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BIOGAS PURIFICATION & ENRICHMENT THROUGH STEPPED SCRUBBING

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ABSTRACT

Biogas is produced by anaerobic digestion of degradable wastes such as cattle dung, poultry droppings, municipal solid waste, sewage water, etc. This anaerobic decomposition causes evolution of Biogas contain Methane, Carbon Dioxide, Hydrogen sulphide, and water vapor, Since the raw biogas have low calorific value and low intensity for ignition due to the presence CO2 , H2S and water vapor. Hence it is needed to enrich biogas by removing these undesirable gases to save compression energy and space in bottle and corroding effect, which can be done by stepped scrubbing. The scrubbing system is found to enrich methane about 95 % or more depending upon biogas inlet and water injection pressure. Biogas can be used for all applications designed for natural gas, assuming sufficient purification.ie: by extraction and separation of these impurities by scrubbing process, we can purify and enrich the percentage of CH4 in raw biogas make its compression and bottling enable. Biogas can be converted in bio CNG after enrichment and bottling LBG, it becomes just like CNG.

KEYWORDS: Liquefied Biogas (LBG), BV- ball valve. NRV- non return valve, PG -pressure gauge, MB - manifold block.

INTRODUCTION

Upgraded biogas is a renewable energy source which can help both in waste management and in building a clean and sustainable environment. This technology is an economically viable option for biogas produced at medium to large scales. The purity of biogas can be achieved up to 90% Methane and this objective can corroborated through the stepped scrubbing process. The purified biogas is equivalent /similar to CNG. The purified biogas is filled in CNG cylinder and supplied for various purposes such as cooking & heating etc. Calorific value of purified biogas is equivalent / similar to CNG. As a matter of fact, the biogas bottling plants are one of the most potent tools for mitigating climatic change by preventing black carbon emission from biomass chulha since biogas is used as a cooking fuel and methane emissions from untreated cattle dung and biomass wastes are also avoided. The purified biogas can be bottled in CNG cylinders and wherever CNG is currently used, biogas bottling can be used as an alternative.

The slurry which comes out of the biogas plant is directly or after drying used as bio/organic manure for improving soil-fertility and reducing use of chemical fertilizers. It is also non-pollutant because it is free from weed-seeds, foul smell and pathogens. The slurry is rich in main nutrients such as Nitrogen, Potassium and Sodium (NPK) along with micronutrients - Iron & Zinc etc. As such there is no pollution from biogas plant. The slurry/manure of biogas plant is being sold to the farmers and used in liquid/solid form by them in agricultural crops. The field trials have indicated the excellent growth in agro-production and substantial improvements in the quality.

Biogas is non-toxic, color less and flammable gas. It has an ignition temperature of 650 - 750^{0}C. Its density is 1.214kg/ m3 (assuming about 60% Methane and 40% CO_2). Its calorific value is 20 MJ/m3 (or 4700 kcal.). It is almost 20% lighter than air. Biogas, like Liquefied Petroleum Gas (LPG) cannot be converted into liquid state under normal temperature and pressure. It liquefies at a pressure of about 47.4 Kg/cm^2 at a critical temperature of -82.1^{0}c. Removing

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carbon dioxide, Hydrogen Sulfide, moisture and compressing it into cylinders makes it easily usable for transport applications & also for stationary applications. Already CNG technology has become easily available and therefore, bio-methane (purified biogas) which is nearly same as CNG, can be used for all applications for which CNG are used. Purified biogas (bio-methane) has a high calorific value in comparison to raw biogas.

GENERAL BIOGAS PROPERTIES

PARAMETERS	VALUE
Calorific value	20MJ/m^3
Density	1.214 kg/m^3
It liquefies at pressure	200 bar
Critical temperature	82 ^{0}C

GENERAL BIOGAS COMPOSITION

S. No.	BIOGAS COMPONENT	%
1	CH_4	50-60
2	CO_2	30-40
3	H_2	5 - 10
4	Moisture	0.5-1.0
5	H_2S	0.3

METHODOLOGY

The biogas scrubbing system consists of three units: Carbon dioxide (CO2) removing unit, Hydrogen sulphide (H2S) removing unit, and moisture trapping unit. The three units are interconnected with plastic hoses. In the purification process of biogas which was conducted; pure water, steel wool, and an adsorbent material (silica gel) were used. The water is to reduce the percentage of carbon dioxide, steel wool is to react with the hydrogen sulphide and the silica gel is to reduce the presence of water vapor in the purified biogas. The experiment was done by taking the raw biogas with pressure builds up in the digester head and passes into the water scrubbing unit for CO_2 separation, further the raw biogas forced through the steel wool on its way to the biogas scrubber unit to remove H_2S.

