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BIOGAS UPGRADING TECHNOLOGIES: A REVIEW

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ABSTRACT

In the major parts of the World the use of biogas is restricted only up to cooking, but its potential is even larger. Biogas can be used directly to generate power, but the large volume of CO_2 & H_2S reduces the heating value of the gas, corrodes the metal parts in their contact, increases the compression and transportation costs and limits the economic feasibility to its uses. Upgradation (purification) of biogas allows for a wider variety of its uses, either for heat and electricity, or for vehicle fuels. In its upgraded form, the biogas (usually contains 50-65% methane) becomes biomethane (with 95% methane) & this upgradation expands its areas of application. Reducing CO2 and H2S content significantly improves the quality of Biogas & converts it into pure methane.Different biogas upgrading techniques such as water scrubbing system, pressure swing adsorption, chemical absorption method; cryogenic separation & membrane separation etc. are reviewed in this paper & the need for this upgradation is also discussed.

KEYWORDS: Biogas, renewable energy, upgradation, scrubbing, Cryogenic & membrane separation.

I. INTRODUCTION

The conventional (non-renewable) sources of energy are depleting at a faster rate day by day and this fact is leading to concentrate on the renewable energy resources. Renewable energy comes from natural resources which include wind, biomass, biogas, tides, geothermal heat & sunlight, these are naturally replenished. In this regard, biogas is one of the cheapest renewable resources of energy. Biogas is not only utilized for the power production applications but also it helps in solid waste management. The world is emphasizing greatly on the establishment of this technology for energy production. Most of the countries like UK, Germany, Italy, China, and India etc. are widely using this technology.

Biogas is the name given to the mixture of gases generated by the bio-degradation of organic substances under the anaerobic conditions. Organic substances is composed mostly of carbon(C), combined with other elements such as hydrogen (H), Oxygen (O), Nitrogen (N), Sulphur (S) etc. to form organic compounds such as carbohydrates, proteins and lipids.

In nature, microorganisms, mainly bacteria, through a digestion process break the complex carbon into smaller substances.

The digestion process which occurs without oxygen is called anaerobic digestion and generates mixtures of gases (biogas) with main content as methane (CH_4) .The gas produces 5200-5800 KJ/m^3 when burned at normal temperature and thus presents a viable environmentally friendly energy source to replace a fossil fuel.

Upgradation (purification) of biogas allows for a wider variety of its uses, either for heat and electricity, or for vehicle fuels. In its upgraded form, the biogas (usually contains 50-65% methane) becomes biomethane (with 95% methane) & this upgradation expands its areas of application.

II. DIFFERENT UPGRADING TECHNIQUES

A. Water and Polyethylene Glycol Scrubbing

Water scrubbing is used to remove CO_2 and H_2S from biogas since these gases are more soluble in water than methane. The absorption process is purely physical. Usually the biogas is pressurized and fed to the bottom of a packed column while water is fed on the top and so the absorption process is operated counter-currently as shown in figure 1.1. The water which exits the column with absorbed CO_2 and H_2S can be regenerated and re-circulated back to the absorption column. Regeneration is accomplished by de-pressuring or by stripping with air in a similar column. Stripping with air is not recommended when high levels of H_2S are handled since the water quickly becomes contaminated with elementary sulfur which causes operational problems.

Polyethylene glycol scrubbing relies on the same underlying mechanism as water scrubbing, with a physical absorption process that works because both CO_2 and H_2S are more soluble than methane in the solvent. Selexol is the trade name for one of the common solvents used for this process. The big difference between water and solvents is that CO_2 and H_2S are more soluble in Selexol which results in a lower solvent demand and reduced pumping. In addition, water and halogenated hydrocarbons (contaminants in biogas from landfills) are removed when scrubbing biogas with Selexol. Selexol scrubbing is always designed with recirculation. Due to formation of elementary sulfur stripping the Selexol solvent is normally done with steam or inert gas rather than with air.

