



Bio-Gas Purification by Pressure Swing Adsorption (PSA)

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What is Bio-Gas?

- ▶ Biogas is a raw gaseous stream produced by anaerobic decomposition of organic matter.
- ▶ The main component of biogas is methane which is a renewable source of energy and fuel.
- ▶ The production of biogas from organic matter is a complex process involving many different bacterial groups. In a simple way, the entire biogas conversion from organic matter can be divided into four steps:
 - Hydrolysis: complex organic molecules are hydrolyzed into smaller units (sugars, amino-acids, alcohols, fatty acids, etc.)
 - Acidogenese: acidogenic bacteria further break down the molecules into volatile fatty acids, NH_3 , H_2S and H_2
 - Acetanogese: the acetanogens transform the molecules into CO_2 , H_2 and mainly acetic acid
 - Metanogese: at the end of the process, the methanogenic archaea transform the H_2 and acetic acid molecules into a mixture of CO_2 , CH_4 and water

Major Sources of Bio-Gas

- ▶ Major sources of biogas production are landfills, waste-water treatment plants, manure fermentation and fermentation of energy crops
- ▶ In India a major source is cattle dung to produce biogas using bio-digesters
- ▶ The methane content which defines the usefulness of the raw biogas varies strongly due to the kind of molecules processed
- ▶ For example, fat has a much higher bio-methane yield than carbohydrates
- ▶ The bio-methane yield of cereal residues is quite high (approximately 200 m³ of CH₄ per ton)

Typical Composition of Bio-gas

- The Table below provides the composition range of Biogas on a dry basis

Component	Volume or Mole Percent
Methane, CH ₄	50-75
Carbon Dioxide, CO ₂	25-50
Nitrogen, N ₂	0-10
Oxygen, O ₂	0-2
Hydrogen, H ₂	0-1
Hydrogen Sulphide, H ₂ S	0-3

Upgrading of Biogas

- ▶ Biogas upgrade requires enriching the methane content of the gas by removal of contaminants such as CO_2 and sulphur compounds and drying the gas
- ▶ CO_2 is a major biogas contaminant in terms of reducing the heating value of the gas and its content has to be reduced to ~2-4% maximum to obtain a bio-methane useful as an energy resource and fuel
- ▶ Sulphur compounds in biogas are both toxic and corrosive and need to be removed to obtain bio-methane with trace amounts of sulphur compounds.
- ▶ H_2S is particularly toxic and corrosive and needs to be removed to trace levels. Automotive CNG specifications in India allow a maximum of 20 mg/m³ of H_2S + other sulfur compounds in the CNG which is primarily Methane.

Technologies for Removal of CO₂ from Bio-Gas

- ▶ Major technologies for CO₂ removal from biogas are:
 - ✓ Scrubbing with Water or any other physical solvent
 - ✓ Chemical Scrubbing
 - ✓ Membrane Separation of CO₂
 - ✓ Pressure Swing Adsorption (PSA)
- ▶ Pressure Swing Adsorption (PSA) technology is a popular technology employed in upgrading biogas.
- ▶ There are several companies globally who supply PSA technology for biogas upgrade such as: a) Carbotech Gas Systems GmbH b) Acronabiomethan, Switzerland c) Cirmac now Atlas Copco d) Gasrec, UK e) Xebec, Canada

