Biogas Compression and Bottling: A Solution to Energy Crises

Vinayak R. Gaikwad
MTech Electrical
Viva Institute of Technology

P K Katti, Ph.D
HOD - Electrical
Dr. Babasaheb Ambedkar University Lonere

ABSTRACT
The ever increasing demand of the combined heat and power particularly electrical energy is in greater demand due to enhanced industrialization and urbanization in last few decades has led to higher pressure on fossil fuels and need for alternatives like renewable energy sources. Biogas is one of the important renewable energy sources which would cope up to cater for heat and power. Being site specific, it is not possible to transport and put in use to the extent it is required. This paper presents a working model to bottle such a gas which can be carried out at the required site as a source of supply for heat and power.

Keywords
Biogas compression, Bottling, scrubbing unit, Compressor, Manifold system.

1. INTRODUCTION
Energy is the key input for the socio-economic development of any nation. Industrialization, urbanization and mechanized agricultural techniques have generated a high demand of energy in all forms i.e. thermal, mechanical and electrical .To meet this ever-increasing demand, fossil fuels such as coal, oil and natural gas have been exploited in an unsustainable manner. This exploitation has been posing serious environmental problems such as global warming and climate change [7]. While we have shortage of energy and are dependent on imports in case of petroleum, we are blessed with plenty of natural sources of energy such as solar, wind, biomass and hydro. Biogas is a clean burning fuel which consists of about 50-60% methane [1]. It has the potential for leveraging sustainable livelihood development as well as tackling local and global land, air and water pollution. Biogas can be used for various applications namely, cooking, heating, space cooling / refrigeration, electricity generation and gaseous fuel for vehicular application [7]. At present it is not possible to transport biogas over long distances and to put in use to the extent where it is required. Biogas is becoming an increasingly important source of energy for rural areas in developing countries, as can be seen by the increased construction of bio digesters. Biogas has become an important fuel source because it is driven by readily available biomass. Because of this, there is a need to increase the versatility and availability of this natural fuel source to accommodate increased use. This biogas is produced by bio digesters that are currently in place. At the moment there is no system available to store the gas that these digesters produce, so all the gas that is created must be used at the same rate that it is produced.

2. BIOGAS POTENTIAL
Biogas is primarily methane that is generated from anaerobic digestion of organic waste by micro-organisms. It is relatively simple and produces a fuel from waste, while technically biogas can be produced from any type of organic waste. This waste could comprise agricultural and crop waste, human waste and animal waste (cow dung for instance) with a calorific value of about 5000Kcal/m^3. Biogas is an excellent fuel for heating purposes as well as for generating electricity [10]. It is estimated that India can produce power of about 17,000 MW using biogas. This is over 10% of the total electricity installed capacity in India. Biogas production has been quite dominant in India at household and community levels (especially in rural areas). In villages especially, thousands of small biogas plants use the cattle waste and provide biogas for household heating and cooking. It is estimated that over 1.8 million such biogas plants have been installed all over India [10].

Table 1. Biogas production from different substrates

Substrate	TS	Biogas production		Methane concentration
	[%]	[m3/ ton TS]	[m3/ ton wet weight]	[%]
Waste water treatment plants	5	300	15	65
Fish waste	42	1279	537	71
Straw	78	265	207	70
Sorted food waste	33	618	204	63
Liquid cattle waste	9	244	22	65
Potato haulm	15	453	68	56
Slaughter house waste	16	575	92	63
Liquid pig slurry	8	325	26	65

3. WORKING MODEL
The biogas compression and bottling process consist of different steps such as biogas purification, compression and bottling. Figure. 1 represents the typical arrangement of biogas compression and bottling process.

Fig1. Typical arrangement of biogas compression and bottling process

The proposed method as depicted in figure 1 has;

1. Biogas digester
2. Scrubbing unit
3. Compressor unit
4. Manifold block

The raw biogas from the digester is first allowed to pass through a set of three scrubbing units for removal of impurities as shown in fig.1. The methane rich content biogas is now allowed to compress by passing it through a compressor. The compressed gas is finally stored into small cylinders with the help of manifold system and adapter. The manifold system used in the prototype is of single input and double output. Gas cylinder is connected to one output port where as a pressure gauge is connected to the other output port. The reverse flow of the biogas is avoided by using ball valve and non-return valve.

