PG&E GAS R&D AND INNOVATION

Water/Chemical Scrubbing Technical Analysis

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What is Water Scrubbing

Water scrubbers operate on the fact that carbon dioxide has a much higher solubility than methane in water. Carbon dioxide is separated from the raw biogas and dissolved into the water in the adsorption column using high pressure. The pressure of the raw biogas is raised to 6-10 bar before it enters the adsorption column. By increasing the pressure, and decreasing the temperature, most of the water in the biogas is separated out. The adsorption of methane and CO_2 is described using Henry's Law, which describes the relationship between partial pressure of a gas and the concentration of the gas in a liquid in contact with the gas. Next, in the desorption column, the carbon dioxide is released from the water by addition of air at atmospheric pressure. The water stream, which does pick up some methane, will be transferred to a flash column where the pressure is dropped to 2.5-3.5 bar. This causes the carbon dioxide to be released from the water. The carbon dioxide is then released from the top of the second column. (Bauer, 2012)

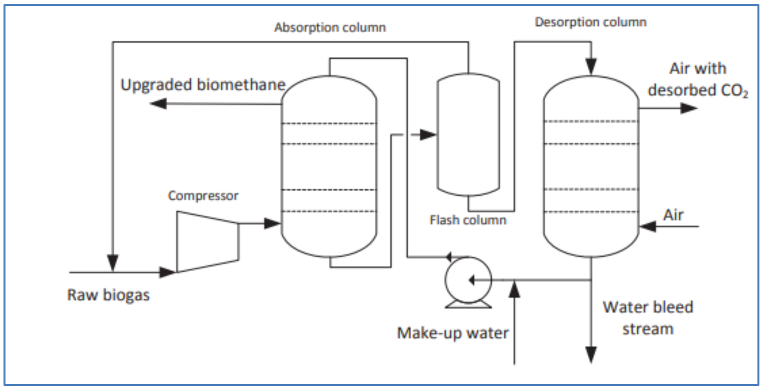

Figure 1 Water scrubbing process flow chart (Bauer, 2012)

The solubility of carbon dioxide increases with water as the temperature decreases and the pressure increases.

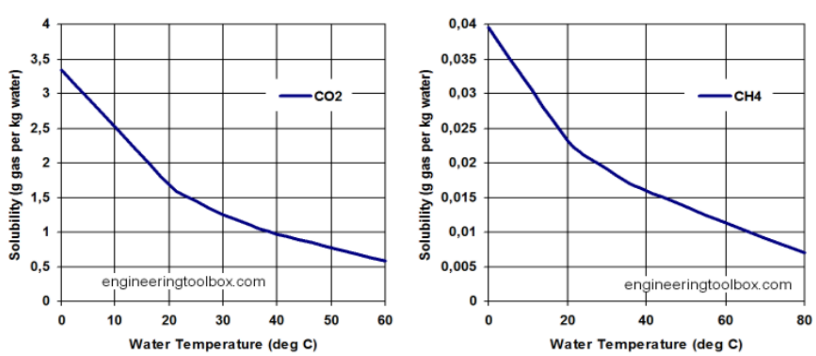

Figure 2 Graphs showing the relationship between solubility of CO_2 (left) / CH4 (right) and water temperature (Vijay, 2018)

Water Scrubber Design

Usually the adsorption column is packed with random packing that will increase the amount of surface area between water and the biogas to ensure carbon dioxide adsorption is as efficient as possible. The height of the bed and the type of packing will ultimately determine the efficiency of the separation column. The diameter will determine the throughput capacity.

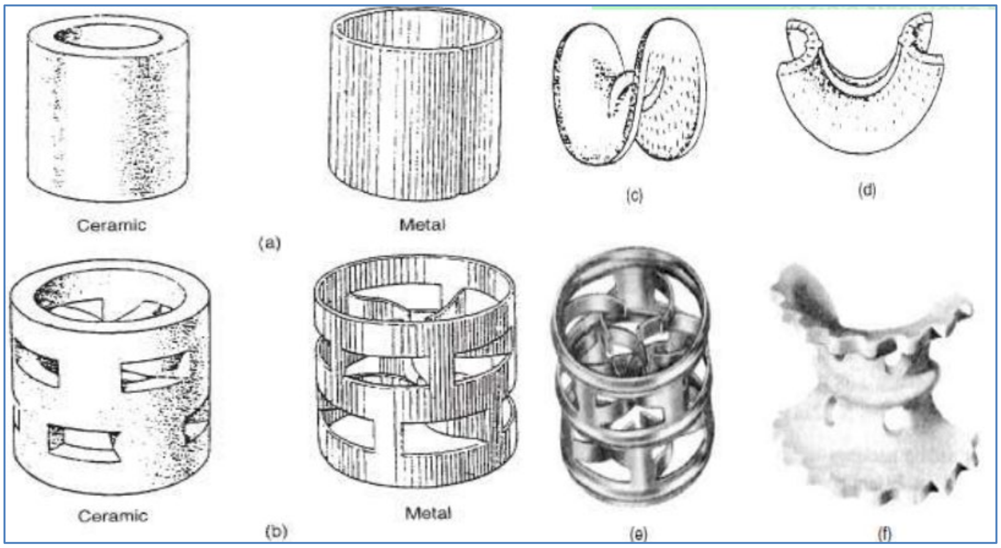

Figure 3 Illustration of the different adsorption column packing material (Vijay, 2018)

