Biogas Enrichment and Bottling for Automobile and Remote Use – A Technology for Rural Development

1. Background

In the present era of ever-increasing energy consumption and dwindling fossil fuel reserves, the importance of biomass based, decentralized fuel such as Biogas has been greatly increased. It is a well established renewable and environment friendly fuel for rural energy needs. Biogas is ideally suited for rural applications where required animal or human excreta and agricultural waste are available in plenty. Biogas production from these wastes fits in very well with waste recycling. Harnessing such a resource promotes rural industries, agriculture, dairy and animal farming in a sustainable way. This will also increase employment in the rural regions and discourage migration to cities.

Biogas is produced by anaerobic digestion of degradable wastes such as cattle dung, vegetable wastes, sheep and poultry droppings, municipal solid waste, sewage water, land fill etc. India has a vast potential of 6.38 X 10^{10} cubic meter of biogas per annum from 980 million tonnes of cattle dung produced. The gas produced from cattle dung itself has a net heat value of 3.12 X 10^{14} kcal**.** A National Project on Biogas Development (NPBD) was launched by Government of India in 1981. A total of about 36.5 lakh family biogas plants have been installed under this programme all over the country till Dec. 2004. This is about 30 % of the total 120 lakh family type biogas plants potential. More than 3380 Community Biogas Plants (CBP), Institutional Biogas Plants (IBP) and Night-soil based Biogas Plants (NBP) have been installed all over the country with most reporting satisfactory performance levels. The family biogas plants in the country are estimated to be saving 39.6 lakh tonnes of fuel-wood per year. Besides, about 9.2 lakh tonnes of enriched organic manure are being produced every year from these plants.

So far, biogas has mostly been used as fuel for cooking and running stationary engines. However, its potential has not fully utilized, yet. There is a great enhancement in its utilization potential particularly where bigger plants are in operation e.g. institutional biogas plants in Goshalas, dairy farms or community biogas plants in villages. Goshalas are running generally on charity basis and most of goshalas are not in sound financial position. Enrichment and bottling of biogas will help to improve it.

Overall, biogas is an excellent energy source and can be used to run generators for electricity production as well as cooking in the households. Enrichment and compressing biogas concentrates energy content, reduces storage requirements and increases pressure to the level needed to overcome resistance to gas flow and thus offer its utilization for mobile engine application. Bottling of compressed and enriched biogas in cylinders gives a lot of flexibility to the user.

Mahatma Gandhi, in his vision for India, envisaged a system of devolved, self-sufficient communities, sustaining their needs from the local environment, and organizing income generating ventures around co-operative structures. Fifty years on, and Gandhi's vision of Swadeshi (self-sufficiency) for India, despite interpreted by some as a romantic and bucolic notion, is perhaps more urgent than ever. Diminishing forests, and a burgeoning, mainly rural biomass-dependent population of more than 1000 million, necessitates a

coordinated effort of rural India to supply itself with a dependable and sustained source of energy.

2. Main Objectives

- Design and Development of Water Absorption Based Biogas Upgradation System
- Performance Evaluation of the Developed System
- Bottling of Compressed and Enriched Biogas in Cylinders
- Applications of Bottled Enriched Biogas

3. Scientific and Technical basis

Water scrubbing involves the physical absorption of CO_2 and H_2S in water at high pressure (1 MPa) and regeneration by a release in pressure with very little change in temperature. The solubility of CO_2 in the water as compared to other constituents of biogas is relatively high. The system depends upon the dissolving of carbon dioxide in water to form diluted carbonic acid.

$$CO_2 + H_2O = H_2CO_3$$

It is the easiest and cheapest method for enriching biogas involving use of pressurized water as an absorbent. The raw biogas is compressed and fed into a packed bed absorption column from bottom and pressurized water is sprayed from top. The absorption process is, thus a counter current one. This dissolves CO_2 as well as H_2S in water, which are collected at the bottom and purified biogas at the top of the tower.

Enriching and compression of biogas reduces storage requirements, concentrates energy content, and increases pressure to the level needed to overcome resistance to gas flow and thus offer its utilization for mobile engine application. Sometimes the production pressure of a biogas source does not match the pressure requirements of the gas utilization equipment. Compression can eliminate the mismatch and guarantee the efficient operation of the equipment.

4. Evolutionary Stages of Development

Glaub studied various methods which could be used for biogas enrichment. Among all he mentioned that water scrubbing method is simple and economical.