4. SCRUBBING UNIT

The purification of biogas is carried out in the scrubber unit which consists of the following sub units;

1. CO_2 separation unit.
2. H_2S separation unit.
3. Moisture separation unit.

The function of each unit is as follows,

CO_2 separation Unit - The raw biogas is first passed through a CO_2 separation unit. Limestone crystals are used to remove carbon dioxide. Limestone reacts with carbon dioxide to form calcium carbonate. The chemical reaction is as follows;

$$CaO + CO_2 \rightarrow CaCO_3$$

H_2S separation Unit – After CO_2 removal, the biogas is passed through a H_2S separation unit. Hydrogen sulphide is removed by using catalyst iron oxide in the form of oxidised steel wool or iron turning from any workshop. Once biogas comes in contact with this wool, iron oxide is converted into elemental sulphur. The chemical equations are as follows; [5]

$$2Fe_2O_3 + 6H_2S \rightarrow 2Fe_2S_3 + 6H_2O$$

$$2Fe_2S_3 + 3O_2 \rightarrow 2Fe_2O_3 + 6S$$

Moisture separation Unit – Finally the biogas is passed through a moisture separation unit. Here silica gel crystals are proposed to separate moisture. Silica gel crystals should be replaced after a specific time according to the rate of purification. The capacities of the scrubbing units are decided according to the size of the biogas plant. Now the out coming biogas from the scrubbing unit is 98% pure. Further, if the purification is required the multiple number of scrubbing units can be used. Fig. 2 depicts the actual assembly of one of the biogas scrubbing unit [7]

Fig 2. Biogas scrubbing unit

It consists of one inlet for raw biogas to enter the unit and one outlet for clean biogas. The glass jar is tightly closed with a lid and hose attachment in order to prevent gas leakage. Likewise two more scrubbing units are connected in series for carbon dioxide and moisture separation. Finally the clean biogas from scrubbing unit is allowed to pass through a compressor.

5. COMPRESSOR UNIT

Pure methane is then compressed and stored in small cylinders or bottles which make it easy to transport at the point of application For the purpose of biogas compression two types of compressors are suggested;

1. Automatic Biogas Compressor.
2. Manual OR Hand Compressor.

Automatic biogas compressors are readily available in the local market. They are available in the pressure range of 2.5 bars up to 200 bars. So depending on the capacity of biogas plant and storage systems appropriate compressor should be chosen. On the other hand if the capacity of biogas plant & storage systems is small a suitable hand compressor can be used. The hand compressor works on the principle of suction and compression similar to that of a bicycle pump.

Fig. 3 Compressor unit assembly

6. EXPERIMENTAL RESULTS

Once the biogas is purified, compressed and is filled into small Cylinder. 2 kg cylinder was used for filling purified biogas. The results obtained during biogas compression and bottling are tabulated as follows,

Table 2. Experimental readings

1.	Weight of Empty cylinder	2.840 Kg
2.	Weight of cylinder after filling biogas	3.936 Kg
3.	Total purified biogas in cylinder 1	3.963 Kg - 2.840 Kg = 1.096 Kg
4.	Time required to fill cylinder	15 Minutes
5.	Flow of biogas	7 litres per minute

7. OIL SAVINGS

Percentage of oil savings is calculated by running an IC engine with the help of purified and compressed biogas. Loading arrangement of engine is shown in figure below,

Fig. 4 Loading arrangement

The engine is operated under three different cases,

1. Oil only
2. Oil + raw biogas
3. Oil + purified & compressed biogas.

Percentage of oil savings was calculated in each condition and graphical results were plotted as follows,

