ADAPTATION OF PETROL ENGINES TO BIOGAS

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ABSTRACT

The substitution of petrol by biogas as fuel in conventional combustion operated engines does not pose any insurmountable problems but requires adaptation works and the establishment of the procedure. This paper identifies the important factors to be taken into account in such a study.

The feasibility of producing and utilising biogas fuel in rural areas of the Sahelian zone is analysed. A 5hp motor pump suitable for small irrigation projects, adapted to run on biogas is described. Overall performance of the water pump is evaluated and compared with petrol use. As biogas is not purified (30% to 40% CO_2) engine performance is lower but water pumping efficiency is still highly self sufficient for energy based only on local resources.

INTRODUCTION

The rapid and intensive development of small irrigated plots in the Casamance and the Senegal river valleys as well as the large OMVS (Organisation de Mise en Valeur du fleuve Senegal) and OMVG (Organisation de Mise en Valeur du fleuve Gambie) schemes for the irrigation of several hundred thousand hectares in Mali, Senegal, and Mauritania, require a perfect mastery of irrigation in isolated areas where shortages in petrol and gas oil supplies are liable to occur.

The use of independent energy sources is therefore a priority for the successful development of these important agricultural valleys. The compost-biogas procedure offers great advantages in that it constitutes a minimal "energy capital" (besides producing organic fertilisers). We have studied the need for and carried out the adaptation of petrol engines to biogas. A biogas production unit and the adaptations and operating characteristics of a 5 hp motor-pump fed with biogas are described below.

BIOGAS UNIT

The biogas unit developed is a batch system whose management and operation seems to be better suited to, and more easily carried out in Sahelian areas. It includes two digesters (diameter = 1.6m, height = 2m) in reinforced concrete, buried according to the IRAT type (Viaud 1983, 1984) (Figure 1).

In this system, the production of biogas starts a few days after the digester has been loaded and closed, then stops when fermentation ends after 50-80 days. Over this period, both the biogas production and its methane content will at first rise for approximately one week, then stabilise and finally decline.

The unit produces an average of 2 cubic metres of biogas per day. The methane content of the biogas varies with the substance used for fermentation. Since our unit was in an urban area we used wastes from Dakar's slaughter-house which were readily available on a regular basis. This also enabled us to carry out an interesting waste disposal experiment. Wastes from cattle paunches begin to ferment very easily and quickly since the fodder has already been chewed then pre-digested for many hours before cattle were slaughtered (Petitclerc and Leclercq 1984).

Biogas analysis is performed by gas chromatography. Methane and carbon dioxide content varies in the course of the fermentation: low methane content at the very beginning of the cycle (50% CH_4, 50% CO_2), medium methane content in the initial and final stages (65% CH_4) and high methane content in the middle of the cycle (70% CH_4). It should be noted that, with the production of biogas from the wastes of cattle paunch, there is a high methane production over a major part of the cycle, since percentages above 80% of CH_4 have been recorded. On the other hand, cattle paunch wastes produce quite a high percentage of hydrogen sulphide. This may be due to the presence of cotton seeds in the cattle cake used for feed.

Since biogas is used to replace standard fuels, it may be useful to compare its physical and calorific properties with those of other standard fuels. These are summarised in Table 1.

OPERATIONS WITH BIOGAS

In principle, the replacement of petrol by biogas can be done without major difficulties. However, in practice, problems will arise because the quality of biogas varies with time while those of petrol, gas oil or LPG (liquid petroleum gas) remain constant.

Under these conditions, a large number of elements and different parameters should be taken into account when adapting petrol engines to biogas (Anon 1983; Liddon 1982; Liddon and Sola 1982). These include: ignition advance; sparking plugs; carburation; compression rate; gas inlet pressure; thermal constraints; biogas methane content; corrosion; purification; moisture; dust; starting conditions; permanent or temporary operations and dual working conditions (petrol and biogas).

Taking all these elements into account, carrying out thorough analysis of their effects and interactions and optimising the parameters that can be checked and adjusted is a highly complex task and generally leads to costly solutions.

In view of conditions prevailing in the Sahel, these problems have been tackled pragmatically, and the most economical and simplest modifications have been devised to ensure valuable operations on standard, and therefore inexpensive equipment.