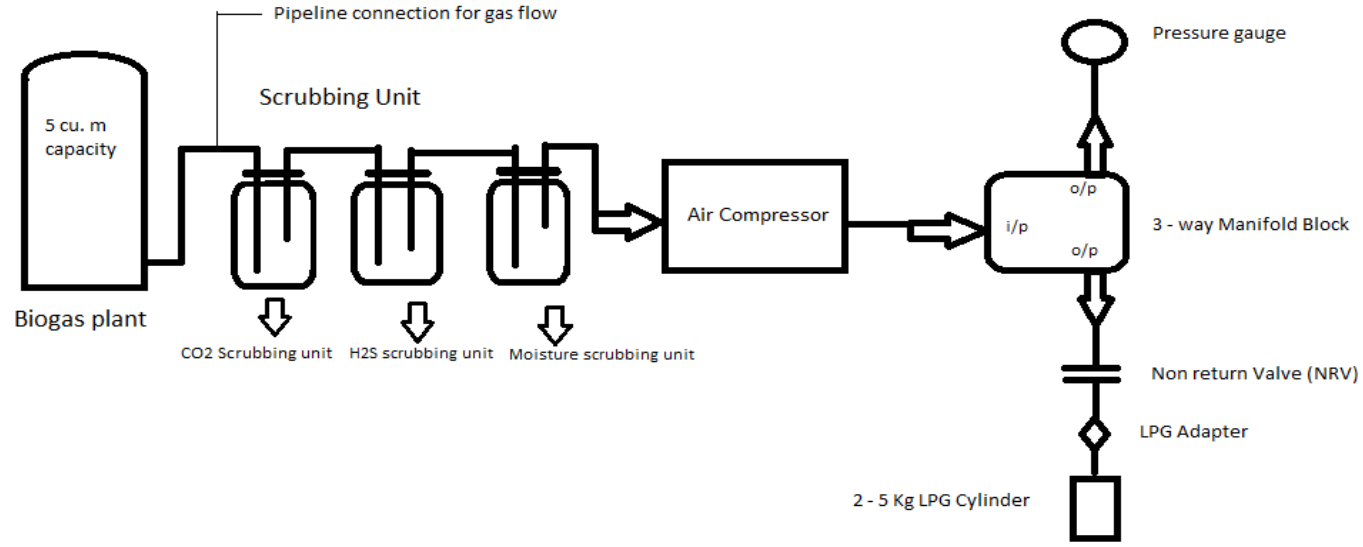

Fig 1: Typical arrangement of biogas enrichment plant.

BV- Ball Valve, NRV- Non Return Valve, PG – Pressure Gauge, MB – Manifold Block

The **Scrubbing unit** consists of the following sub units;

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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.

When carbon dioxide dissolved in water carbonic acid (H_2CO_3) is formed. It is a weak acid.

$H_2O + CO_2 = H_2CO_3$

The liquid leaving the scrubbing unit will thus contain increased concentration of carbon dioxide, while the gas leaving the scrubbing unit will have an increased concentration of methane. The purified biogas that was collected at the top of the scrubber unit has some water vapors. Water vapor is the leading corrosion risk factor. To reach water contents as low as in the purified biogas, silica gel was used in this experimental set up. Silica gel is a material that has a capability of absorbing moisture.

CO_2 Scrubber also consist limestone bedding since limestone crystals are used to remove carbon dioxide. Carbon dioxide reacts with Limestone to form calcium carbonate.

