The Feasibility of Producer Gas in Electricity Generation*

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ABSTRACT

Combustible gas known as producer gas can be obtained by partial combustion of solid fuels. Producer gas can be utilized as fuel for internal combustion engines and was used extensively during the Second World War as fuel for buses and cars. The rising energy price has led to a renewal of interest in producer gas. One interesting application seems to be local electricity generation with internal combustion engines.

Producer gas systems were designed and fabricated to provide gaseous fuel to gasoline engine-generator sets. The performances of various components in the system were studied, and necessary modifications were made to ensure satisfactory operation. Experiments were carried out to investigate the specific fuel consumption, fuel cost, the temperature in the gasifier, the quality of gas and the performance of the system when commercial charcoal, rubber-tree charcoal and rubber-tree wood were used as fuels.

The performances of the system when operating with various types of solid fuel are compared with that of the system operating with gasoline. Fuel costs in generating electricity with solid fuels and gasoline are presented and compared. The economic feasibility of producer gas in electricity generation is discussed.

The technical feasibility of producer gas in electricity generation and some practical aspects concerning the performance and operation of the system and the quality of gas produced are considered.

INTRODUCTION

Producer gas is a low calorific value gas obtained by heating solid fuels with a restricted supply of air. The process of forming producer gas is called gasification, as it converts solid fuel into combustible gas, which can be used as fuel for internal combustion engines. The process of gasification is not a new technology. Producer gas was used extensively during the Second World War in Northern Europe and countries under the Japanese occupation as fuel for buses and cars. After the war, the availability of cheap oil led to the decline in the utilization of producer gas. The increase in the price of oil has led to a renewal of interest in producer gas, especially during the past few years. For countries which have to import oil and have agricultural and forest industry

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residues available, producer gas can be an important alternative source of energy.

Electricity generation with the use of internal combustion engines has played an important role in developing countries, especially in areas which could not be reached by the national grids. In areas where there is an excess of local solid fuels, it is reasonable to consider the utilization of these fuels to replace oil as an energy source for electricity generation. Technically, this can be done by direct combustion of such fuels in a steam power plant, but a small-scale steam power plant is expensive and inefficient. With producer gas, the existing engine can be used with the addition of a gasifier. It is therefore of great interest to investigate the possibility of using locally available fuels to generate electricity by using internal combustion engines.

Prince of Songkhla University, with the support of the International Foundation for Science, has started a programme of research and development on producer gas with the intention of developing the technology of utilizing producer gas as an alternative source of energy in this country. This paper presents experimental results and experience obtained from the first stage of the work, which was intended to study the feasibility of producer gas in small-scale electricity generation and to familiarize researchers in the team with producer gas systems before proceeding to the next step of the work.

THEORY

Gasification Process

In the process of gasification, combustible gases are produced by an incomplete combustion process, which is caused by the restriction of oxygen supply. Producer gas is formed by the process of gasification of solid biomass in a gasifier or a reactor, and air is used in the process.

In the gasifier, the reactions at high temperature between oxygen in the air and solid fuel occur in the *combustion zone* to form carbon dioxide and water vapour. If there is a surplus of solid fuel, carbon dioxide and water vapour from the combustion zone may pass through the glowing layer of charcoal and are reduced to carbon monoxide and hydrogen in the region known as the *reduction zone.*

In the combustion zone the reactions which are exothermic are

$$C + O_2 \longrightarrow CO_2 \qquad (1)$$
$$2H_2 + O_2 \longrightarrow 2H_2O \qquad (2)$$

The main reactions in the reduction zone are

$$C + CO_2 \longrightarrow 2CO \qquad (3)$$
$$C + H_2O \longrightarrow CO + H_2 \qquad (4)$$

As reactions (3) and (4) are endothermic, the temperature will decrease during reduction.

Apart from reactions (3) and (4) other reactions may take place in the reduction zone as follows:

$$C + 2H_2 \longrightarrow CH_4 \qquad (5)$$
$$CO + 3H_2 \longrightarrow CH_4 + H_2O \qquad (6)$$
$$C + 2H_2O \longrightarrow CO_2 + 2H_2 \qquad (7)$$
$$CO + H_2O \longrightarrow CO_2 + H_2 \qquad (8)$$

The combustible components of producer gas are carbon monoxide, hydrogen and methane, the percentages of which should be made as high as possible.

The quantity of carbon monoxide in the gas depends on the degree of reduction of carbon dioxide to carbon monoxide in the reduction zone. The degree of reduction depends on many factors, e.g. the active surface area of the charcoal, the relative velocity between the gas and the charcoal bed and the temperature in the reduction zone. The temperature in the reduction zone seems to be the most important factor, as it has been found that to obtain good reduction the temperature in the reduction zone should be high enough. According to The Swedish Academy of Engineering Sciences,[1] to obtain complete reduction, i.e. to obtain 34.5% of carbon monoxide, the temperature in the reduction zone must be above 1,100°C, and to obtain 90% reduction, a temperature of above 900°C is required.

For producer gas generated from charcoal, reaction (3) is the final result, i.e. carbon monoxide is the only main combustible component. However, if water vapour is present, hydrogen and methane may also be formed as indicated by reactions (4), (5), (6), (7) and (8).

Reaction (4) is very important as it can enrich the gas with hydrogen, and thus enhance its calorific value. This has led to the practice of injecting water into the gasifier to make the condition favourable for the formation of hydrogen. However, if too much water is added, carbon monoxide may react with water vapour to form carbon dioxide and hydrogen, as indicated by reaction (8), and thus the carbon monoxide content will be reduced.

When wood and other uncarbonised biomass is used as fuel, the addition of water is not necessary since these materials contain a sufficient quantity both of absorbed water and chemically combined water. The formation of methane is of minor importance, and need not be discussed within the present context.

Gas Compositions

As mentioned earlier, the composition of producer gas varies in relation to many factors. Typical compositions of producer gas from charcoal and wood, according to Kjellstrom,[2] are given in Table 1.

Table 1

Components	Typical Composition of Charcoal Gas (%)	Typical Composition of Wood Gas (%)
CO_2	3.0	9.5 – 9.7
C_xH_y	0.1	0 – 0.3
O_2	1.3	0.6 – 1.4
CO	28.7	20.5 – 22.2
H_2	3.8	12.3 – 15.0
CH_4	0.2	2.4 – 3.4
N_2	62.9	50.0 – 53.8

Types of Gasifier

Gasifiers can be classified, according to the direction of gas flow, into three types: up-draught, down-draught and cross-draught.