Stewart reported that removal of the carbon dioxide by washing with water under pressure is the simplest and cheapest method for small scale operation and is also considered to be most economical on a larger size. The scrubber also removes all traces of sulfides that might otherwise cause corrosion problems in the compressor or vehicles.

Wellinger and Lindberg reported the water scrubbing method as the most popular method among other methods for CO_2 removal in sewage sludge based biogas plants in Czech Republic, France, Sweden and USA. They also reported that 1.0 MPa pressure for inlet gas can give more than 90% CH_4 in enriched biogas.

This type of system was apparently first used in the USA for stripping CO_2 from biogas at a wastewater treatment plant in Modesto, California. It is also the most commonly used biogas clean-up process in Europe, Sweden etc. The Modesto plant, operated in the 1970s and early 1980s, was rather simple and crude, and had no separate H_2S removal system. It produced a renewable methane stream that was compressed to fuel vehicles at the sewage treatment plant. The system was discontinued due to corrosion problems as well as lack of interest when the energy crisis abated.

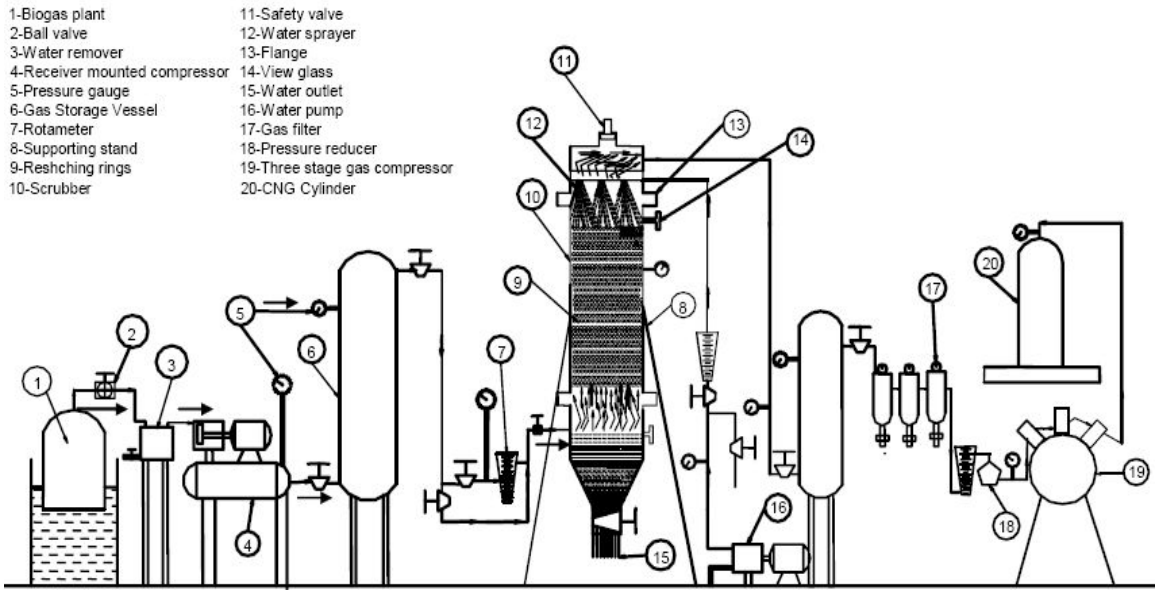
A variety of processes are available for enrichment i.e. removing CO_2, H_2S and water vapour. Most of these processes have been developed for use in the natural gas, petroleum and petrochemical industries. As a consequence, some of them may not be suited for biogas applications unless high flow rates are involved. Commonly CO_2 removal processes also remove H_2S.

5. Design and Technical Specifications including instructions for use

One of the easiest and cheapest methods involves is the use of pressurized water as an absorbent liquid. Due to simplicity, it suits rural applications. In this method, the biogas is pressurized and fed to the bottom of a scrubber column where water is sprayed from the top. In counter-currently operated absorption process, the carbon dioxide and hydrogen sulfide present in the biogas is absorbed in down going water and methane goes up and collected in vessel. Water scrubbing is the simplest method of removing impurities from biogas. However, water requirement in this process is high.

The scrubber is made of x mm diameter and y mm height with z mm packed bed length. Enriched biogas is made moisture free by passing it through filters after that it is compressed upto 250 bar pressure using a three stage gas compressor. Compressed gas is stored in high pressure steel cylinders as used for CNG. The compression pressure depends on the quantity of gas is to be filled in cylinders. The complete system is available with us, New Delhi.

