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WOOD GAS GENERATORS FOR SMALL POWER (-r5 hp) REQUIREMENTS

U. SHRINIVASA AND H.S. MUKUNDA*

Department of Mechanical Engineering. * Department of Aerospace Engineering, Indian Institute of Science, Bangalore 560 012, India.

ABSTRACT

Experimental and developmental studies were conducted for about 12 months on wood gas generators meant for running 5 hp diesel engines used in irrigation water pumping.

Based on the critical design inputs obtained during the study, a prototype of the gas generator has been built and tested along with a diesel engine-pump set. The results of various tests on the system indicate that the' lowest amount of diesel required to run the engine on wood gas is about 15% of the normal consumption. On the other hand, for obtaining the same work output, that it is for pumping the same amount of water at a given head, the best replacement of diesel obtained is about 75%. The paper also includes some comments on the cost of such systems.

INTRODUCTION

THOUGH producer gas as a fuel has been known since 1785, gas generators for use with engines came into existence only around 1920. The Second World War created a very large demand for gas generators for **use** in automobiles and other transport vehicles. A number of reactor designs were evolved and perfected during the war years; an essential feature of these designs was that theywere developed forengines of 20-200 hp. No smaller reactors were built. The seat translation of a Swedish report' summarises excellently the gas generator technology of that period.

In India, because of the unhappy position today as regards petroleum fuels as well as electricity for motive power, the development of `gas generator based power supplies' for small ranges of power for use in rural ateas appears desirable. The present effort was therefore undertaken to fill this gap in development in early 1981. With in a span of about nine months, many of the developmental problems were solved and a satisfactory design for the gas generator was evolved.

Gas Generators-How do they work? Figure 1 shows the various features of a typical gas generator. As the wood chips move downward and approach the air inlet, they get charred due to the heat transmitted from the combustion zone C. During charring, (pyrolysis) the chips lose most of their moisture content and some volatiles. This takes place at the upper portion of the Zone P in figure 1, where the temperature is about 200°C. The partially charred wood and the gases move further down to meet the oxygen from the air near the inlet nozzles and combust fiercely (1200°C). The peices of charred wood get reduced in size during combustion and move downward to the reduction cone.

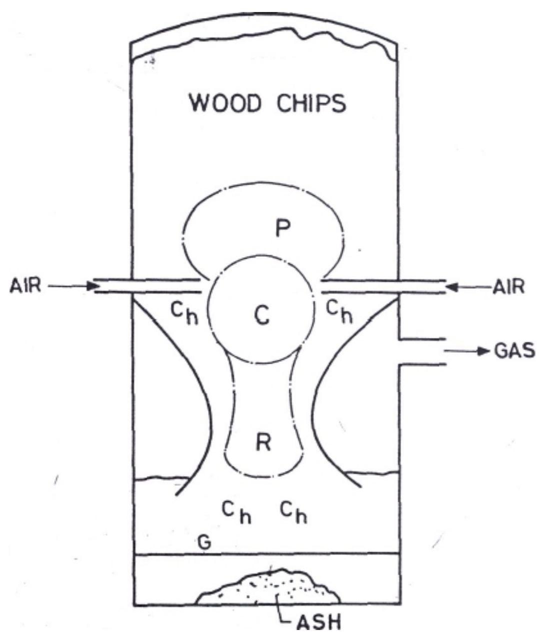

Figure 1. Typical gas generator. Ch-Char, G-Grate, P-Pyrolysis, C-Combustion, R-Reduction

The gases produced in the combustion zone are typically COz and H20. They proceed further, (along with Nz from the incoming air) and meet a hot zone of the charcoal. There, the COz gets reduced to CO with Hs0 participating in two of the three reactions given below:
C + COz ~ 2 CO; C -l- Hs0 - CO + Hz;

COz + H_z ~ CO -F Hz0

A typical composition of wood gas is CO (16-18%), H_z (16-18%), C02 (8-10%), H20 (7-9%), and N_z (4550%) with traces of other combustible gases like methane and higher hydrocarbons. If the gas is cooled, the moisture gets condensed and one obtains a relatively dry gas; its heating value is 1100-1250 kcal/kg. This would mean that to produce shaft output equivalent to that of 1 litre of gasoline, 3 kg of wood (or 1.7 kg of charcoal) is required in practical operations.

THE PRESENT DESIGN

It retains the essential elements of several older designs like that of Imbert, Brandt, and Zeuch available for larger power ratings [1,2].