So far, the down-draught type has received the most attention as it can be designed to give tar-free gas which is suitable for use as fuel for internal combustion engines. This type of gasifier has been found to be suitable with wood and other types of uncarbonised fuels. Design data and experiences for this type of gasifier are available in most of the literature.

Other types of gasifiers, i.e. the up-draught and cross-draught types, have also been used, but to a lesser extent.

Internal Combustion Engines

Both gasoline and diesel engines can be operated using producer gas as fuel.

Gasoline engines can be operated on 100% producer gas with little or no modification of the engine at all. Modern high speed engines with small inlet valves are not suitable for operation with producer gas as the entry of gas is restricted and the rate of combustion of air-producer gas mixture is much lower than that of air-petrol vapour mixture. Because of the fact that the calorific value of air-petrol vapour mixture is higher than that of air-producer gas mixture, operation with producer gas results in the down-rating of the petrol rated engine. It has been estimated by Breag and Chittenden[3] that if producer gas is used as fuel, the system is down-rated to 50-60% of the petrol rated output. However, the output power of the system can be increased by modifying the engine, i.e. increasing the compression ratio, advancing the timing of the engine and installing a turbo charger.

Diesel engines cannot be operated on producer gas alone, but can only be operated using a dual fuel system in which 10-20% of diesel fuel still has to be used. However, modification can be made so that diesel engines can be operated with producer gas alone. This is done by removing the fuel injection system, replacing it with a spark plug and reducing the compression ratio to about 10:1. However, this conversion is rather complicated.

Overall Efficiency of the System

In electricity generation, the overall efficiency of the entire system, η_{tot}, can be defined as

$$\eta_{tot} = \frac{P_e}{m_s c_s} = \eta_g \ \eta_{en} \ \eta_e$$

where P_e = is the electric power generated,
m_s = is the mass flow rate of solid fuel,
c_s = is the calorific value of solid fuel,
η_g = is the efficiency of the gasifier,
η_{en} = is the efficiency of the engine
η_e = is the efficiency of the electric generator.

For the gasifier, if the sensible heat cannot be utilized, as is normally the case when the gas is used as fuel in an engine, the efficiency is called the cold gas efficiency, which is defined as:

$$\eta_g = \frac{m_g c_g}{m_s c_s}$$

where m_g = is the mass flow rate of producer gas,
c_g = is the calorific value of producer gas

Typical efficiency data for a producer gas plant of 50 kW electric power are given by Kjellstrom[2] as:

Gasifier	η_g	=	70% – 75%
Engine	η_{en}	=	25% – 30%
Electric Generator	η_e	=	90%
Total Efficiency	η_{tot}	=	16% – 20%

Note: Smaller plants will show lower efficiencies while larger plants higher efficiencies.

EXPERIMENTS

Experiments were carried out on two producer gas engine-generator systems. The first system, which will be referred to as the small system, incorporated a 5 HP gasoline engine-generator which had a gasoline rating of 2 kW. The second system, which will be referred to as the large system, incorporated a 40 HP gasoline engine driving a 10 kW generator through a set of V-belts.

Fig. 1 shows the experimental lay-out, which consists of a gasifier, a cyclone, a cleaner, a gas-air mixer and the engine-generator.

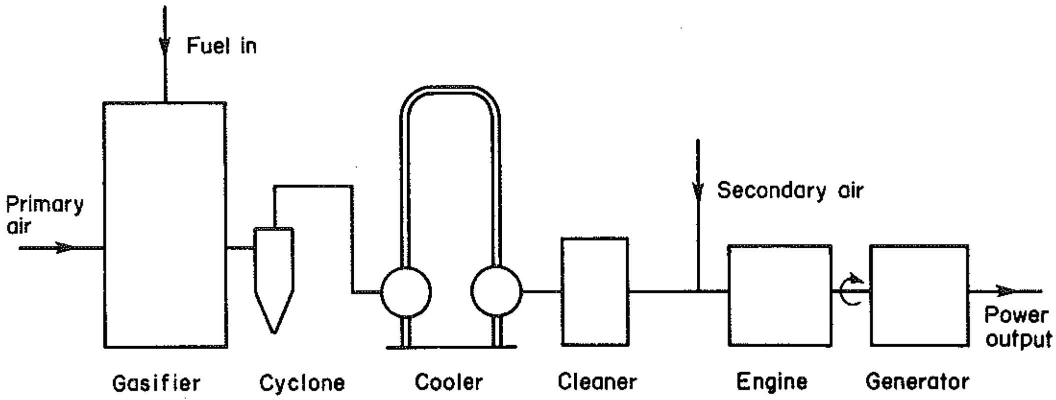


Fig. 1 Lay-out of experimental apparatus

Gasifiers

For the small system, the gasifier used was a down-draught type designed for operation with charcoal as fuel (see Fig. 2a). It was made from steel sheet, steel pipe and refractory material. The throat section consisted of rafractory material held in place by conical steel sheets. The primary air intake, which was made from a steel pipe, was located on the side of the fuel container. From the intake, the air flowed through a pipe bent 90° downward to the combustion zone. The gas outlet was located at the wall underneath the grate. The ignition hatch was installed to facilitate the ignition process.