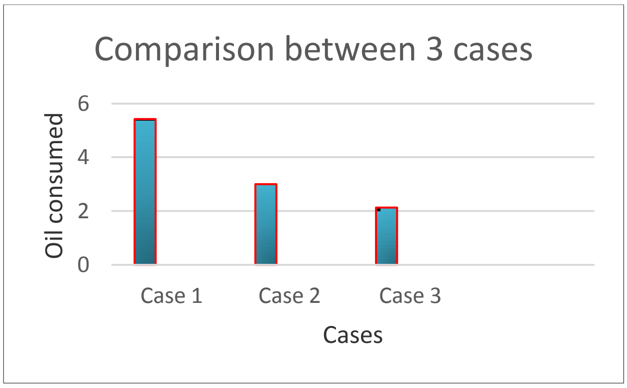

Fig. 5 Oil savings Bar chart

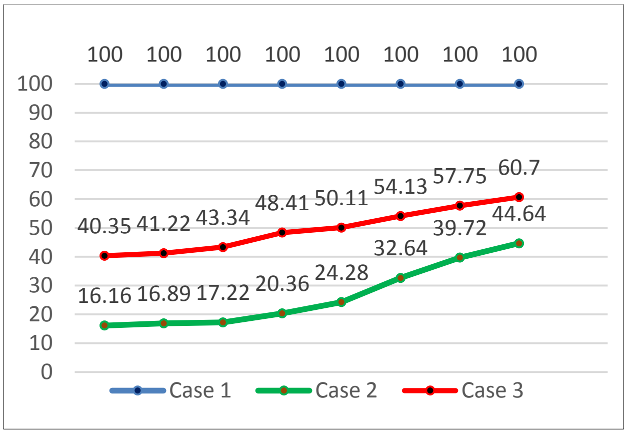

Fig. 6 Line graph for oil savings

8. CONCLUSION

On the studies carried out, it is clearly seen that the renewable and alternating energy sources need to be tapped on the background of scarce fossil fuels and climate change issues. Biogas is seen to be one of the best alternatives as depicted in this paper. It is observed that compressed biogas could hold successfully in the measuring cylinder after purification. Testing of gas consumption has been carried out by running IC engine. It is also observed that with raw biogas oil replacement takes place from 16.6% to 44.64% , whereas the purified and bottled biogas could successfully replace from 40.35% to 60.7%. Finally, therefore it is very clear that purification and bottling of biogas will ease mobilization of gas as an energy source while improving the efficiency. Thus, it is felt that commercial application of bottling of bio energy could led to revolutionarize use of renewable energy and could reduce the foreign exchange pressure.

9. REFERENCES

[1] Syed Zafar Ilyas, "A case study to bottle the biogas in cylinders as source of power for rural industries development in Pakistan". Group of renewable energy and environment, Department of Balochistan, Quetta, 87300, Pakistan.

[2] S.S Kapdi, V.K. Vijay, S.K. Rajesh, Rajendra Prasad," Biogas scrubbing, compression and storage: perspective and prospectus in Indian contex"t. Centre for rural development and technology, Indian Institute of Technology, New Delhi 110 016, India.

[3] Vinayak R. Gaikwad, Dr. P. K. Katti, " Bottled biogas; A future source of renewable energy", Department of Electrical engineering, Dr BATU, Lonere, Maharashtra.

[4] Vinayak R. Gaikwad, Dr. P. K. Katti, " Biogas compression and bottling", Department of Electrical engineering, Dr BATU, Lonere, Maharashtra.

[5] Virendra K. vijay, Ram Chandra, Parchuri M. V. subbarao and shyam S. kapdi, "Biogas purification and bottling into CNG cylinders: producing bio CNG from biomass for rural automotive applications". Mechanical Engineering department, Indian Institute of Technology, Delhi, Hauz khas, New Delhi- 110 016, India

[6]]Piyapong Singbua and Ratchaphon suntivarakorn, "Development of Biogas compression system for using in household", Department of Mechanical Engineering, Faculty of Engineering, khon Kaen Uni, Maung, Khon Kaen 40002, Thailand.

[7] Michael, Jason, Peter and James Faupel, "Design and Development of a Biogas compression and storage system capable of implementing in the developing world", Department of Mechanical, Materials and manufacturing Engineering

[8] Biogas support program,"A study report on efficiency measurement of biogas, kerosene and LPG stoves

[9] Basic data on biogas by Swedish gas centre, www.sgs.se

[10] Case study of biogas bottling in India by Akshay urja, April 2012, Volume5.