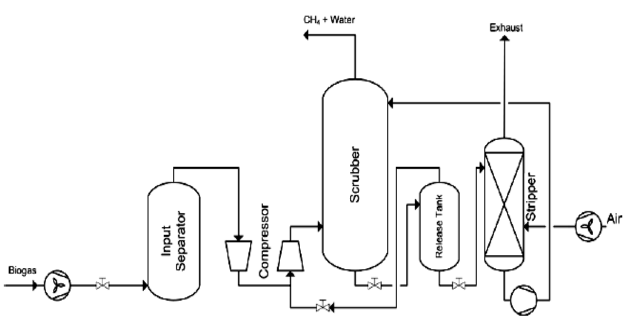

Fig 1.1 - Water Scrubbing Technology schematic

B. Pressure Swing Adsorption

Pressure Swing Adsorption (PSA) is a technology used to separate some gas species from a mixture of gases under pressure according to the specie's molecular characteristics and affinity for an adsorbent material (Figure 1.2). It operates at near-ambient temperatures and so differs from cryogenic distillation techniques of gas separation. Special adsorptive materials (e.g., zeolites and active carbon) are used as a molecular sieve, preferentially adsorbing the target gas species at high pressure. The process then swings to low pressure to desorb the adsorbent material.

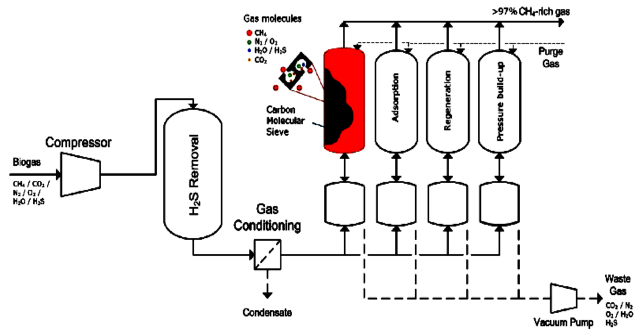

Fig 1.2 –Pressure Swing Adsorption Technology schematic

The PSA process relies on the fact that under pressure, gases tend to be attracted to solid surfaces, or "adsorbed". The higher the pressure, the more gas is adsorbed; when the pressure is reduced, the gas is released, or desorbed. PSA processes can separate gases in a mixture because different gases tend to be attracted to different solid surfaces more or less strongly. If a gas mixture such as air, for example, is passed under pressure through a vessel containing an adsorbent bed that attracts nitrogen more strongly than it does oxygen, part or all of the nitrogen will stay in the bed, and the gas coming out of the vessel will be enriched in oxygen. When the bed reaches the end of its capacity to adsorb nitrogen, it can be regenerated by reducing the pressure, thereby releasing the adsorbed nitrogen. It is then ready for another cycle of producing oxygen enriched air. However, during biogas purification, the adsorption material adsorbs H_2S irreversibly and thus is poisoned by H_2S. For this reason a preliminary H_2S removing step is often included in the PSA process.

PSA using zeolites or activated carbon at different pressure levels is an effective method for the separation of CO_2 from methane. Activated carbon impregnated with potassium iodide can catalytically react with oxygen and H_2S to form water and sulfur. The reaction is best achieved at 7 to 8 bar (unit of pressure) and 50 to 70°C. The activated carbon beds also need regeneration or replacement when saturated. The advantages of PSA technology are more than 97% CH4 enrichment, low power demand, and low emission and removal of nitrogen and oxygen. The main disadvantage of PSA technology is an additional H_2S removal step needed before PSA. Also, tail gas from PSA still needs to be treated.

C. Chemical Absorption

Chemical absorption involves formation of reversible chemical bonds between the solute and the solvent. Regeneration of the solvent, therefore, involves breaking of these bonds and correspondingly, a relatively high energy input (Figure 1.3). Chemical solvents generally employ either aqueous solutions of amines (i.e. mono-, di- or tri-ethanolamine) or aqueous solution of alkaline salts (i.e. sodium, potassium and calcium hydroxides).

Bubbling biogas through a 10% aqueous solution of mono-ethanolamine (MEA) reduces the CO_2 content of biogas 40 to 0.5–1.0% by volume. MEA solution can be completely regenerated by boiling for 5 min and is then ready for re-use. The advantages of chemical absorption are complete H_2S removal, high efficiency and reaction rates compared to water scrubbing, and the ability to operate at low pressure. Because of these advantages, the process is commonly used in industrial applications, including natural gas purification. The disadvantages are the additional chemical inputs needed and the need to treat waste chemicals from the process.