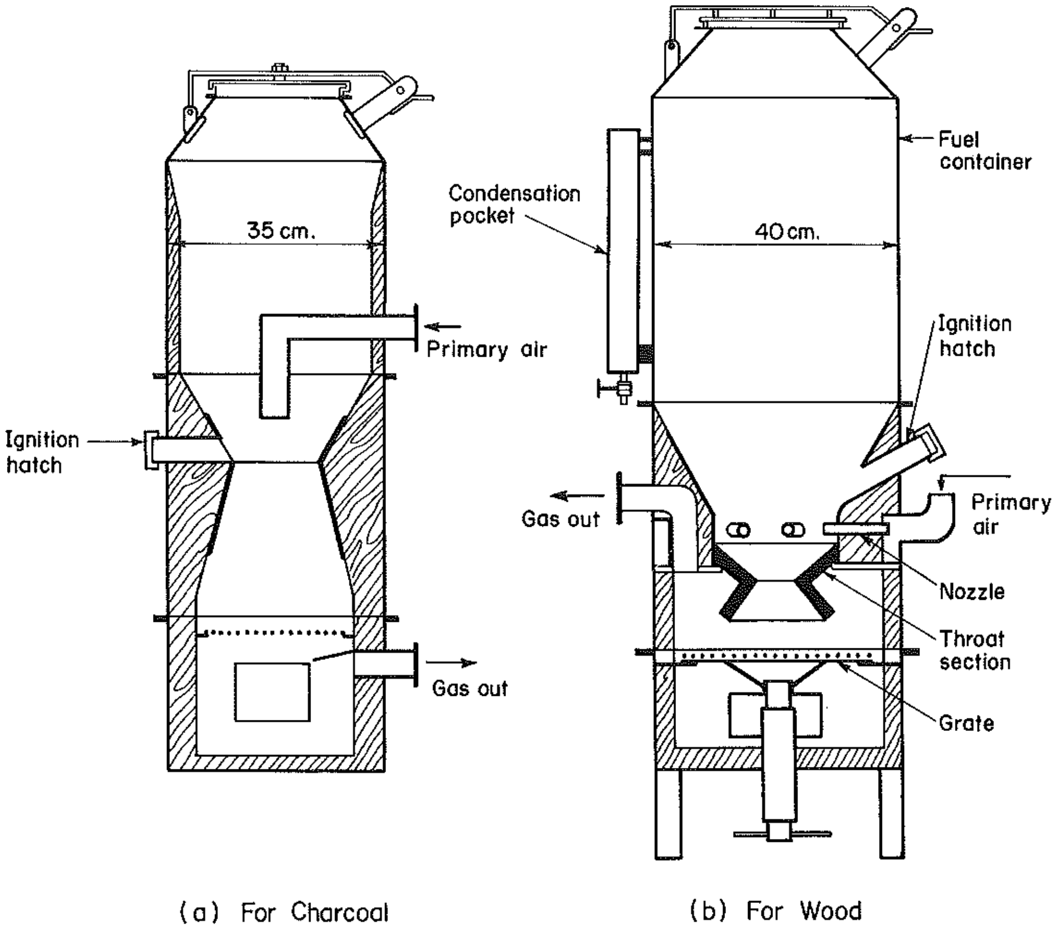


Fig. 2 Gasifiers

For the large system, the same gasifier was used when operating with charcoal as fuel. As the fuel consumption for the large system was quite high, the fuel container could be extended to prolong the operation between refuelings. When operating with rubber-tree wood, a gasifier designed specially for operation with wood block as fuel (see Fig 2b) was used. The fuel container, which had a capacity of about 0.1 m^3, was in the form of a cylindrical shell made from steel sheet. The fuel container was equipped with a condensation pocket which was fitted with a draining valve. The function of the condensation pocket was to condense vapour in the fuel container. From the fuel container a conical passage was provided for fuel to enter the combustion zone. This conical passage also acted as a charing region for wood before combustion. The primary air was fed in through five nozzles evenly distributed over the periphery and directed radially inward. The nozzles were 10 mm in diameter. To maintain the temperature high enough for efficient tar cracking and good gas quality, the throat of the gasifier was made rather small, i.e. a throat diameter of 8 cm was used. The throat section, which was made of ordinary cast iron, was supported by a 15 mm thick mild steel ring welded on the wall of the combustion chamber. The throat section could be easily replaced if it was damaged or the size of the throat needed to be altered. Arrangements were made to enable the grate to be rotated manually. An electric motor could be installed to rotate the grate automatically if desired.

Gas Cooling

The gas from the gasifiers had to be cooled in order increase its density, which improves the volumetric efficiency of the engine. Air-cooled heat exchangers with a finned external surface were used to cool the gas. Drain valves were installed in the coolers for the purpose of draining condensate which was condensed as a results of cooling. Apart from gas cooling, these coolers also acted as parts of the cleaning system in the form of condensation cleaners, as water vapour was condensed with dust particles which caused dust to precipitate together with water in the form of sludge. Coolers with effective cooling surfaces of 0.476 m^2 and 1.550 m^2 were used for the small and large systems respectively.

Gas Cleaning

The cleaning system consisted of a cyclone cleaner, a condensation cleaner, and finally a cloth or cork cleaner. The gas from the gasifier was led to the cyclone, which acted as a coarse dust separator, then to the condensation cleaner, and finally to the cloth or cork cleaner, which acted as a fine cleaner.

Gas-Air Mixer

A simple gas-air mixer, which was in the form of a concentric tube, was used. The air which flowed in the tube joined the producer gas immediately after the producer gas had passed through the 90° bend. The mixing section was followed by at least 70 cm of pipe before the mixture entered the engine manifold.

Capacity Control

The capacity control was achieved by regulating the mixture of producer gas and air into the engine. For the purpose of regulating the supply of the mixture, a globe valve was used for the small system and a butterfly valve was used for the large system.

The producer gas to air ratio to the engine was varied by means of a valve installed on the air inlet line.

Engine/Generator

For the small system, a single cylinder 4-cycle engine coupled with a generator, which had a gasoline rating of 2 kW, was used. The operational speed of the engine was 3,000 r.p.m.

For the large system, the engine used was a 4-cylinder, 4-cycle and 1,288 cc capacity automobile engine normally fuelled on petrol with a compression ratio of 8.5:1. The engine was coupled to a 10 kW generator through V-belts. As the operational speed of the generator was 1,500 r.p.m., the pulleys were selected in such a way that the operational speed of the engine was 2,400 r.p.m.

No modification of the engine was made apart from the removal of the carburetor, and the producer gas-air mixture was fed directly into the intake manifold.

System Loading

Resistance wires and light bulbs were used as artificial load on the system. The loading system was arranged in such a way that it could be varied at 100 W intervals.

Instrumentation

The output power from the electric generator was measured with a voltmeter and an ammeter. A platform scale was used in the determination of the fuel consumption rates. This was done by mounting the entire gasifier assembly on the platform scale to enable the gasification rate to be determined at any time on a test run. The production of ash and char residue was estimated by weighing after a test run period.

The temperature in the throat of the gasifier was measured with a chromel-alumel thermocouple. Temperatures at other positions in the system were measured with chromel-alumel thermocouples and thermometers. The flow rates of the mixture of producer gas and air and the secondary air were measured with orifice meters. Gas samples were analysed for their contents of carbon monoxide, carbon dioxide and oxygen by the Orsat apparatus.