Rating: The reactor is rated for supplying enough wood gas to drive a 5 hp engine: since 70 to 80%o diesel substitution is expected, the gas generator is designed for an out put equivalent to 3.5 to 4 hp.

The various reactor dimensions that need to be specified are: the throat diameter, dn; the nozzle ring diameter, d,; the nozzle opening circle diameter, dm; the reduction cone bottom diameter, dm; the distances h, h,, hz and ha between the planes corresponding to the nozzles, throat, end of the reduction cone, grate and the bottom of the reactor respectively. These are shown in figure 2.

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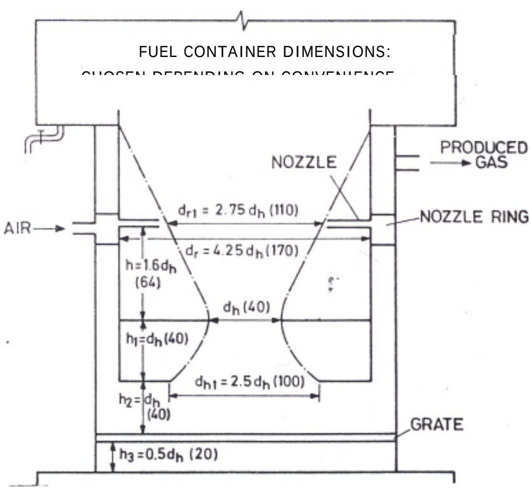

Figure 2. Critical. reactor parameters (figures within parenthesis are prototype dimensions in mm).

Hearth Load:Bn (Nm^3/cm^2-hr) which, by definition, is the quantity of producer gas prepared in (Nm^3/ hr) divided by the smallest passage (throat) area in cm^2. (N $_{M3}$ refers to normal m^3 (Im^3 at 0°C and I atm. pressure). From Ref. I, Bn $_{max}$=0.9 Nm^3/cm^2 hr and the rated. power of 3.5 hp is assumed to be obtainable at a Bn rated =0.8 N m^3/ cm^2-hr.

Specific fuel consumption

b (kg/ hp-hr)=632/ri$_{ge}$„. 77$_{m°}$t.H;

where rl$_{gen}$ = generator effeciency (taken as 0.7 in the present design), 77$_{m°c}$ = engine efficiency (= 0.22, a typical figure) and H; = effective heating value of wood (3500 kcal/ kg corresponding to 20% moisture content). For these values, b = 1.3 kg/ hp-hr.

Fuel consumption at 3.5 hp =4 kg/ hr and the ~ maximum fuel consumption (at 4 hp) = 5.2 kg/ hr. Throat diameter dn is obtained from the maximum fuel consumption and Bn $_{mex}$. From ref. l the quantity of gas generated is about 2.2 N m^3 for every kg of wood with 20% moisture content. Therefore the maximum gas generation= 11.5 $_{NM}$^{3}/hr. Hence the throat area = 11.5/ 0.9 cm ^{2} = 12.8 cm^2, or dn (throat diameter) = 4 cm.

Other Hearth Dimensions: Ref. 1 presents graphs and recommendations for a number of other hearth parameters.They have been obtained from the values taken from a range of successful generators. Using these data and extrapolating them whenever necessary, the following parameters have been fixed. d$_r$(=4.25dn)=170Trim; d,,(=2.75dn)=110mm;h (= 1.6 dn) = 64 mm; h$_l$ (= dn) = 40 mm; dnr (= 2.5 dn) = 100 mm

Nozzle Dimensions: The ratio Aa,/ An between the total nozzle area, A$_m$, and the smallest passage area of the hearth, An, is assumed to be 12%. Similarly the number of nozzles were chosen to be 3 leading to a nozzle diameter of 8 mm for each nozzle. These are based on the Hasselman recommendations'.

The complete configuration is shown in figure 3 which includes the reactor and the scrubber cleaner. The hopper dimensions are chosen to hold about 8 hours supply of wood chips. The design adapted for the scrubber cleaner (figure 3') has provision to cool the hot gases to room temperature; this design has been recommended for both stationary and marine engines in literature. The overall dimensions of the cooler have been chosen to be the same as those of the

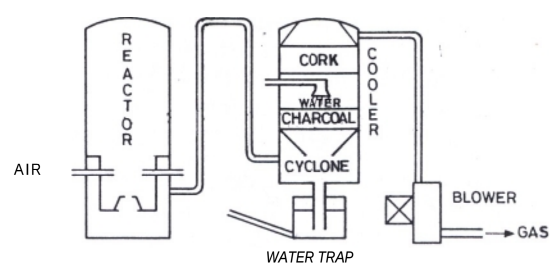

Figure 3. Reactor-cooler system.

gas generator based on the photographs of various working units given in ref.l.

