 | 0·695 |

3·2. The power output of the engine which characterises the performance of the vehicle depends on the properties of the fuel. The following are main considerations:—

(*a*) The net calorific value of the fuel air mixture.

(*b*) The change of specific volume on combustion.

(*c*) Specific heats of the products of combustion and the degree of dissociation at high temperatures.

(*d*) The latent heat of evaporation of the fuel (if liquid).

(*e*) The specific gravity of the fuel-air mixture.

(*f*) The radiation from the flame and the hot products.

(*g*) The velocity of combustion under engine conditions and possibilities to influence (*a*).

The two fuels which are compared are No. 3 petrol as specified in technical data on fuel[3] and producer gas of the following analysis: $CO = 32\%$, $H_2 = 1\%$, $CO_2 = 2\%$, $N_2 = 65\%$, which may be regarded as an average of what is known as producer gas.

3·3. Though the energy liberated by complete combustion from a cubic inch of air if mixed under stoichiometric conditions with any fuel is practically constant, the comparison on the cubical capacity of the engine gives erroneous results, when one of the fuels is liquid and the other fuel is gaseous. Assuming petrol to be a gas in the fuel air mixture the volume of petrol is less than 2% in a stoichiometric fuel air mixture. Actually the petrol will be in the form of a vapour inside the cylinder and as such this figure is further reduced, since in the liquid form it only forms 0·013% by volume of the air fuel mixture. While the percentage of petrol by volume is very small in a correct fuel air mixture the percentage of producer gas in a correct fuel air mixture is nearly 55·50%. Hence the comparison should be made on the basis of unit volume of the fuel air mixture.

The following figures are taken as a basis of comparison between the two fuels:

| | No. 3 Petrol | Producer Gas |
|---|---|---|
| Chemical composition .. | C=85·1% H=14·9% by weight | $CO$ =32% $H_2$= 1% $CO_2$= 2% $N_2$=65% by volume |
| Calorific value of the fuel | 95 B.T.U./cu.ft. | 59 B.T.U./cu.ft. |
| Specific volume change on combustion, *i.e.*, volume of products net at S.T.P. to volume of mixture at S.T.P. | 1·062 | 0·907 |
| Mean specific heat of products of combustion 0° C.–2200° C. | 0·02385 B.T.U./cu.ft. | 0·0270 B.T.U./cu.ft. |
| Latent heat of evaporation | 254 B.T.U. | .. |
| Specific gravity of the fuel | 0·784 | 0·97 |

3.4. The effect of the above factors on power output cannot be estimated individually but it is possible to estimate their combined effect. The important factor is the difference in the calorific value of the mixture, which is 38% less in case of producer gas. Practically the power output on gas should be less by this percentage; but the other factors are to be taken into account. The specific volume change shows an expansion of 6·2% on petrol and a reduction of 9·3% with producer gas, so that the ratio of volumes after combustion is

$$\frac{V_g}{V_p} = \frac{0\cdot907}{1\cdot062} = 0\cdot855.$$

This naturally favours petrol as it indicates a higher pressure rise with a lower working temperature. The higher specific heat of the products of combustion of producer gas reduces the flame temperature.

The theoretical flame temperature with petrol under conditions given is 2,080° C. or 2,353° K. while that with producer gas is 1,920° C. or 2,193° K. The effect of this on the pressure development is against producer gas by a factor of 0·932, *i.e.*, by roughly 7%. Taking into consideration the above factors the ratio of pressures developed under ideal conditions will be

$$0\cdot 855 \times 0\cdot 932 = 0\cdot 80,$$

so that the pressure development on gas is less by 20·0%.

3·5. The specific volume change depends on mixture strength; when the mixture strength increases there is a certain amount of potential heat in the exhaust gases and is thus lost. There is a limit up to which increasing of mixture strength is advantageous, but further increase will reduce the thermal efficiency on account of the loss of heat in the exhaust gases.