$CaO + CO_2 = CaCO_3$

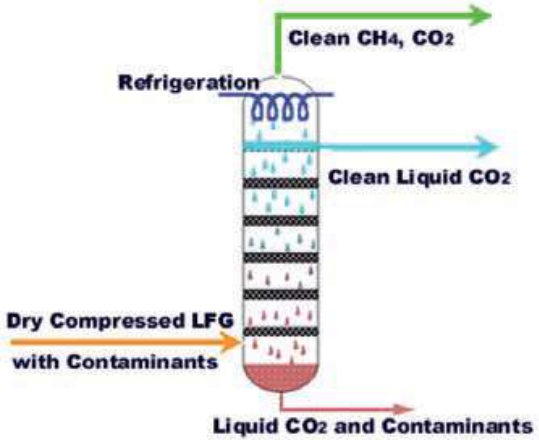

Fig 2: Schematic view of the CO_2 Wash

H_2S Separation Unit:

Hydrogen sulphide is removed by using catalyst iron oxide in the form of oxidized steel wool or iron turning from any workshop. Once biogas comes in contact with this wool, iron oxide is converted into elemental Sulphur.

$2Fe_2O_3 + 6H_2S = 2Fe_2S_3 + 6H_2O$
$2Fe_2S_3 + 3O_2 = 2Fe_2O_3 + 6S$

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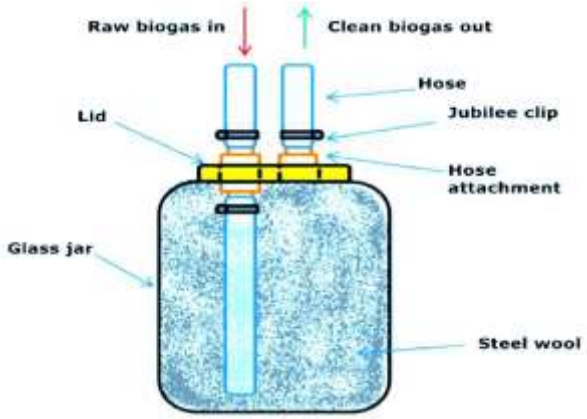


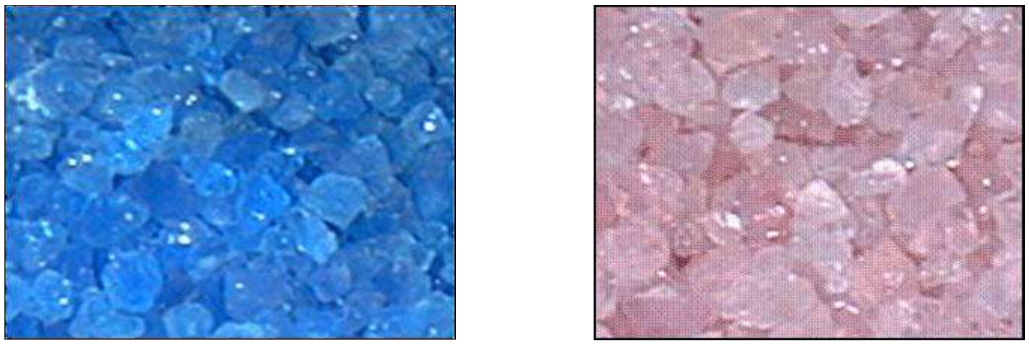
Fig 3: Hydrogen Sulphide Remover

a) Steel wool before scrubbing *b) Steel wool after scrubbing*

Fig 4: Steel wool before and after scrubbing

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.



a) Ready to use silica gel *b) Silica gel turns pink once it has soaked up moisture.*

Fig 5: Moisture Absorber

EFFECTS OF BIOGAS ENRICHMENT

Comparison between raw and enriched biogas:

Raw Biogas

- A low Grade fuel (CH_4 55-65 % & CO_2 35-45 %) with lower percentage of methane.
- On site or nearby, Cooking
- The presence of CO_2 besides being noncombustible, restrains its compressibility there by making biogas difficult to be stored in containers

Upgraded Biogas (BIS-16087:2013)

- A high grade fuel CH_4> 90 % and < 10 % other gases) with high percentage of methane.
- Remote applications.
- Methane burns faster hence yields a higher specific output and thermal efficiency compared to raw biogas when used as engine fuel.
- Upgrading , compression and bottling facilitates easy storage and transportation as a vehicle fuel, as a cooking fuel, for electricity production

CONCLUSION

1. It is proved that the concentration of methane available in the purified biogas was higher than that of raw biogas. The approximate methane concentration for purified and raw biogas was 68 ± 2.52 % and 90 ± 1.53 % respectively.
2. Biogas enrichment tends to utilization of biomass in four verticals: 1. Low Carbon fuel generation. 2.Manure formation as a byproduct from digester. 3. Excellent solid waste management & 4. Sustainable development

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