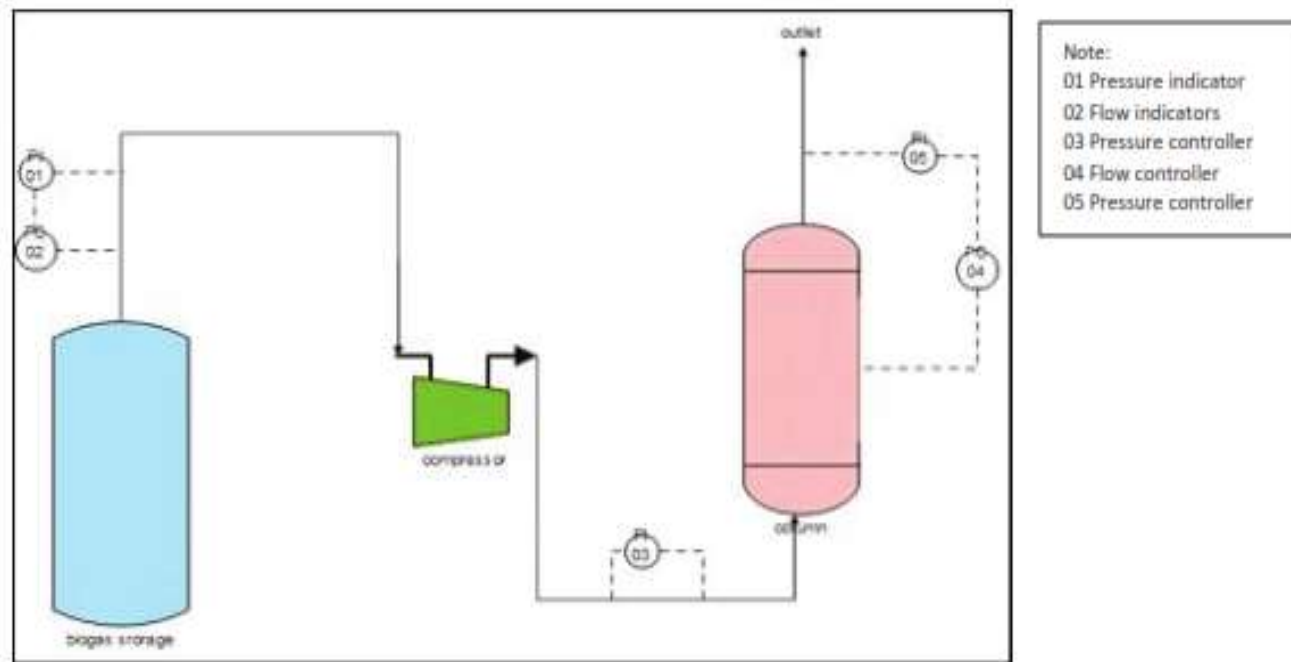
PSA Technology Description-1

- ▶ Biogas is compressed to 4-10 barg before being fed to PSA unit
- ▶ The PSA unit is a vessel (column) packed with a solid adsorbent material
- ▶ Commonly used solid adsorbents are Carbon Molecular Sieves (CMS), activated carbons, zeolites, and others (titanosilicates)
- ▶ Main characteristics of adsorbent should be high selectivity, good porosity, high surface area to volume ratio and long life
- ▶ The biogas is fed to the PSA column from the bottom and the enriched bio-methane obtained from the top
- ▶ The CO₂ is adsorbed in the PSA column which after a certain time is saturated and needs to be regenerated to remove the adsorbed CO₂
- ▶ The enriched bio-methane (generally >90% methane) is obtained at the top of the column with a small pressure drop across the column

PSA Technology Description-2

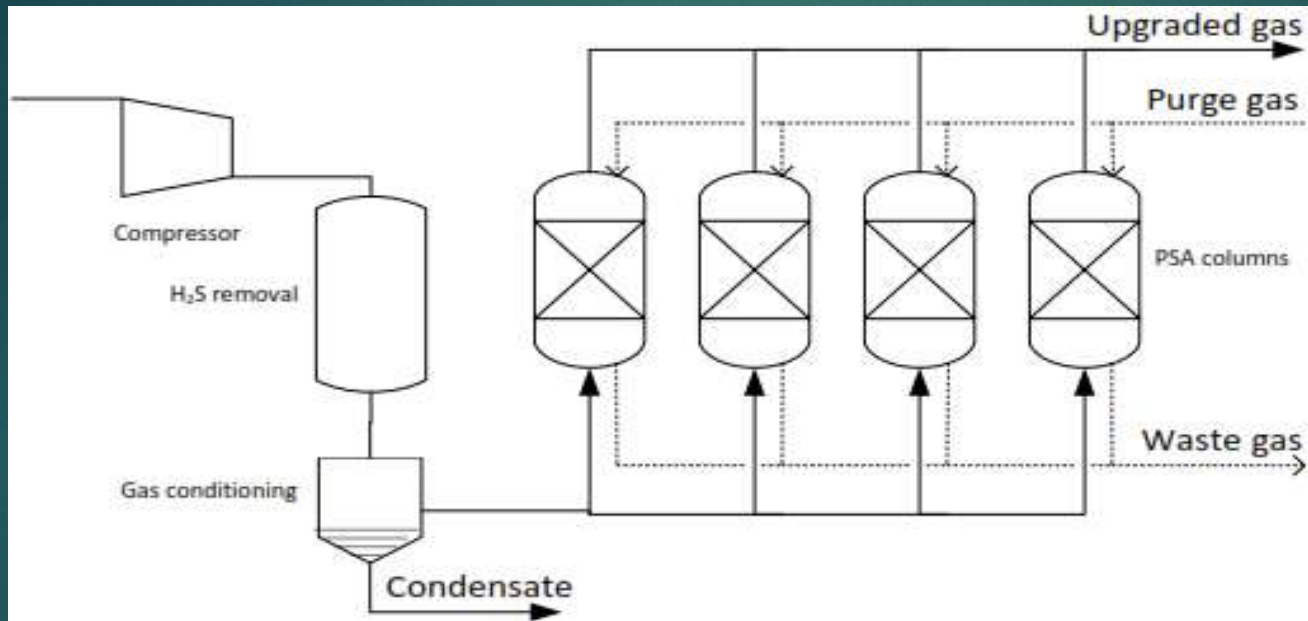
- ▶ Regeneration of the saturated PSA column is done by reducing the pressure to vacuum through a vacuum pump (liquid ring)
- ▶ Adsorbent material such as zeolite 13X and Carbon Molecular Sieve (CMS) CMS-3K (Takeda Corp) not only show high selectivity towards CO_2 but are also able to reduce the concentration of water vapor in the outlet gas.
- ▶ However, if the H_2S level in the feed gas is high then a pre-treatment is required to reduce the level of H_2S in the feed to the PSA unit since it cannot be desorbed (irreversible adsorption) from the adsorbent material.
- ▶ PSA units should be fed biogas with ≤ 200 ppm of H_2S . As mentioned earlier if this level is exceeded in the feed biogas a pre-treatment step is required to bring down the H_2S level in the feed biogas.

Single Column Bio-gas PSA System Process Flow Diagram (PFD)



Single Column PSA System for Biogas Upgrade

PFD for Bio-Gas Pre-conditioning & Multiple PSA columns for continuous process



Bio-Gas Pre-conditioning and Multiple Bio-Gas Upgrade PSA Columns operating and regenerating in parallel for a Continuous process