EXPERIMENTAL PROCEDURE

The gasifier was first filled with charcoal crushed to about 3 cm size up to the level of the throat constriction, and the gasifier was ignited through the ignition hatch by cotton wool mixed with some inflammable material. With the lid of the gasifier closed, a blower was then used to blow air through the primary air pipe until the charcoal was burning evenly. The gasifier was then filled with more charcoal or wood until it was full. With the lid opened, the blower was used to blow air into the gasifier for about 3 minutes, and the lid was then closed with the blower still in operation.

After the gas was tested by ignition in the atmosphere and was burning with what appeared to be a clean flame, the engine was started. For the small system the starting was done by hand cranking and for the large system the starting was done by battery, using a conventional cranking motor. With the valve in the air-producer gas mixture line partially opened, load was applied until a voltage of 220 volts was obtained.

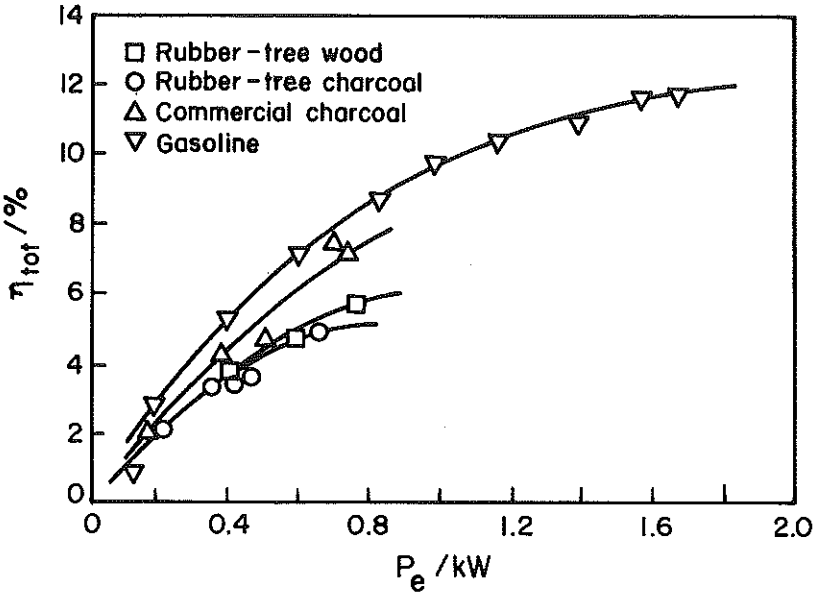
After the system was left running for about 15 minutes, the flow of the air-producer gas mixture was regulated together with the secondary air inlet to give the required capacity with the voltage kept at 220 volts. Various data were obtained 20 minutes after the system had been running at the required capacity. For the small system, data for the determination of fuel comsumption rates were obtained at four intervals of 30 minutes each, which involved a period of 2 hours for each run. For the large system data were obtained at two intervals of 20 minutes each.

The output capacity could be varied quite successfully by regulating the flow of air-producer gas mixture with some adjustment on the flow of the secondary air. For the small system, capacity control by this technique was difficult at low capacity as the fluctuation in voltage was large.

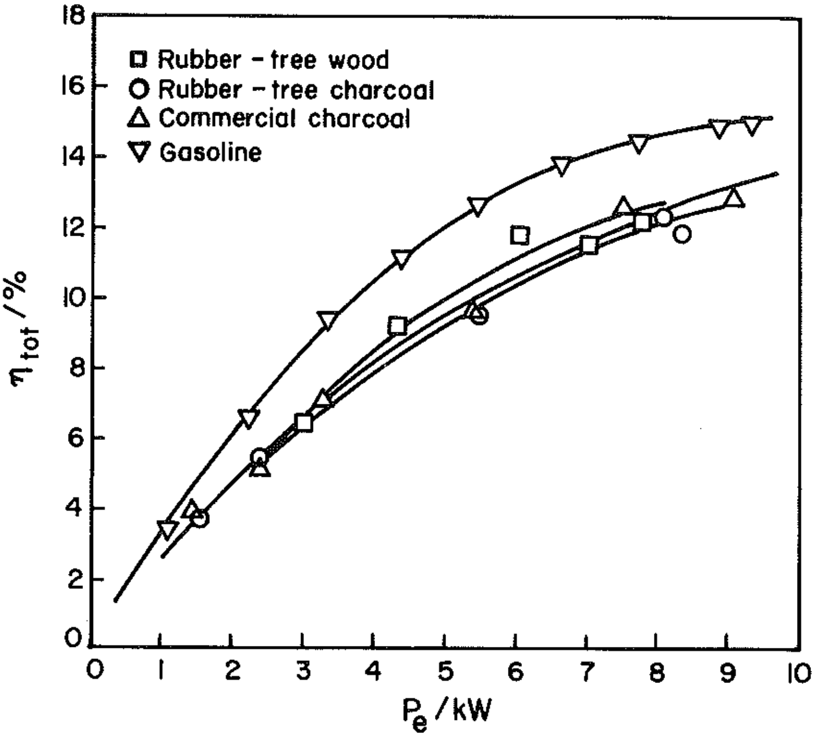
EXPERIMENTAL RESULTS

Both engine generators were first tested with gasoline to examine the fuel consumption rates at various values of output power from the generators. These tests enabled the performances of the systems to be studied when operated with gasoline.

From the experimentally determined fuel consumption rates for solid fuels and gasoline, the overall efficiencies and the specific fuel consumption were determined and are shown as a function of output power in Figs. 3 and 4 respectively.



