PRACTICAL ACTION
Technology challenging poverty

PRODUCER GAS
FOR AUTOMOTIVE USE

technical brief

Introduction
Producer gas is formed by the partial combustion or gasification of a solid carbonaceous fuel with a restricted air flow in a suitable furnace, generator, or producer unit; hence the name producer gas.

The actual chemistry is complex and depends upon prevailing conditions inside the gas generator. When air is passed through a hot (glowing) bed of fuel at about 1000°C, oxygen tends to combine with carbon to produce a mixture of gases rich in carbon monoxide (CO). Unfortunately, the mixture is diluted by the inert nitrogen of the air, and if the temperature or contact time is insufficient, there will be an undesirably high level of carbon dioxide (CO_2). If the fuel is damp there will be hydrogen present and a little water or steam may be injected to raise the calorific value of the gas and reduce the proportion of nitrogen dilutant. Excessive amounts of hydrogen or moisture are a disadvantage, and as metering is difficult, especially in a mobile unit, this provision may be omitted.

Some 700,000 units were probably in use during the 1940's, mostly in Europe, but due to their inherent inconvenience they were quickly abandoned once liquid fossil fuels became available, and the commercial manufacture of producer gas units ceased.

A producer gas unit consists of a number of components.

Generator
The gas generator is usually cylindrical in shape for strength and ease of manufacture. Fuel is fed by gravity from the upper hopper section into the lower fire zone section. There are four kinds of generator, named from the air flow direction. Down-draught units have a restriction around the hearth causing an increase in air velocity and higher operating temperature which tends to gasify tars which would otherwise be a problem when using green wood as fuel. Updraught generators are efficient producers of industrial type heating gas where higher tar contents are no problem.

Cross-draught generators have a small intensely hot fire zone with air fed from a nozzle or tuyere. The refuelling lid and ash removal door must be air tight, and gas is sucked out by the engine through a lateral delivery pipe, hence the alternative name of suction gas. The air-jet provides sensitivity to varying gas demand as in an automotive engine, when compared with a stationary engine. During World War II some models had water cooled tuyeres to prolong their life to about six months, but work in Australia suggests that heat resistant alloys may allow a life of about 150,000 kilometers without the complication of water cooling. With a restricted fire zone, it is not necessary to protect the casing with refractory or stainless steel lining, but it is essential to use evenly sized well packed fuel if gasification is to be efficient. A fourth type is a combination of the above.

Cleaning section
On leaving the generator, producer gas must be cleaned of impurities such as soot, ash, unburnt fuel dust and tar in order to prevent engine damage. The design and sequence of components will depend upon requirements of fuel and engine, but must not offer excessive resistance to the gas flow if engine starvation is to be avoided.

Primary removal of coarse material may be effected by a simple expansion box, a baffle box or a cyclone, in which particles drop out of the gas stream when the gas changes direction and loses velocity.

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Secondary cleaning, which may follow the cooling section, may be a dry or wet process. The gas may be filtered dry through sisal, wood, wool, felt, paper, fabric, or close set brush bristles, and electrostatic filters are also on the market. In wet filtration, the filter element is wetted with oil or water. Water is not very effective against tar but may reduce the incidence of explosions. Wet filtering is also called scrubbing or washing.

The choice of filters should not be made on technical efficiency alone but rather on possible operational reliability. Experience with agricultural tractors has indicated that for example, although modern paper air filter elements may be capable of high efficiency, the importance of the odd hole may be ignored with serious and costly breakdowns in equipment and operations under practical third world conditions.

Cooling section

Cooling the gas will increase its density, so allowing a greater charge (by mass) per cylinder, and exposed piping when cooled will become less of a fire hazard. After the primary cleaning unit, the gas may then be passed through a radiator unit mounted at the front of the vehicle or above the cab in the slip stream. In a boat, there will be ample water for a cooling jacket around the gas delivery pipe.

The cooler may be by-passed by means of butterfly valve for starting from cold if condensation is found to clog dry filters. A fine wire gauze or felt cloth placed before the engine as a "security filter" will clog up and provide warning of failure of the cleaning-cooling sections when the engine stalls.

Mixing valve

Efficient engine operation requires adequate adjustment of the proportion of air and gas, and the quantity of the resulting mixture reaching the engine. In its simplest form the valve consists of a Y-piece. The gas enters through one branch, the air from an air cleaner through the second branch, and the resulting mixture flows through the stem to the existing engine induction system between the carburettor and the induction manifold.

The admission of air is controlled by a butterfly valve in the air branch. The supply of mixture to the engine is regulated by a throttle valve in the stem, coupled to the vehicle's accelerator pedal. If liquid fuel is also used, this is best controlled by an additional independent control. Ignition timing must also be considered. If the air-gas mixture control is manual this will tend to give a lean mixture at lower speeds (and gas velocity) and a richer mixture at higher speeds unless careful attention is paid to driving, or an automatic control is installed.