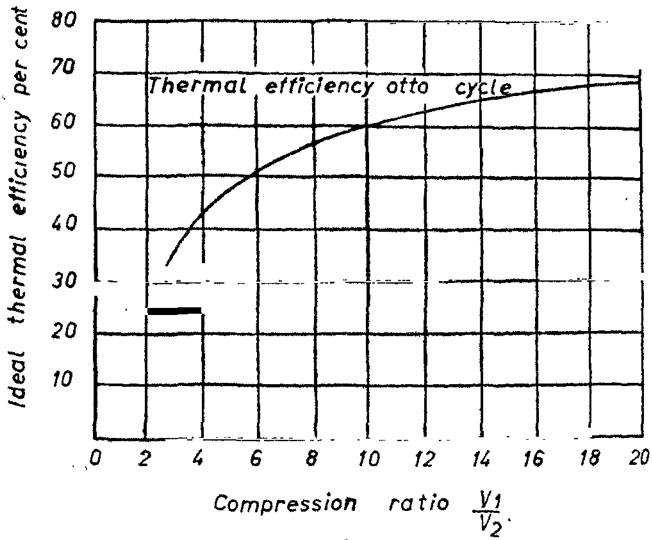



FIG. 2

3·6. The latent heat of evaporation has a marked effect on the volumetric efficiency of the engine.[4] In case of petrol the air fuel charge is cooled by 28° C. and the result of this cooling is to increase the volumetric efficiency by 7%. This intrinsic effect is absent in case of gas and the intake charge is warmer and this reduces the charge density. The output is directly proportional to the weight of the charge inducted and is thus proportional to the volumetric efficiency.

3.7. The effect of viscosity and specific gravity of the air fuel mixture on the discharge characteristics through the valve gear cannot be individually estimated. But the equivalent effect on an engine is inversely proportional to the square root of the density. In this case the advantage is with producer gas.

$$\frac{d_{petrol}}{d_{gas}} = \frac{1 \cdot 04}{0 \cdot 966} = 1 \cdot 04.$$

3.8. The cooling losses from the burning gases are difficult to estimate owing to the unsteady conditions in the engine cylinder. At low temperatures (100 °C. to 500 °C.) the rate of cooling is proportional to the temperature difference between the gas and cylinder; but at high temperature (1,500° C.) the rate of cooling is proportional to the square of the temperature and at 2,400° C. it varies as the fifth power of the temperature difference.[5] It can thus be seen that though the calculated flames temperature between gas and petrol differ only by 160° C. the effect of this radiation from gas to the cylinder wall will be considerably less for producer gas.

The radiation losses may be considered to be mainly from carbondioxide and water vapour present in the explosion products. The radiation loss may be calculated from the formula[6]

$$Q\,CO_2 = 3 \cdot 5\ \sqrt[3]{PS} \left(\frac{T}{100}\right)^{3.5}$$

$$Q\,H_2O = 35\,P^{0.8}S^{0.6} \left(\frac{T}{100}\right)^{3},$$

where $Q$ = Radiation kcal/m$^2$ hr.

$P$ = Partial pressure in atmospheres.

$S$ = Depth of radiating layer in meters.

$T$ = Temperature °K.

The radiation from the other gases can be neglected.

3.9. From the above formulæ it is seen that the radiation from the water vapour predominates. On account of the small percentage of hydrogen present in producer gas, it is possible to expect less radiation loss from the combustion products. Thus it can be expected that the thermal efficiency with producer gas will be slightly higher than in case of petrol.

The determination of the cooling water jacket loss gives the total loss due to radiation, conduction from hot gases and from incandescent carbon particles.

3.10. Combining the effects of calorific value, specific volume change and volumetric efficiency ratio, the power output on producer gas will be

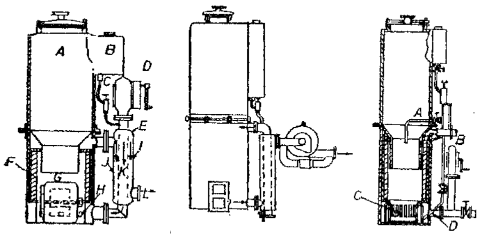
$$0 \cdot 62 \times 0 \cdot 8 \times 0 \cdot 95 = 0 \cdot 47$$

nearly 47% of the power developed on petrol. This power output can be expected at low speeds since at high speeds the volumetric efficiency considerably falls off in case of the producer gas.

## 4. METHODS OF IMPROVEMENT

4.1. To improve the performance of the power plant, improvement in the gas generation and the engine have to be considered separately.