MOTOR PUMP UNIT

The motor-pump unit modified for use in these tests consists of a 5 hp Brigg & Stratton petrol engine with a capacity of 206 cc (Preveral 1983). It is an air-cooled monocylinder with ignition by magnetic wheel and a rolling string starter.

The original petrol supply is provided by a "pulse-jet" membrane pump. A speed regulator is centrifugal and acts on the throttle valve. There is an oil foam model air filter. The pump fitted and delivered with the motor unit is a Grotherm centrifugal pump (L Barrere & Co builder). The body of the pump consists of a polyester mono-block. The diameters of the inlet and outlet nozzles are 1.5" (40/49mm).

The test bed is shown in figure 2. It consists of a 6 cubic metre supple tarpaulin storage unit at atmospheric pressure and a 1.2 cubic metre gasometer unit under a pressure of 5 cm of water. Before biogas is used, H_2S is removed by means of a steel wool filter. This is essential to prevent the very rapid corrosion of copper and alloy engine parts. The biogas consumption of the motor-pump is measured by means of a gasmeter suitable to measure gas delivery between 50 1/h and 3.5 m^3/h.

Simulating the location of the water storage tank and variable irrigation conditions is done by means of a set of 200 1 drums in which water is recycled and rate of flow measured. Manometric height can be varied from 3 to 30 metres by adjusting a bushel gate in the pump outlet.

ENGINE MODIFICATIONS

The most significant adaptation on the motor-block consists of changing the original inlet pipe in order to allow for the direct injection of gas into the cylinder. This is shown in Figure 3. The intake pipe is replaced by a 3/4" elbow in galvanised metal. The original flanges are re-welded and a 3/8" pipe is brazed on the elbow so that air and biogas may flow in at right angles, thus ensuring a homogeneous air-biogas mixture. The location of the exhaust pipe has been changed by turning the outlet downwards to drain off condensation water and prevent it from flowing back into the engine when it is off.

In this engine, the ignition advance cannot be adjusted. It has been slightly advanced from 18° to 22° by increasing spark gap spacing on the primary circuit, to the detriment of sparking quality. The spark spacing of the plug which was initially 0.76mm was reduced to 0.50mm.

Biogas intake in the mixing chamber is at atmospheric pressure. An increase of 5 cm of water can be achieved by passing the biogas over the bell gasometer. This results in an increase of engine power and speed.

In the course of our first tests, the engine was started by means of petrol. Biogas was then used as soon as the engine was hot. Our subsequent tests have proved that it was possible to start the engine directly using biogas provided the intake pressure was nil (biogas at atmospheric pressure), and the biogas inlet was open slightly after the engine was started at half course of the string of the rolling-starter. The possibility of using biogas to start the engine is quite advantageous in so far as the carburettor, which is a costly engine part, can be removed.

Although an increase of the compression rate is desirable and recommended with biogas in order to increase the performance of the engine, this has not been examined because the technological design of the motor-pump would not withstand any increase in mechanical stresses.

The effect of the variation of CO_2 concentration in biogas is quite significant; at the beginning of the fermentation cycle, in particular, when the gas has a low methane content, it is more difficult to start the engine. Furthermore, the rotation speed is lower than with a high methane content biogas (70% to 80%).

EXPERIMENTAL RESULTS

In order to compare the operating conditions with petrol and biogas, we have recorded a certain number of characteristic parameters in Table 2 and Figure 4. The results presented here and the experiments described by various researchers (Leduc 1983; Lefevre 1981; Liddon 1982; Liddon and Sola 1982) suggest that the replacement of petrol by biogas is a feasible technological process. Table 2 shows that the operating parameters are very similar, except for temperature and the CO rate in exhaust fumes.

However, a strict comparison of the two supply types is difficult, since the nominal speed of a petrol-fed engine is 3000 rpm while the test was carried out at 2000 rpm. This is clear in Figure 4 which shows that the rate of flow and the manometric height of the pump "fall" completely when the pump operates at 2200 rpm. This can be improved but will add to the cost of the motor-pump.

CONCLUSION

The present tendency is for engine builders to manufacture units that are well-suited to biogas (special alloys, ceramic parts). These units must take into account the power loss due to their fuel and the presence of harmful gases (H_2S), but this significantly increases the cost. For the same reasons, carbon dioxide and water vapour should be removed from biogas to achieve a 20% to 50% or even 60% increase of the calorific value. However, purifiers are costly and require consumable materials for their operation.