Some design refinements

Some sixty firms were known to be manufacturing automotive type producer gas units in the 1940’s, including Mercedes-Benz, Imbert, Panhard, Deutz, Zeuch, Grunert, Volvo and Henschel. Different firms used different designs and refinements. These included a spring loaded top cover on the generator to lift when explosions occurred in the generator, one way air valves and flame arrestors, an annual tuyere, the provision of a shaker grate, fuel cut-off slide, condensate tank and drain cock, air pre-heating and a flue with valve for use when the engine was stopped temporarily.

The unit can be mounted on a trailer. This allows the unit to be used to power alternative stationary engines, and access for maintenance would be facilitated. However, there is the additional mass and cost of the trailer, the presence of which will complicate reversing and preclude the opportunity of towing.

The use of producer gas in the 1940's was largely to operate existing spark ignition (SI) petrol lorries for the transport of men and materials. Agricultural work was still done largely by hand or with horses.

Engine designs were not critical. Manifolds and porting were large enough to accept any increase in gas mixture volumes. Slow revving engines facilitated up to 10 degrees of additional ignition advance required for use of slower burning producer gas. All vehicles possessed a strong chassis on which to mount gas producer components, and people were less concerned with styling and appearance than is the case now. Compression ratios quoted were between 4: 1 and 8: 1, which is below the critical compression ratio (CR) for hydrogen, above which hydrogen tends to detonate with loss of performance and damage to the bearings resulting.

Producer gas will form a mixture with air to replace a petrol-air mixture in a petrol engine, but it will not ignite like diesel does in a compression ignition (CI) engine. The addition of spark ignition to a diesel engine is considered impractical, and detonation of hydrogen in diesels with CR greater than about 9 : 1 may preclude the possibility of using the new generation of modern diesel engines. Some success has, however, been obtained using diesel engines as dual-fuel or pilot-fuel engines in which normal diesel fuel is used to start the engine and operate it at idle. Further power is obtained by supplying producer gas. As fuel consumption at idle is approximately 10% that at full load, this system of operation would result in up to 90% fuel saving. However, as surveys show that up to 50% of farm work only uses about 50% of tractor capacity, the actual fuel saving might be nearer 50%.

Loss of engine performance

When using producer gas, power loss may occur in four ways:-

1 The presence of nitrogen from the atmosphere as an inert dilutant of the gas-air mixture will cause a reduction in power of about 35 to 50%.
2 The power required to carry the additional load of the gas unit, of between about 200-700 kg for units to operate engines up to 3 litre capacity.
3 The normal derating or unblown engines due to increasing altitude and ambient temperatures round in many Third World countries.
4 Due to the above, a modern engine designed for use with high grade fuels, may no longer be able to operate on the centre of its power curve, resulting in excessive use of gears and further loss of performance. This could be a serious limitation with agricultural tractors where effective pulling power is essential for efficient ploughing and land cultivation.

Driving

Starting involves the provision or a brand or other fire source and draught to the generator fire zone, taking care in case any residual gas explodes. The draught must be provided either as suction by the engine already started on liquid fuel or from an external source such as an electric fan or foot bellows. Sufficient gas should be available after 10- 15 minutes for the activation or the fuel change over valve by means or a mechanical linkage system or electrically operated solenoid.

Finer adjustments to the mixing valve and the refuelling of the generator will come with experience. An efficient tuyere will allow short stops of up to 15 minutes. Longer stops will require "banking" of the generator unit or repetition of the cold start procedure. A 'banked' vehicle should always remain in the open and a producer gas operated vehicle always requires a well ventilated garage in order to disperse the poisonous gas which tends to leak out of a unit when running down.

The driver will become accustomed to the slight loss of response to the accelerator.

Maintenance

A producer gas unit must be refuelled before the fuel level has dropped more than about three quarters, or to keep at least 300 mm of fuel above the fire zone, or the production of gas will be interfered with and the possibility of explosions increases.

Generator size should be such that the vehicle will at least 100 -200 km on a refuelling.

Maintenance will include refuelling, the removal of ash and any clinker from the generator, and the removal of dust and condensates from the cleaning and cooling sections. Normal lubrication should be unaffected. Engine wear may be reduced with an efficient gas unit due to there being less corrosives, a lower exhaust gas temperature, less carbon deposited, and less bearing wear due to a smoother slower rate of burning. It is important that no leaks are left unrepaired, so regular frequent inspections are essential in order to maintain the unit in an efficient and safe condition. This may not be done unless arranged through a central garage service.

German experience in the 1940's indicates a need for over an hour a day general maintenance plus welding and minor repair work on a monthly basis.

Task	Time (Min)	Total time per month (Min)
Daily preparation	25	600
Daily cleaning	30	720
Weekly clean and check	150	600
		1920 or 32 hours

Under these good conditions, the German estimate of economic life for a portable gas producer was ten years for a lorry doing 250,000 km, but they stressed the expense and inconvenience of continuous maintenance to achieve this.

Fuel

Any carbonaceous material can be converted to producer gas but automotive use requires a reliable source of high quality gas, low in dust, moisture, tar and sulphur. The fuel must be evenly graded, of moderate particle size, with a high reaction response, high calorific value, and having low ash and clinker characteristics. The fuel should be cheap, readily available and uncontaminated by soil and water.