Layout for Biogas Enrichment and Compression System



Raw Biogas is sent to a single stage compressor after removing moisture and stored in a pressure vessel after compression. Through rotameter, compressed raw biogas at desired flow rate is fed into the scrubber. A non-return valve was provided in the pipeline to prevent back returning of the gas. Gas and water flow rates are regulated through valves and a counter flow of gas and water is maintained.

In the bottom section of the scrubber column, water level is maintained up to half mark in view glass by regulating water flow through adjusting valve. It acted as a water seal and prevented escape of compressed biogas from the bottom of the scrubber column. Carbonated water i.e. water with absorbed carbon dioxide is discharged through outlet of the scrubber column. The out coming gas from the top of the scrubber column is analyzed for CO_2 content and stored in the pressure vessel for further compression and storage in cylinders.

6. Performance Appraisal and Cost

Around last five years, the system has been evaluated and observed that the method is best in terms of availability and cost of solvent (water) required and also the regeneration of the solvent is quite simple (Sprinkling of water in open atmosphere). In terms of energy required for purification operation it is equivalent to other methods.

Performance of the biogas enrichment system was evaluated in terms of carbon dioxide removal. Parameters studied were inlet gas pressure, inlet gas flow rate, inlet water flow rate and pressure. Effect of variation of these parameters was observed on the percentage removal of carbon dioxide from biogas. The initial carbon dioxide content in the raw biogas was also measured.

The enriched biogas is compressed using a three stage compressor in high pressure steel cylinder of 0.06 m^3 water capacity (i.e. CNG cylinder) upto 250 bar pressure. The compression pressure depends on the quantity of gas is to be filled in cylinders. The time required for the compression of enriched biogas with change in pressure inside the cylinder is depended on the capacity of the compressor used.

In this way biogas enrichment and bottling plant will prove a beneficial rural enterprise in villages. The profit will increase if capacity of biogas plant will be more thus more gas would be available for bottling. It will give direct employment to 3 persons and indirect employment to many persons.

Also, Goshalas and dairy farms have a more profit. The biogas enrichment and bottling plant at goshalas and dairy farms have a clear cut an extra advantage over community biogas plant in villages. More they have their own input material for biogas plant and working under single management, they have less managerial problem in managing the complete system than community biogas plant. Biogas enrichment and bottling plant may become a boon of profit for them to improve their financial conditions, especially in Goshalas.

7. Dissemination Status

The Biogas Upgradation and Compression System have been installed at Bhilwara, Jaipur Ghaziabad and various places of India and abroad. These systems are running smoothly. The enriched and compressed biogas is being used in existing designs of CNG operated vehicles and luggage carriers.

Biogas enrichment and compression system is recommended for large size biogas plants as there is sufficient biogas available for bottling, thus make it as an economical venture. Three cases are here taken where biogas enrichment and bottling plant can become a success:

- Rural entrepreneurship for community biogas plants
- Goshalas
- Dairy farms

8. Entrepreneurship Possibilities and Expected Benefits

In village plenty dung is available, so community biogas plant can be constructed. Through review of literature it is found that most of community biogas plants are plants are not working satisfactorily as they are not link with monetary gain. If these plants are transformed in rural enterprises based on biogas production, enrichment, bottling and sell of bottled biogas, then they may reverse the whole scenario. They will create employment and promote decentralized renewable source of energy for various rural applications.

Goshalas generally have none milking, old and stray cattle and run on charity. Often financial conditions of Goshalas are not good. Since they have a good number of cattle, thus dung availability is sufficient to operate large size biogas plant. Biogas enrichment and bottling plant link with these large biogas plants can generate good profits which help to boost their economy.

Similarly dairy farms have a good number of cattle for milk production. Generally they face problem in safe disposal of dung, which is generated daily in huge quantity. If they erect biogas enrichment and bottling plant then they will boost the profit and also find the best solution for disposal of dung.

- Self employment
- Electricity production
- Automobile application

9. Facilitating further promotion and wide spared use

As in the future, main substitute for petrol is bio-methane (i.e. enriched and compressed biogas at high pressure) and for diesel is bio-diesel. Therefore interlink between biogas plant and biodiesel plant is most important in the sense of by-product of bio-diesel (i.e. oil press cake) is raw material for biogas production.