4.2. The gas generators may be classified as (1) up draught, (2) down draught, (3) double draught[6] (see Fig. 3). The gas is led to the engine through a series of coolers and filters.




Updraught Producer — A Hopper, B Water, C Air intake, D Blower, E Hot jacket, F Refractory lining, G Fire, H Distributor ring with six ports, J Gas, K Air, L Outlet.

Down Draught Producer

Double Draught Producer — A Air inlet down draught, B Gas exit double draught or updraught and air inlet down draught, C Vertical coke grate, D Air inlet up draught and gas downdraught.

FIG. 3

The suction produced by the engine induces the air flow through the bed. The speed and power output of a mobile unit are continuously varying and as such the rate of air flow through the bed is irregular. This change in air flow rate affects the combustion and gas generation. At high speeds the rate of flow of gas is high and hence the gas cannot be cooled efficiently. This reduces the charge admitted to the cylinder and the power output falls.

4.3. These drawbacks can be overcome if a centralised gas generating station is installed. The gas generation can be held under ideal conditions such as a constant rate of air flow, and controlled combustion. As there are no space limitations the gas cleaning and removal of tarry matter can also be complete. The gas that is supplied to the engine will be at room temperature, and this increases charge density.

4.4. The centralised gas generation is possible if there are proper distributing sub-stations. By the use of gas bags (see Fig. 4) the problem of carrying the gas can be solved for small vehicles whose travelling range is limited. But in case of trucks and buses this system cannot be used, and the use of nigh pressure (3,000—5,000 lb./sq. in.) cylinders can be adopted. This, however, implies that heavy bottles have to be carried about.

4.5. This actually means high pressure compression of gas and development of high pressure cylinders (see Fig. 5). The compression of gas is not difficult as there are no unsaturated hydrocarbons as in case of other gaseous fuels.[7] The use of high pressure cylinders can be permitted only if proper testing of these cylinders is carried out regularly. The use of this type of cylinders reduces the additional weight due to the gas producer and also the space occupied.

4.6. The possibility of development of light weight producer gas unit such as cyclone type gas producer,[8] is also feasible. This type of gas generator has an advantage over the orthodox type in ejecting out the clinkers which are a source of trouble. The attention required for maintenance is also less. Due to the possibilities of high velocity of flow, the size of the plant can be much smaller than the orthodox type, but the system is limited to accepting only pulverised or liquid fuels.

4.7. On the engine also the following changes can be made to improve the performance. It would have been noted from (Fig. 2) that the thermal efficiency increases with the expansion ratio. Fortunately the carbon monoxide in producer gas can work under higher compression ratio without detonating. In a normal converted vehicle, the engine running on producer gas is expected to work on petrol in emergencies; this is especially important also for starting the engine. In view of the above requirement the compression ratio can be increased only up to about 8·25. With this compression ratio the gas forces will not increase beyond the values obtained in a normal petrol engine.[9]

Referring to Fig. 2, the increase in thermal efficiency due to the increase of compression ratio is nearly 10%. The increase in compression ratio decreases the quantity of gas in the clearance volume, and the dilution of the incoming charge by the residual gas is also reduced. Thus the volumetric efficiency may be expected to increase. But the cycle temperatures are increased or in other words the temperature of the residual gas will be higher. The two effects may probably cancel each other.

4.8. Since the gas does not require any additional heat for an evaporation as in the case of petrol engines, the otherwise hot spot in the inlet manifold has to be insulated from the exhaust manifold and this will also tend to lower the temperature of the incoming charge.

4.9. The net effect of these changes may result in a slightly improved power output due to the increase of the thermal efficiency, and will be about $47 \times 1 \cdot 1 = 51 \cdot 7$ say 52%, of the maximum power developed on petrol under the conditions. Any further increase in the power output requires considerable alterations both to the engine and gas producer.

The power developed is proportional to the weight of the charge that could be pumped into the cylinder per cycle. The easiest way of achieving this is by having an engine of higher cubical capacity or by supercharging the engine and the gas producer to supply gas at a faster rate, under a higher pressure.