The one fuel which closely approaches this ideal is good quality retort produced charcoal from hardwoods. Fine grained material such as sawdust would be as good if briquetted, but this process is difficult and expensive in practice, especially as the end product must be low in tar, moisture and clinker, a situation aggravated by most binders. Coke may be improved by the use of an activator such as lime or sodium carbonate. Coking and charring remove undesirable tars.

Good quality hardwood charcoal may contain less than 1 grain of tar per kg. By comparison, maize cobs contain 80- 100 times this amount of tar which is extremely difficult and expensive to remove in a mobile gas unit. It is far better to process the fuel at a central static fuel site and not try to do it in a moving gas unit. The best charcoal, evenly burnt and free of contamination, is produced in a retort.

Charcoal from a pit may contain soil and unburned pieces high in tar. In an emergency, fairly good charcoal can be produced in an old fuel drum.

To change seasonally from one kind of fuel to another could involve major modifications to equipment if this involves a change in fuel characteristics.

Fuel consumption

Figures quoted by different sources vary considerably due to variations in fuel, in gas and in operating conditions. Good quality producer gas may have a calorific value (CV) of about 4,200 kJ/m^3 at normal temperature and pressure (NTP). The problem is that while a high contact temperature is required in the fire zone of the gas generator for efficient gasification, a low air-gas temperature is required for efficient engine operation (volumetric efficiency). Calculated on a cold gas basis at NTP, producer gas has an efficiency of about 72%.

Efficiency = potential heat in qas/total heat in fuel

However, this may be reduced in practice by the incorrect proportion of air admitted, and by temperatures which in practice will be higher than 'normal' (NTP), hence the importance of temperature control in gas units.

1 kg air dry wood (15 -20% mc) produces approximately $2.3m^3$ gas
1 litre petrol = approximately 2.5 to 3 kg wood
1 litre diesel = approximately 3 to 3.5 kg wood
1 kWh requires approximately 1.0 to 1.3 kg charcoal
2.5 kg wood, or 2.4 to 3.2 kg rice husk

In a Danish economy run, trucks averaged 60g charcoal per tonne kilometer, and the winner did about double this. A Mercedes Unimog in Belgium recently did 100 km in one hour running at full power and used 20 kg of charcoal, with a gas producer unit of 450 kg mass with a range of 3 hours at 60 km/h.

In the 1940's, a German estimation of wood requirement for 10,000 trucks, averaging 30,000 km each per annum at approximately 1 kg/km was 3 thousand tonnes, per annum. Such an order would provide considerable employment and economic activity for any forestry enterprise, especially if the wood was converted to charcoal.

Costs and implementation

Data is required to evaluate a scheme but with producer gas, there are no commercial manufacturers. World War II experience was not commercially motivated, and modern technology is not always readily comparable, e.g. truck and agricultural tractor prices are weighted by the introduction of accessories, power operated equipment and safety items.

Local fuel supplies can be evaluated and the number of vehicles known from imports. Liaison with an existing firm with expertise in producer gas work would eliminate the need to start up a new R and D programme, and they would provide production drawings, quantities, and advice concerning manufacture using local facilities as far as possible which would create employment.

Any manufacturing programme would need to consider patent rights, the risk of litigation, manufacturing rights, and the need for a national programme as part of a total energy policy, backed by media propaganda and any necessary alteration in legislation to legalise modified vehicles that might otherwise become illegal or penalised.

Such an energy programme could itself lead to a reduction in liquid fuel consumption, without the introduction of producer gas, simply because of the establishment of social acceptance to giving lifts, travel planning, economising and other intangibles. Farmers in several countries have already reduced their fuel consumption in some areas by up to 20% through the introduction of new minimum tillage techniques.

Other possible side effects of an introduction of a new fuel system might include reduction of pollution, a cut in government revenue from liquid fuel tax, the diversion of low value biomass material to an alternative new and possibly lucrative market, resulting in the possible impoverishment of soil, crop failure and increased poverty amongst the low income sector of the community least able to withstand change, so converting what might appear to be a technical fuel problem into a social disaster.

Conclusion

The advantages and disadvantages of using producer gas in existing commercial vehicles for Third World Countries involves many technical, economic and social factors, related to local conditions, and to generalise may be misleading. Each case must be considered individually.

The mounting of a gas unit will invariably result in the loss of some vehicle performance, load carrying capacity, visibility, convenience and access. Fire and gas poisoning are hazards, and operation will also require new expertise and more maintenance work than is needed for liquid fuelled engines. The saving of scarce foreign currency might be more easily achieved with alternative fuels or technology supported by an overall national fuel policy including research, development and education.

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Conversion factors

Length	1 metre = 39.37 in = 6.214 x 10^{-4} mile
Speed	1 km/hr = 0.6214 mi/hr
Mass	1 kg = 2.205 Ib; 1 metric ton = 1000 kg
Power	1 hp = '745.7 watt

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