(a) Small System



(b) Large System

Fig. 3 Overall efficiency (N_{tot}) as a function of output power (P_e)

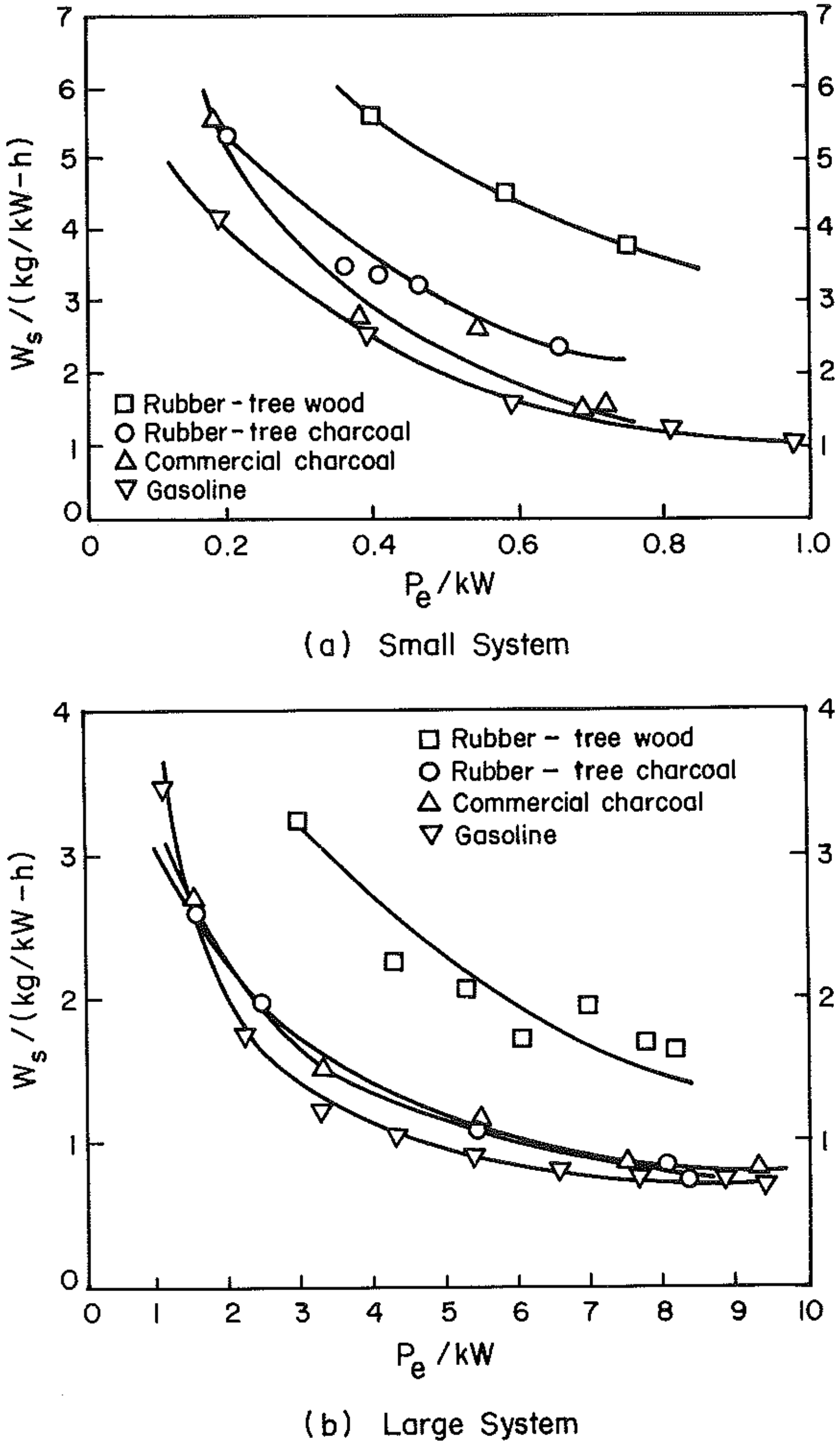


Fig. 4 Specific fuel consumption (W_s, V_g) as a function of output power (P_e). For solid fuel in (kg/kW-h) and for gasoline in (l/kW-h)

The fuel costs in electricity generation for various types of fuel were estimated and are shown as a function of output power in Fig. 5. The estimation of fuel costs took into account the fact that not all fuel materials bought could be used as fuels for the gasifiers due to losses during the process of fuel preparation. The fractions of fuel materials which could be used as fuel were approximately 85%, 60% and 90% for commercial charcoal, rubber-tree charcoal and rubber-tree wood respectively.

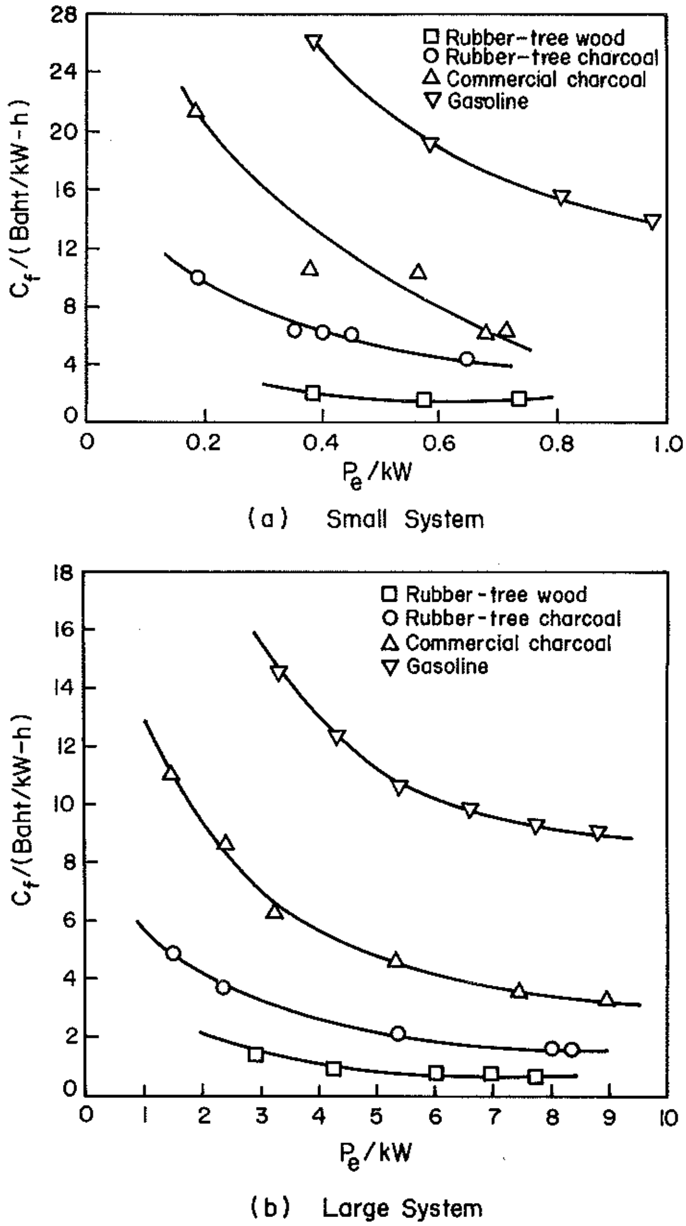


Fig. 5 Fuel cost (C_f) as a function of output power (P_e)
Note: US\$1 = 23.0 baht

The prices of raw materials used in the calculation were local prices and are listed as follows.