It is also possible to supercharge the engine in order to improve the efficiency of biogas engines. Another possibility is the use of electronic ignition, which will adjust ignition advance in real time according to operating conditions, for the same purpose. Unfortunately, all these improvements involve an increase in costs and the use of sophisticated technologies with recurrent adjustment, maintenance and operating difficulties.

Under these conditions, it appears more "acceptable" and perhaps more beneficial in the short term, to lose 30% of the output with otherwise standard and reliable equipment than to manufacture more efficient yet more costly and less reliable equipment. It is therefore urgent to define the means to reach a compromise solution so that isolated and low-income rural areas can gain access to means of production.

In the case of the motor-pump unit presented here, a great degree of freedom is available with the fitting of the engine and the pump. It is therefore possible to fit out a pump suited for a 3 hp engine and a 2000 rpm speed with a 5 hp engine. Technological adaptations should be carried out along these lines if we are to meet urgent needs as rapidly as possible (Lagrange 1979).

In the middle term, the numerous teams that are tackling the problems of biogas engines will succeed in developing economical and efficient models as soon as the market is guaranteed, and research into the perfection of new prototypes has advanced.

This problem always arises with technological progress. For example, the petrol engine was made more and more reliable and efficient over the past hundred years through slight or considerable improvements. However, the research work, which in less than 5 years brought about a 20 to 30% decrease in fuel consumption, was undertaken and carried out successfully only because external constraints were becoming unbearable. The history of the petrol engine proves that it is quite possible to develop totally reliable biogas engines which are as easy to use as the present petrol engine.

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FIGURE 1: General diagram of the biogas unit

A - digestor on loading   B - empty digestor   C - gasometer bell

D - tarpaulin gasometer   E - raw material and compost storage area

F - control panel   G,H - biogas outlet and connecting pipes

i - stopping grid   j - airtight plastic top cover

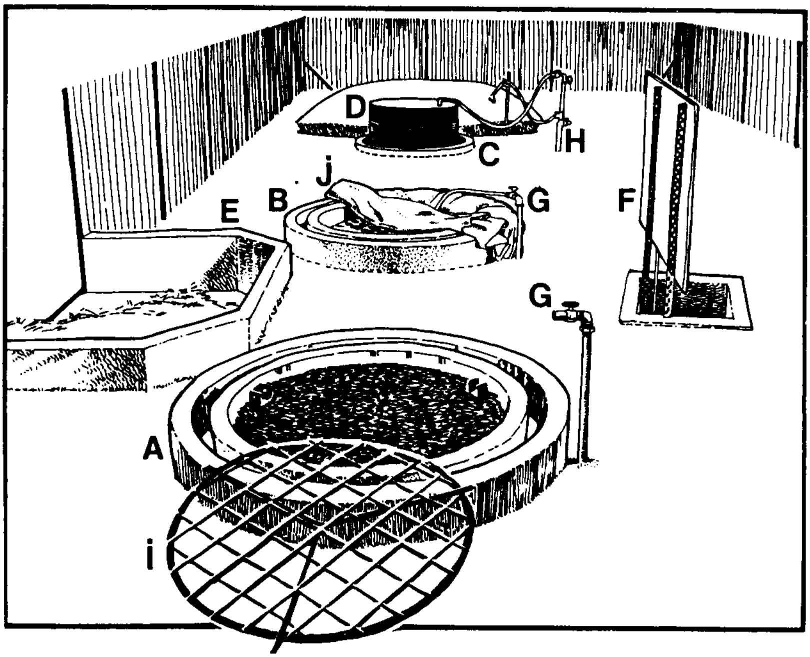

FIGURE 2: Test bed with simulated recycling tank and irrigation system

A - motor pump unit   B - gasmeter   C - H_2S filter   D - drums set

E - inlet pipe   F - outlet pipe (variable height simulation)

