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AN INVESTIGATION OF COMPRESSION AND PURIFICATION OF BIOGAS AND IT'S USE FOR DOMESTIC INSTANT WATER HEATING APPLICATION

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ABSTRACT

In this work a method of compressing, purification and storing of biogas is investigated. A burner is designed and developed for instant water heating application by using bio gas. Experimentation is carried out with purified and unpurified bio gas and the parameter like total quantity of water heated, maximum temperature of water, mass flow rate of bio gas are measured. The results are compared with LPG geyser. It is found that biogas can be a good replacement for LPG for domestic instant water heating application.

KEYWORDS: bio gas, geyser, LPG, biogas-burner

Introduction

Heating water is a need for daily household chores. LPG gas geyser is one of the widely accepted mean of water heating, in which heat energy obtained by burning liquefied petroleum gas is used as an energy source. LPG being a costly fuel it is not affordable to every class of people. Since LPG is a non renewable energy source which is depleting at faster rates with increasing population, here arises a need for developing an economic, environment friendly as well as an energy conserving way of heating water. Biogas is one of the best options available in order to satisfy all the above mentioned requirements. Once installed, it is almost free of cost. It is a clean gas and also can be made easily available locally. It has been observed that only few modifications in existing gas geyser are required to make it suitable for using bio gas as a fuel. It is also possible to store compressed bio gas in portable cylinders. Bio gas is a flammable mixture of different gases that is produced by decomposition of biodegradable organic matters by microorganisms in absence of air (or oxygen). Biogas is produced by anaerobic digestion of biological wastes such as cattle dung, vegetable wastes, sheep and poultry droppings, municipal solid waste, industrial wastewater, landfill, etc. Biogas is constituted of different component gases the majority of them being methane (CH_4) and Carbon dioxide (CO_2) with traces of Sulphur Dioxide (H_2S) and Hydrogen (H_2) gas[1]. Typical composition of biogas sample is given in the table 1.[6]

Table.1 Typical Composition of Biogas

Constituent	Composition
CH4	50 - 60%
CO2	30 - 40%
N2	3 - 5%
H2O	1 - 2%
H2S	TRACES

Due to this lack of portability of biogas there have been very few efforts whatsoever to commercialize the use of biogas. The main problems associated with the commercialization with biogas are:

- Its low energy content per unit volume.
- It is difficult to liquefy.
- It is not produced in large amount at the place of application.

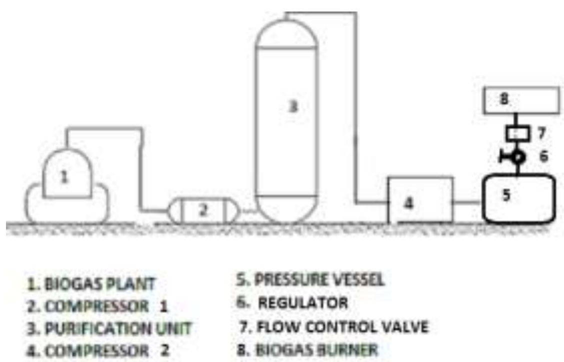
This project deals with production, purification, compression and storage of Biogas. It also deals with utilization of compressed bio gas for domestic instant water heating application. For this investigation a compact biogas plant is erected. The generated biogas is purified by selective absorption of impurities by various chemicals. The biogas is compressed by using hermetically sealed compressor of domestic refrigerator. A biogas burner is designed and fitted in LPG geyser. Experiments are carried out with purified and unpurified biogas in order to measure the parameters like total quantity of water heated in a single fill and maximum temperature of water. The results are compared with LPG geyser.

MATERIALS AND METHODS

1. Biogas generation

A compact biogas plant is erected for generation of bio gas. It consists of two plastic tanks one 1000 lit (digester) and the other 750 lit (holder).Initially the digester if filled with a mixture of 15 kg of cow dung and water to the capacity. Then 2 kg of waste food and 15 lit of water is fed to the plant daily. The generated bio gas gets collected in the holder which rises by 65 cm. The volume of biogas generated is calculated to be 0.420 m^3. The corresponding mass is 0.325 kg by considering density of biogas 0.774 kg/cm^3 [7]

Figure.1 Experimental set up of compressed biogas geyser



2. Purification

Raw biogas is passed through the Purification unit as shown in fig.1. The purification unit consists of three phases. In first phase, hydrogen sulphide (H_2S) is removed by passing the gas through aqueous solution of copper sulphate (100gm of $CuSO_4$ in 1 litre of water). In the next phase the gas passes through aqueous solution of calcium carbonate (1kg of $CaCO_3$ in 5 litrs of water) which removes carbon dioxide. In the last phase the biogas passes through sawdust (1/2 kg) which absorbs moisture from it.