Gasoline	11.76 baht/l*
Commercial charcoal	3.60 baht/kg
Rubber-tree charcoal	1.10 baht/kg
Rubber-tree wood	0.35 baht/kg

*At current rates US$1 = app. 23 baht

The weights of various types of solid fuel to produce the same quantity of electrical energy as that produced by one litre of gasoline were also calculated for the sake of comparison, as shown in Fig. 6 as a function of output power.

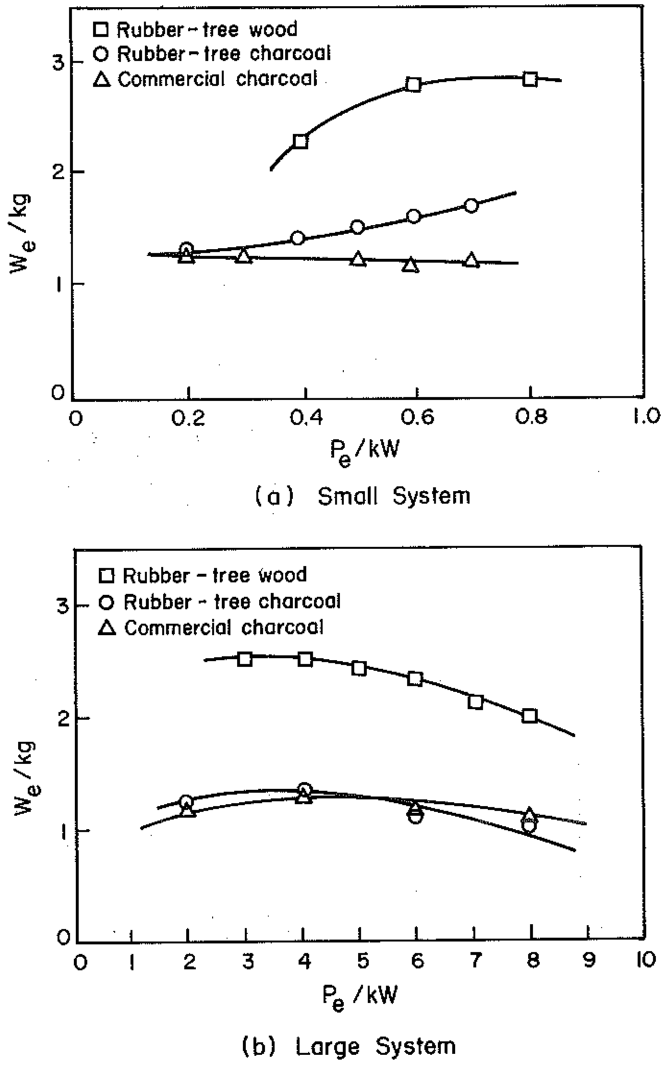


Fig. 6 Weight of solid fuel to give the same quantity of electrical energy as that given by 1 litre of gasoline (W_e) as a function of output power (P_e)

Table 2
Throat temperature and composition of gas at various values of output power when operating with charcoal.

Capacity (kW)	Throat temperature (°C)	Composition of gas		
		%CO	$\%CO_2$	$\%O_2$
0.188	780	19	8	0
0.545	910	25	5	0
1.496	1100	—	—	—
5.39	1250	28	2	0

An analysis of the gas composition was not made for all runs, as a gas analyzer capable of analyzing the contents of all gases was not available. Analysis was carried out for a limited number of runs by using the Orsat apparatus to examine the carbon monoxide, carbon dioxide and oxygen content.

The carbon monoxide content of the gas and the temperature in the thraot are shown in Table 2 at various values of output power. The calorific values of all solid fuels were determined by a bomb calorimeter. The calorific value of producer gas could not be determined as a gas calorimeter was not available.

The efficiencies of the gasifiers in converting solid fuel to gaseous fuel were estimated, basing the calorific values of producer gas recommended by The Swedish Academy of Engineering Sciences,[1] and the flow rates of producer gas measured in the experiments are shown in Fig. 7 as a function of output power.

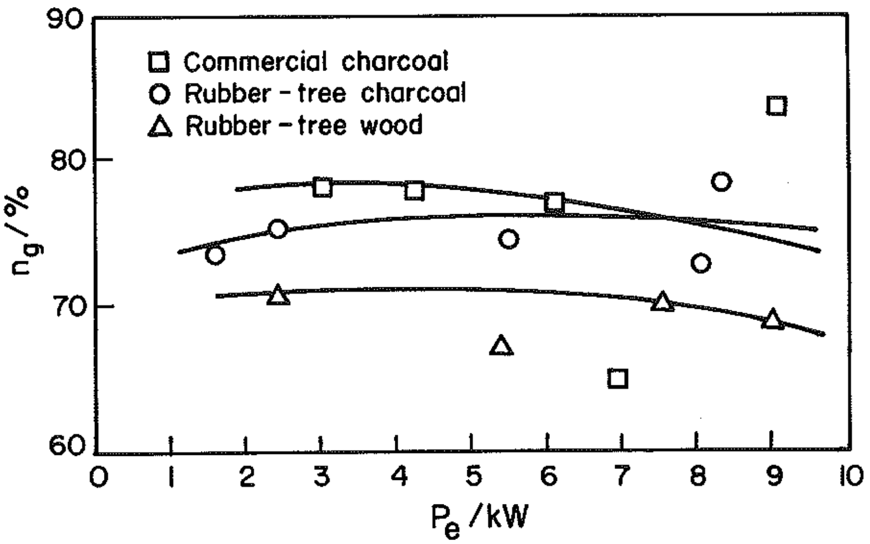


Fig. 7 Efficiency of the gasifier (N_g) as a function of output power (P_e)

The values of producer gas flows and air flows into the engine are shown in Fig. 8 as a function of output power. The ratios of producer gas flows to air flows measured in the experiments are also shown in Fig. 8.