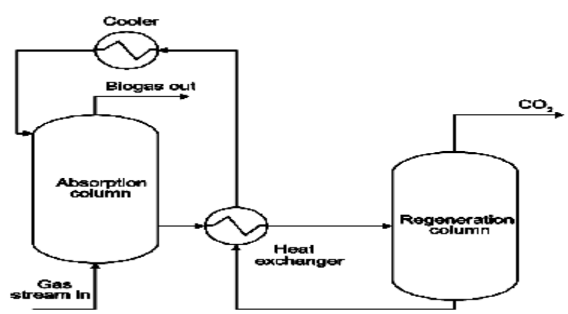

Fig 1.3 – Chemical Absorption schematic

D. Cryogenic Separation

Cryogenic separation of biogas is based on the fact that CO_2, H_2S and all other biogas contaminants can be separated from CH_4 as each contaminant liquefies at a different temperature-pressure domain. This separation process operates at low temperatures, near -100°C, and at high pressures, almost 40 bars. These operating requirements are maintained by using a linear series of compressors and heat exchangers (Fig 1.4).

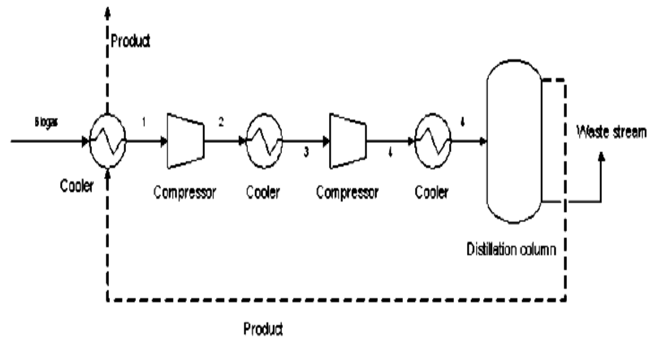

Fig 1.4 – Cryogenic Separation method Schematic

Crude biogas streams through the first heat exchanger which cools the gas down to 70°C. This heat exchanger makes use of the product stream as cooling medium, which is energy efficient and has the advantage of preheating the upgraded biogas before leaving the plant. The first cooling step is followed by a cascade of compressors and heat exchangers which cool the inlet gas down to -100°C and compress it to 40 bars before it enters the distillation column. Finally, the distillation column separates CH4 from the other contaminants, mainly H2S and CO2.

The main advantage of cryogenic separation is the high purity of the upgraded biogas (99% CH4), as well as the large quantities that can be efficiently processed. The main disadvantage of cryogenic separation is that cryogenic processes require the use of considerable process equipment, mainly compressors, turbines and heat exchangers.

E. Membrane Separation

The principle of membrane separation is that some components of the raw gas are transported through a thin membrane while others are retained. The permeability is a direct function of the chemical solubility of the target component in the membrane. Solid membranes can be constructed as hollow fiber modules or other structures which give a large membrane surface per volume and thus very compact units (Figure 1.5). Typical operating pressures are in the range of 25-40 bars. The underlying principle of membrane separation creates a tradeoff between high methane purity in the upgraded gas and high methane yield. The purity of the upgraded gas can be improved by increasing the size or number of the membrane modules, but more of the methane will permeate through the membranes and be lost.

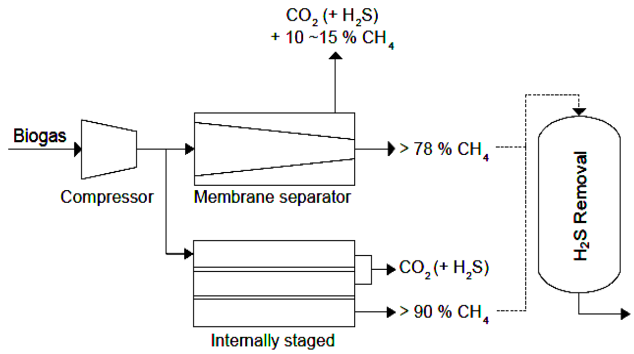

Fig 1.5 – Membrane Separation method Schematic

There are two membrane separation techniques: high pressure gas separation and gas-liquid adsorption. The high pressure separation process selectively separates H_2S and CO_2 from CH_4. Usually, this separation is performed in three stages and produces 96% pure CH_4. Gas liquid adsorption is a newly developed process that uses micro-porous hydrophobic membranes as an interface between gas and liquids. The CO_2 and H_2S dissolve into the liquid while the methane (which remains a gas) is collected for use. The advantages of membrane separation are that the process is compact, light in weight, has low energy and maintenance requirements and easy processing. The disadvantages of membrane separation are relatively low CH_4 yield and high membrane cost.

III. CONCLUSION

In the present energy crisis, biogas utilization after up gradation can be one of the cheapest methods for the power generation applications. Biogas can be used as transportable fuel & for all other applications designed for the natural gas after the removal of these elements. By adopting the cleaning of biogas the waste manure of dung can be managed i.e. this is the best way of solid waste management as well.

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