The composition of raw biogas and purified gas is tested in "Agharkar Institute Pune". The Results are listed in table no. 2.

Table 2. Actual composition of raw and purified biogas

Constituent	Unpurified biogas (% by volume)	Purified biogas(% by volume)
CH4	50	85
CO2	30	9
N2	5	6

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This reveals that methane content is increased from 50% to 80% by the said method.

3. Compression and storage

The purified gas is compressed by another hermetically sealed compressor upto 10 bar pressure and store in the commercially available cylinder which is used for storage of CNG for automobile vehicle[4]. Near adiabatic compression is preferred due to simplicity and low cost.[2] This gas is then supplied to the biogas burner through a commercially available LPG pressure regulator as shown in fig.1 which reduces the pressure up to 1.5 bar [3].

4. Design of biogas burner

A burner suitable for using biogas is designed for instant water heating for bathing purpose. Cumulative flow area for biogas is calculated by writing energy balance for biogas and LPG for same rate of heat transfer [8]. Stoichiometric air is calculated by writing balanced chemical reaction for complete combustion of biogas. The actual air is calculated by considering 20% excess air [5]. The diameter of single fuel jet is finalized considering six number of fuel jets similar to that of LPG burner. The results of calculation are listed in table 3.

Table 3. Calculated dimensions of biogas burner

Parameters	Raw biogas	Purified biogas
Diameter of fuel jet (mm)	1.70	1.40
Stoichiometric air fuel ratio	5.65	13.301
Actual air fuel ratio	6.78	15.96
Diameter of air passage(mm)	-	15

This burner is installed in LPG geyser available in market for experimentation purpose.

5. The Experimentation

The experimental setup is as shown in figure 1. Experiments were carried out by using both raw and purified biogas for same outlet temperature of water. In both cases biogas was compressed upto 10 bar and supplied to the burner. In case of experiment with raw biogas water flow rate is adjusted by flow control valve in order to obtain 42^0C water. Flow rate of water is measured by stopwatch and measuring flask. The Gas control valve is kept fully open. The geyser is operated until the all the biogas in the cylinder gets utilized.

In case of experiment with purified biogas water flow control valve is adjusted by trial and error so as to obtain same outlet temperature of water as before.

In both cases, the duration of the trial is measured by stopwatch and temperature of water is measured by a mercury thermometer at an interval of 15seconds in order to find response time of the geyser. The amount of hot water collected is also measured by measuring flask. The trial is repeated for three times.

Similar trials are conducted by using commercial LPG geyser.

RESULTS AND DISCUSSION

It is observed that the compressed biogas (10bar) stored in cylinder lasts for 15 minutes duration.

The response time (time required for attaining maximum steady temperature) of geyser with unpurified and purified biogas is 105 sec. and 120 sec. respectively whereas for LPG it is 12 sec.

The amount of hot water (at 42^0C) obtained with unpurified and purified biogas is 45 lit and 65 lit respectively, whereas LPG geyser supplied 45 lit water in the same duration. The increase in the quantity of hot water and decrease in response time with purified biogas is an indication of higher methane percentage per unit volume of biogas after purification.

CONCLUSION

From this study, it may be concluded that biogas can be compressed and stored for domestic utilizations like water heating by using hermetically sealed compressor of domestic refrigerator. The methane content can be increased from 50% to 85% with the help the simple purification process as explained in the paper. The amount of hot water

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(at 42^{0}C) obtained and the response time of the geyser working on purified as well as unpurified biogas is at par with that of the LPG geyser.

Since biogas can be produced from domestic food wastes, the operating cost is almost zero whereas the cost of water heating of a family of 4 members by LPG geyser is around Rs. 12.00 per day in India. Hence the biogas geyser can be considered as a good replacement for LPG geyser.

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