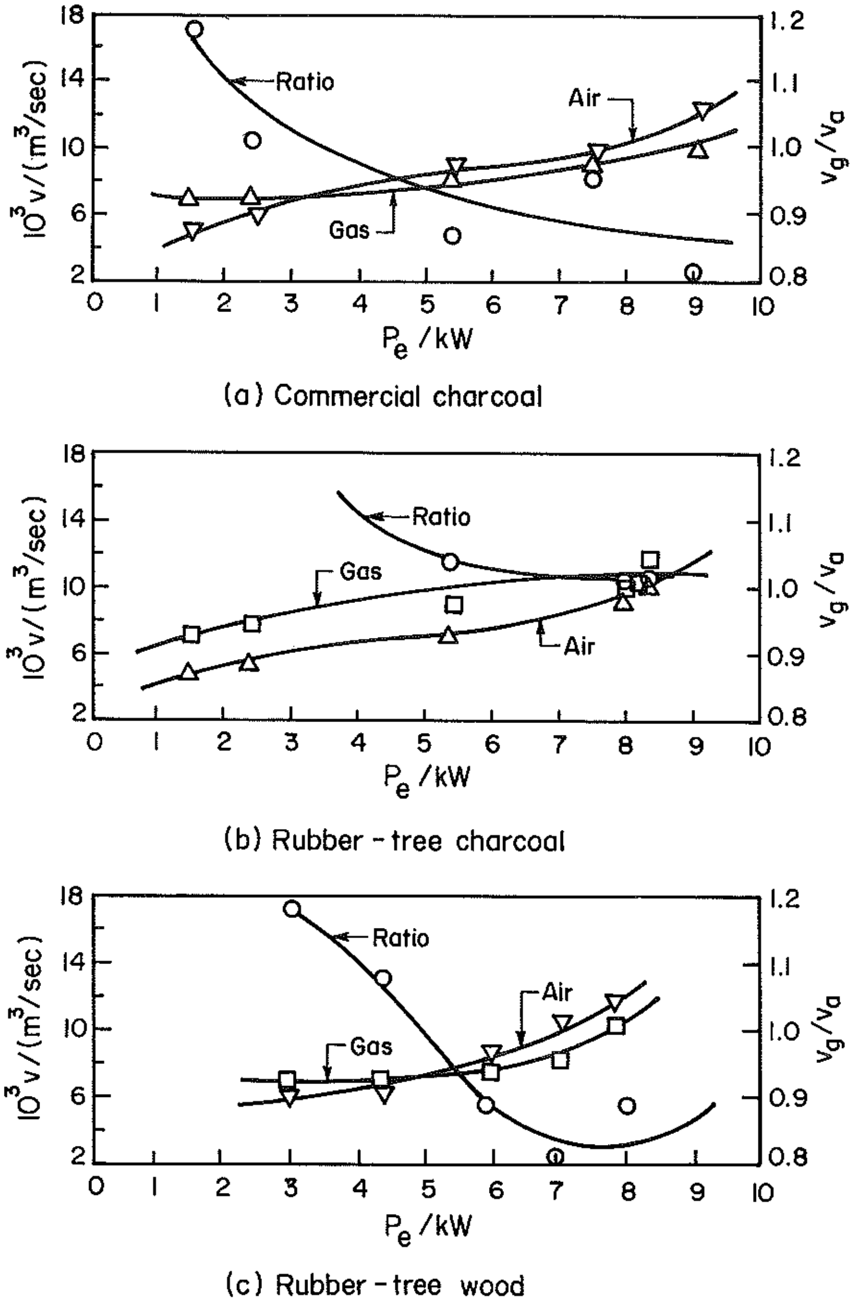


Fig. 8 Flow rates of producer gas and secondary air (V) and ratios of the gasflows to air flows (V_g/V_a) as a function of output power (P_e)

DISCUSSION

It was apparent from about 300 hours of test runs on both systems that no serious problems were likely to be encountered when running a gasoline engine on producer gas. A reduction in output power relative to that normally obtained with gasoline was to be expected as the calorific value of air-producer gas mixture is lower than that of the air-petrol vapour mixture. Capacity control could be achieved quite satisfactorily by regulating the flow of air-producer gas mixture into the engine. The output voltage from the generator at any particular loading could be maintained within $\pm 5\%$ of 220 volts by fixing the valve, which was used to control the flow of air-producer gas mixture, at a particular setting. For the small system, voltage control by this technique was more difficult at low output power because of larger voltage variation. It is anticipated, however, that in practice the small system will always be operated at high load. It has emerged from the experience during test runs that the use of a simple centrifugal control as an automatic control device for the producer gas-fuelled system may be possible and should be given further attention.

Of considerably more importance was the ability to supply clean tar-free gas to the engine continuously. It was found that gas from charcoal was much easier to deal with as it contained little or no tar at all. The combination of a cyclone and a cloth cleaner was quite sufficient to clean the gas provided that the charcoal was dry enough. Both the small and large systems have been operated with charcoal as fuel without much difficulty in the operation and maintenance of the systems. The gas from wood was much more difficult to handle. Apart from tar, it contained a much greater quantity of solid particles and moisture. An attempt to use wood in the gasifier shown in Fig. 2a, which was designed for operation with charcoal, was not successful, because the tar content in the gas was high. After only a few hours of operation, tar was deposited on the valves and ultimately siezed up the engine. When the gasifier designed specially for operation with wood (as shown in Fig. 2b) was used, the problem of tar was overcome. The gas generated by this gasifier was tar free, as tar was destroyed when the gas was subjected to a very high temperature in passing through the throat of the gasifier. The use of a cloth cleaner as a fine cleaner with wood gas was not very successful because of problems caused by condensation in the cleaner. A cork cleaner was tried and the result was better, and the maintenance of the cleaner was easier. However, more work still has to be done in improving the performance of the filtration equipment for systems operating with wood as fuel.

It was also found that the size and moisture content of the fuel were very critical to the operation of the systems. The quality of gas generated depends to a large extent on the fuel size. The maximum dimension of fuel used varied between 2 cm and 4 cm. It was found that larger fuel size resulted in poor gas quality and an uneven flow of gas. Consequently, a reduction in power or even stoppage of the engine resulted. Fuel with high moisture content presented more problems in the maintenance of the system and reduced the quality of the gas produced. The moisture contents of charcoal and wood to be used as fuels should not be higher than 10% and 20% respectively.