TEST PLAN

The test set up consisted of a 3 hp **blower, the** reactor, the scrubber cooler, a burner with a chimney and a 5 hp diesel engine-pump set. Figure 5 shows the engine pumping water from a drum while operating in the co-generation mode.

The following measurements were made during test runs: temperatures at the throat and at the end of the reduction cone; pressure drops across the reactor and, the cooler and when -using the engine, its rpm, the pumping head and the fuel consumption.

The load on the engine was varied by changing the pumping head with the help of a throttle vavle in the pump delivery line.

The modifications made on the diesel engine for running on gas were:

(i) The filter at the air intake was removed and an additional manifold for mixing the air with the gas from the reactor was fixed in its place. This mixture was fed directly into the cylinder using engine suction.

(ii) The governor link available outside the engine for shutting off the fuel supply was modified to facilitate its locking at suitable positions for controlling diesel injection.

TEST RESULTS AND EXPERIENCE

The set up consisting of the reactor, cooler, blower and the chimney was run using wood chips as fuel and with the blower sucking the gas from the cooler and delivering it to the chimney. The gas generated could be flared satisfactorily. The reactor was run continuously for 8 hours without any significant change in the flame. The throat temperature remained between 925 and 1125°C. The highest pressure drop recorded across the reactor was 25 mm of water and that across the cooler was 100 mm of water. The gas composition was measured using an Orsat apparatus. The results of the measurement, shown in table l, indicate the proportions of CO and COz to-be roughly the same as those obtained in other reactors.
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The system was then coupled to the engine-pump set. In this mode, the gas could satisfactorily be generated using only engine suction-265 mm of water as measured at the generator outlet, the value of which was more than the pressure drop observed across the gas generator and cooler. The results from the various tests are discussed in the next section..

The governor used with the engine appeared to be sluggish and could not cut down injection of diesel when gas was introduced. At this point, the governor control was used manually to cut down fuel injection and the gas throttle was progressively opened. The control lever was then locked at the lowest possible fuel injection position at which the engine could run on its own. In this mode, it was found that the combination of the reactor and the engine with load could run smoothly without requiring much attention.

TABLE 1 *Composition of the wood gas (Volumetric %)*

Temperature at the throat of the hearth	% CO* Volumetric	% COa* Volumetric	%HzT	%Nzf
			Estimates	
1050° C	18.8 to 19.6	6 to 4	19	57