G - gasometer bell and tarpaulin storage

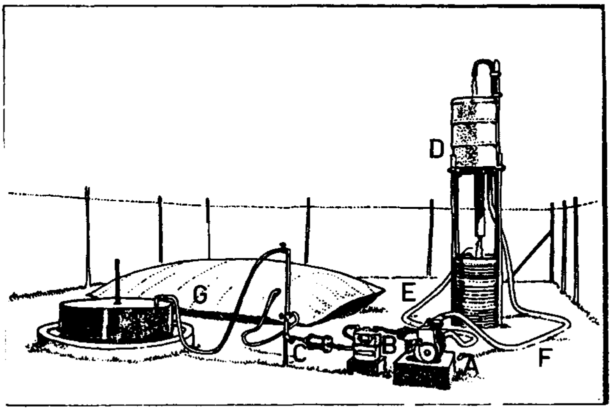

FIGURE 3: Assembly of the modified intake pipe

A - 3/4" elbow tube replacing the original inlet

B - 3/8" biogas inlet pipe welded on the air pipe

C - biogas vane   D - air filter   E - original carburettor

F - exhaust pipe

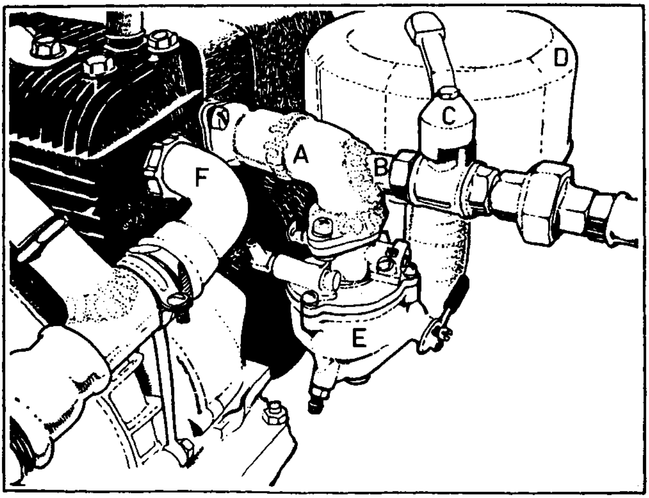

FIGURE 4: Characteristic features of the motor-pump unit

Q water flow in cubic metre per hour and MH manometric height in metres.

Uppercurve : petrol feed at 3000 rpm; lower, biogas feed at 2200 rpm.

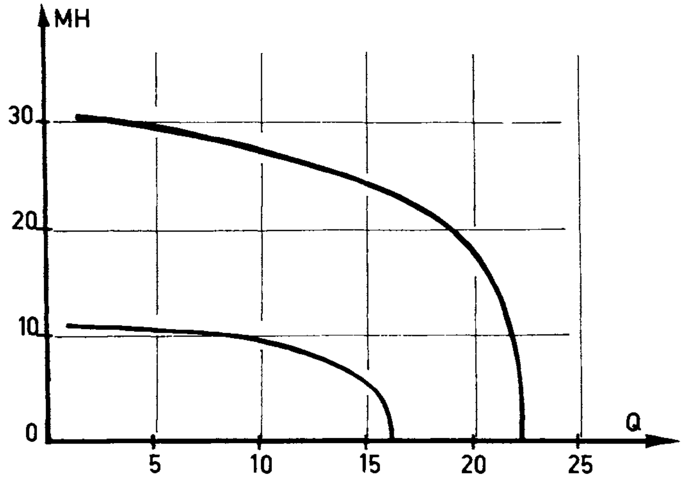

TABLE 1: Properties of biogas compared with those of petrol and gas oil. M.C.V. minimum calorific value

Biogas	Poor 50%	Medium 65%	High 80%
Density/air	1.034	0.897	0.468
MCV kJ/m³	20,000	26,000	32,000
Equiv. m³/l petrol	0.55	0.70	0.85
Equiv. m³/l gas oil	0.50	0.60	0.70

TABLE 2: Comparison between some parameters of petrol fed and biogas fed engine

Parameters	Biogas 70%	Petrol
Rate rpm	2000	2200
Cylinder head temperature °C	130	140
Exhaust fumes temperature °C	660	570
Oil temperature °C	100	110
Ignition advance	22°	18°
Spark spacing mm	0.50	0.76
Spark gap spacing	0.60	0.50
Consumption *	$1.9 m^3 lh^{-1}$	$1.8\ lh^{-1}$
Inlet depressure H_2O centimetre	35	38
%CO exhaust fumes	0.2	5

* This figure is coherent with Table 1 since in a centrifugal pump, the power is a function of the cubic power of rotation speed; then at 2000 rpm petrol engine consume $1.4\ l\ h^{-1}$