The overall efficiencies of systems operating with solid fuels are lower than that of systems operating with gasoline for the same output power, as shown in Fig. 3. This is to be expected as there is energy loss in converting solid fuel to gaseous fuel. The amount of energy loss depends on the efficiency of the gasifier, which was estimated to be between 70% and 80%, as shown in Fig. 7. The overall efficiencies for different types of solid fuel differ, but the differences are not appreciable. The overall efficiencies for the small and large systems are 7% and 12% respectively. These values are consistent with the values of efficiency quoted by Kjellstrom.[2] According to Kjellstrom, a 50 kW system will have an overall efficiency of 16% to 20%. The efficiency of the larger system will be higher and the efficiency for the smaller system will be lower.

The overall efficiencies obtained in this work, i.e. 7% for the small system and 12% for the large system, compares reasonably well to the efficiencies obtained by other self-contained biomass solid-fuelled systems at these power output levels. For comparison, a non-condensing steam engine with a power output of 10 kW would have an overall efficiency of about 5%. It may still be possible to improve the overall efficiencies of the systems by improving the performances of various components in the systems. As the main aim of this work is to try to develop reliable systems first and try to reach higher efficiency later, no attempt has been made so far to improve the efficiency of the systems. The next step of this work will be to improve the efficiency through modifications of various parameters in the systems.

Fig. 4 shows that the specific fuel consumption increases with decreasing power output for all types of fuel. For the costs of electricity generation, Fig. 5 shows that the fuel costs in electricity generation by solid fuels are much lower than when gasoline is used. The fuel costs for commercial charcoal and rubber-tree charcoal are 40% and 20% of that for gasoline respectively. The fuel cost for wood is only about 10% of that for gasoline. However, if the cost of fuel preparation is taken into account, i.e. the cost of fuel preparation is assumed to be the same as the cost of wood, cost of fuelling with wood is about 20% of that of fuelling with gasoline. It should be pointed out that these figures are by no means conclusive for large-scale electricity generation by this technique. More data on larger-scale tests are required before a general conclusion can be made. It is anticipated, however, that operation at high capacity would be more economical than the small-scale tests carried out in this work.

It should be pointed out also that although the fuel costs in generating electricity with solid fuels are lower than those with gasoline in this work, these fuel costs may still be higher than they would be when electricity is generated by a large conventional thermal plant. Here again, cost comparisons in this respect should be made when results from producer gas systems with higher capacities are available.

Fig. 6 shows that to produce the same quantity of electrical energy, about 1.2 kg to 1.5 kg of charcoal correspond to 1 litre of gasoline. For wood, it can be estimated from Fig. 6 that about 2.1 kg to 2.8 kg of rubber-tree wood correspond to 1 litre of gasoline. These figures agree fairly well with the theoretical prediction made by the Swedish Academy of Engineering Sciences.[1] According to the Academy, to produce the same power output, 1.45 kg of charcoal corresponds to 1 litre of gasoline, while 2.70 kg of wood corresponds to 1 litre of gasoline.

However, it has emerged from this work that the solid fuels which are readily available in the Southern part of Thailand, i.e. rubber-tree charcoal and rubber-tree wood, have great promise as fuels for producer gas systems. This is because the costs of generating electricity using these fuels are fairly low and may be competitive economically with those required for large conventional thermal power plants, if a producer gas system with a larger capacity is used.

It can be seen from Fig. 7 that the efficiencies of the gasifiers vary between 70% and 80%, which is quite a high variation. High conversion efficiencies are probably due to the fact that the combustion zones of the gasifiers used were insulated with refractory material and the heat loss was very small. It should be noted that these values are approximate, as the calorific values of gas used in the calculation were those recommended by the Swedish Academy.[1] This is because equipment was not available to measure the calorific values of the gas directly.

Fig 8 shows that as the output power increases, the flow rates of producer gas and air into the engine increase, but the flow rate of air increases at a faster rate. The ratio of gas flows to air flows varies between 0.8 and 1.2, being lower at a lower power output.

The quality of the gas was found to improve as the power output was increased, as indicated by the carbon monoxide content of the gas shown in Table 2, i.e. a carbon monoxide content of 19%, 25% and 28% was obtained at output capacities of 188 W, 545 W, and 5.39 kW, because of the increase of the degree of combustion at high capacity, resulting in an increase in the temperature in the gasifier. From the temperature measurements, it was found that the temperature in the throat increased steadily as the output power increased and reached a value of 1,250°C at a power output of 5.39 kW.

CONCLUSION

The studies so far have shown that electricity generation by using a gasoline engine driven by producer gas is technically possible. The system fuelled by charcoal has been improved considerably and the techniques of operation and maintenance are quite well understood. Preparation is now being made for field tests and subsequent transference of the technology. For systems fuelled with wood, the problem of tar, which was very serious, has been overcome, and the filtration system has been gradually improved. The reduction the amount of particles from the gasification process and the associated operational and maintenance problems are receiving further attention. System control is essential, especially for systems with a high capacity, and an appropriate governing device will have to be developed for the producer gas fuelled system. Further work will be concentrated in this area.

The overall efficiencies for conversion of the thermal energy in the charcoal or wood to electrical energy of about 12% compares reasonably to efficiencies attained by any other biomass solid-fuelled system at the same power output level. The maximum overall efficiency for conversion of the thermal energy in gasoline to electrical energy at 10 kW capacity for the same engine-generator combination is about 15%.

Generation of electricity by solid fuels is feasible economically. The fuel costs when using solid fuels are significantly lower than when gasoline is used and may compare favourably to the costs involved when electricity is generated by a conventional power plant, if larger producer gas fuelled systems are used. Results from this work have shown that the available fuels in the Southern part of Thailand, i.e. rubber-tree charcoal and rubber tree wood, have great promise as fuels for producer gas systems.

Studies of the specific fuel consumption have revealed that to generate 1 kW/h of electricity, about 0.8 kg of charcoal and 1.6 kg of wood are needed respectively. The studies have also revealed that the specific fuel consumption improves with the output power and therefore lower specific fuel consumption will certainly be attained if systems of higher capacities are tested. When comparing the consumption of solid fuels and gasoline, it has been found that to produce the same quantity of electricity 1 litre of gasoline corresponds approximately to 1.2 kg of charcoal and 2.1 kg of wood respectively.

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