* Measurements t Estimates

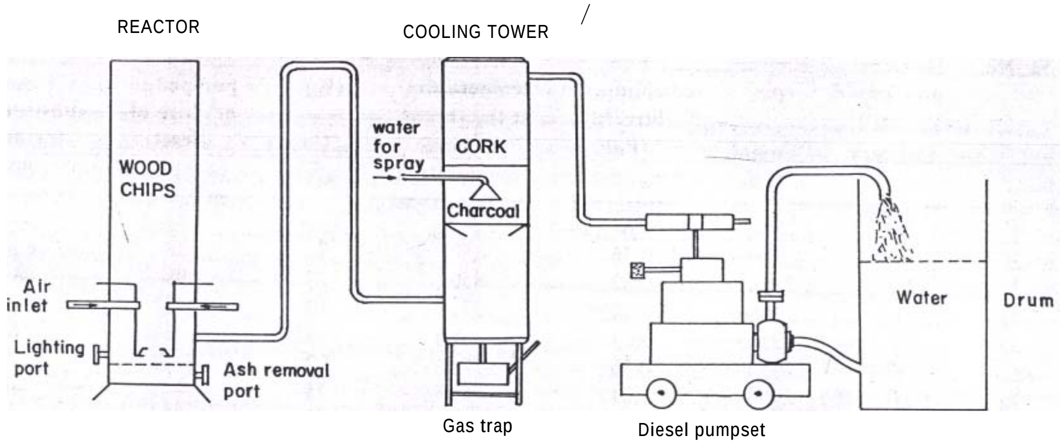


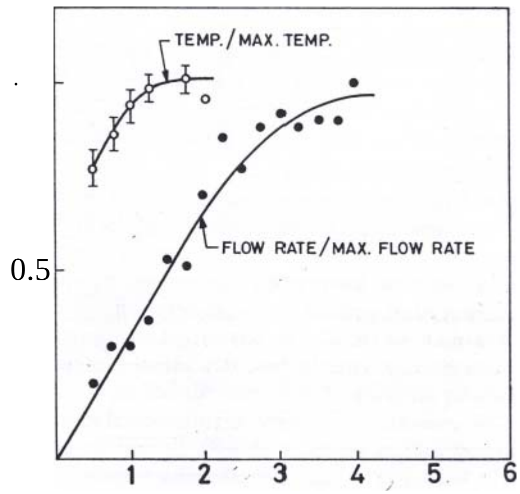
Figure 5. Engine running in co-generation mode.

While running the reactor with the blower, the best performance, as judged by the visible qu'ality of flame, was obtained at the highest measured flow rate. Figure 4 shows the variation of temperature at the throat with the gas flow rate; the temperature decreases with decrease in flow rate. While running the engine, the hearth temperature was about 875°C as compared to ,925 to 1125° C obtained with the blower in the suction mode. In figure 4, this corresponds to 80 to 90% of the temperature with the maximum flow and to about 50 to 80% of the maximum flow rate. This suggests the choice of a smaller hearth diameter for the range of parameters for which the engine-pump combination has been tested.

Other workers[3] while trying to design reactors for the same 5 hp engine used a throat diameter of 60 mm and a number of larger diameter nozzles. This could not give ignitable gas and produced unmanageable quantities of tar confirming the observations made in this section that for a 5 hp engine one should use a dn < 40 mm.

The data from the tests on the engine-reactor configurations are presented in table 2 which also contains the computed values of `fuel consumption/ maximum observed fuel consumption', water pumped per litre of diesel injected, and the extent of diesel substitution. From this table, one can draw the following conclusions:

(i) The engine while pumping water with a delivery pressure of 1 kg/cm ^{2} could be operated using wood gas with as little as IS to 20% of the fuel required for the `diesel only' mode. The exact point of operation will depend on the ability of the operator to `fine tune' diesel injection.



THROTTLE N4LVE OPENING (N0. OF TURNS) Figure 4.

Reactor .temperature and air flow rate.

(ii) About 25% of the nominal diesel consumption is required to pump a known quantity of wafer (measured values varying between 22 and 28%) against a head corresponding to 1 kg'/ cm^2 of delivery pressure: This percentage is likely to be different for different pumping heads and therefore is expected to vary between *20 to 30% i.e.* with a given quantity of diesel' one could pump 3 to 5 times more water as compared to the `diesel only' mode.

As far as the cost of the system is concerned, one must consider the gas generator as well as the power generation/ utilisation device together. In the present

TABLE 2

Test Results

Sl. No.	Delivery pressure (kg/ cm ^{s})	Engine rpm	Fuel consumption (litre/ hr) (F~)	Reactor temperature at the throat (°C)	F,/F.max (%) '	Water pumped in m^3/litre of diesel	Extent of diesel substitution for unit water pumped
l.	1	2850	1.62*	-	100	31	-
2.	1	2200	0.36	850	22	88	65
3.	1	2200	0.32	850	20	98	68
4.	1	2200	0.22	875	14	143	78
5.	I	2250	0.23	-	14	137	77
6.	1.2	2450	0.36	950	22	-	-
7.	1.7	2900	1.21	-	75	-	-
8.	1.6	2700	.0.84	-	52	-	-
9.	0.9	2100	0.46	-	10	-	-

*with diesel alone

context the diesel engine-pump set is a commercially available one, costing about Rs.6000/-. The first generation experimental gas generator costs about Rs.3500/-. There are possibilities of reducing the cost to about Rs. 1500 to Rs.2000 both through alterations in the design (size) and the fabrication scheme.

The next phase of the work on the gas generator concerns the evolution of a model which has design features for convenient operation and is also economical in terms of production. The model when developed will be field tested for about six months before qualifying it for production.

CONCLUSION

On the whole, the feasibility of running a 5 hp diesel engine-pump set on a wood-gas-diesel mixture with diesel replacement being about 75% has been demonstrated. While further optimisation of some parameters may be possible, the present performance compares favourably with those reported in Ref. I for large reactor-diesel engine systems.

4 June 1983; Revised 22 September 1983.

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