4.10. The supercharger can be driven by an exhaust gas turbine. This no doubt uses the exhaust energy available, but in an automobile unit the exhaust energy is continuously varying from zero at idling or at no load to maximum at full load. A geared supercharger will not have the same disadvantage but the increase in brake mean effective pressure will be lessened. Introduction of a supercharger unit into the power plant has to be investigated before any mass production of such units can be taken up.

4.11. Here the remark from Dr. C. M. Walter will not be out of place.[10]

" If we consider the case of an engine working on a constant quantity variable quality cycle so designed that during the induction stroke a full charge of air is taken into the working cylinder, the fuel being added in proportion to the load at a certain point, in the compression stroke, we will find that under widely varying condition of load the volumetric efficiency remains very nearly constant, with the result that very high thermal efficiency will be obtained over a wide range of speed and power outputs. With an engine working in this manner it is quite possible that an average brake thermal efficiency approximating to 30% might be obtained, even at a comparatively low load factor as compared with a figure of 13-15%, which represent the average figure obtained with present designs of engines when running under average conditions. This would mean that the fuel consumption would be reduced by approximately 40% which would in turn result in the radius of action for a given charge being considerably increased. It is hoped in the near future that experiments will be conducted on specially designed engines working on this principle."

4.12. It may be mentioned here that experiments on an engine with town gas on similar lines as above have shown that the power output of the engine was nearly 30% above the power developed in a normal engine running on fuel oil, though the power output of a converted engine with town gas as fuel is about 60 to 70% of the power output on petrol.

## 5. Disabilities of Producer Gas Vehicles Under Existing Regulations

5.1. Inducement to use producer gas on account of its low cost is not enough on account of the existing regulations. The fuel cost forms only 20 to 30% of the operating cost; and the resulting economy by the use of producer gas is off set by the increase in maintenance cost and also on account of higher rate of taxation.

5.2. The taxation of road vehicles for carriage of goods is based on the unladen weight of the vehicle. The weight of the producer unit with its accessories places the vehicle in a higher class of taxation. Even the speed limit is fixed on the basis of unladen weight and the permissible speed of the producer gas vehicle is less than that of a vehicle of same capacity running on petrol.

5.3. Any commercial vehicle depends for its earning capacity on its pay load in the difference between its unladen weight and gross weight that is allowed by the regulation. The pay load is thus reduced by the weight of the producer unit.

5.4. Development of producer gas vehicles under these disadvantages is possible if the Government can change the regulation so that the user of producer gas vehicles is not penalised. In the initial stages subsidy towards the cost of converting the petrol driven vehicles is necessary. Such kinds of subsidy and reduction in taxation for producer gas vehicles has encouraged the use of producer gas vehicles on the continent.[11]

## 6. Conclusions

6.1. On account of shortage of natural sources of petroleum products, the development of producer gas vehicles is vital to our country.

6.2. There are no insurmountable difficulties on the technical development of producer gas units.

6.3. Development of producer gas unit and its wide use is only possible under changed regulations of taxation. The producer gas vehicles must be permitted to carry the same load and operate at the same speed as petrol engines of equal capacity.

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## APPENDIX I

$CO$ = Carbon Monoxide.
$H_2$ = Hydrogen.
$CO_2$ = Carbon Dioxide.
$N_2$ = Nitrogen.
% = Per cent.
B.T.U. = British Thermal Unit.
Cub.Ft. = Cubic Feet.
S.T.P. = Standard Temperature and Pressure.
° C. = Degrees Centigrade.
° K. = Degrees Kelvin.
kcal/$m^2$ hr. = Kilo calorie per square metre per hour.
lbs/sq.in. = Pounds per square inch.

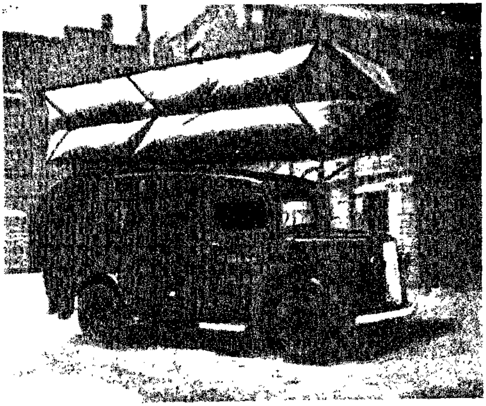

Fig. 4

Fig. 5