Examples of packing material that will increase surface area between water and the biogas

The flash column is designed to be narrower than the adsorption column in order to slow the vertical speed of the water to allow time for the small gas bubbles to rise to the top before being sent to the desorption column.

Biogas is injected from the bottom, and water is injected from the top. Counter flow is important to minimize energy consumption and minimize methane loss. The water leaving the column has been equilibrated with the highest partial pressure of CO_2 and the lowest partial pressure of methane, meaning the water has as much CO_2 and as little methane as possible.

Variations

For water scrubbing you can either recycle the water, or only add new water.

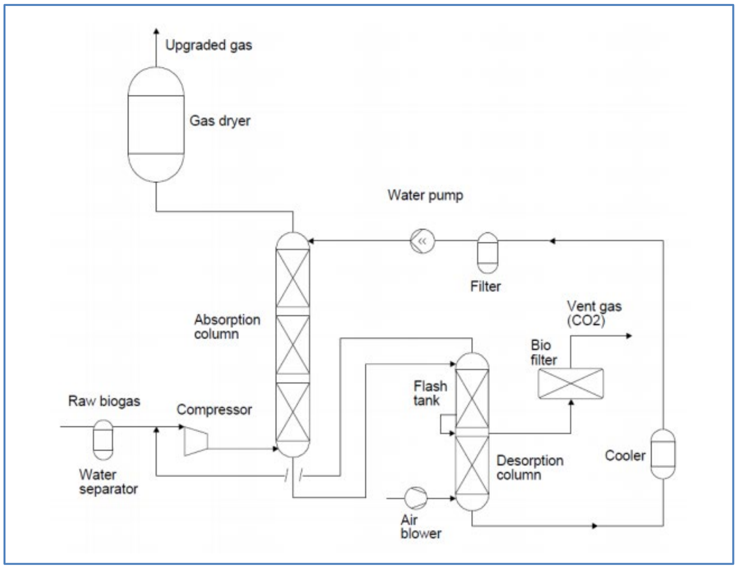

Figure 4 Water scrubber variations process flow chart (Brendelokken, 2016)

A water scrubber schematic that uses recycled water.

High pressure water scrubbing (HPWS)

The main difference between HPWS and conventional water scrubbing is the very high pressure of the system, usually around 150 bar. Also, the system is operated as a batch-wise system using two adsorption columns.

Due to the higher pressure requirements, there is higher energy consumption. The approximate energy needed to operate is 0.4-0.5 kWh/Nm^3 of raw biogas. The produced biomethane is at such a high pressure that it could be used in a vehicle fuel filling station with only minor additions for compression. (Bauer, 2012)

Typically, the footprint of these systems is smaller because of the higher pressure capability, however, the equipment will need to be designed to withstand the higher pressures.

Rotary Coil Water Scrubber:

This method of water scrubbing uses a rotating coil where the compression and scrubbing occur. A company called Biosling, based out of Sweden, has developed this method. Biogas and water are alternately input into the coils that are rotating. By rotating, you naturally increase the pressure from 2 to 10 bar. In the process, the carbon dioxide will be dissolved into the water. (Bauer, 2012)

This process is not able to obtain counter flow current, so the rotary coil method is not able to achieve 97% CH_4. The rotary coil method can output 94% CH_4. For this reason, this method is useful for applications where lower product purity is sufficient. A conventional water scrubbing unit can be used in series with this method. For the rotary coil system alone, the energy requirement is 0.15-0.25 kWh/Nm^3 of raw biogas. (Bauer, 2012)

Figure 5 Illustration of a rotary coil water scrubber (Bauer, 2012)

Energy Consumption

Most of the energy consumption goes toward water pumping. Also, compression to 20 MPa consumes a significant amount of energy.

Estimated 0.3-0.33 kWh/Nm^3 raw biogas. (Budzianowski, 2017)

The thermodynamic efficiency of biogas upgrading is 2-2-9.8% depending on the configuration. Biomethane compression efficiency is around 55%. The upgrading efficiency has significant room to improve, whereas the compression efficiency is pretty close to the thermodynamic limit. (Budzianowski, 2017)

With a lower capacity (~20 Nm^3/hr), you can create a mobile unit, as shown below.

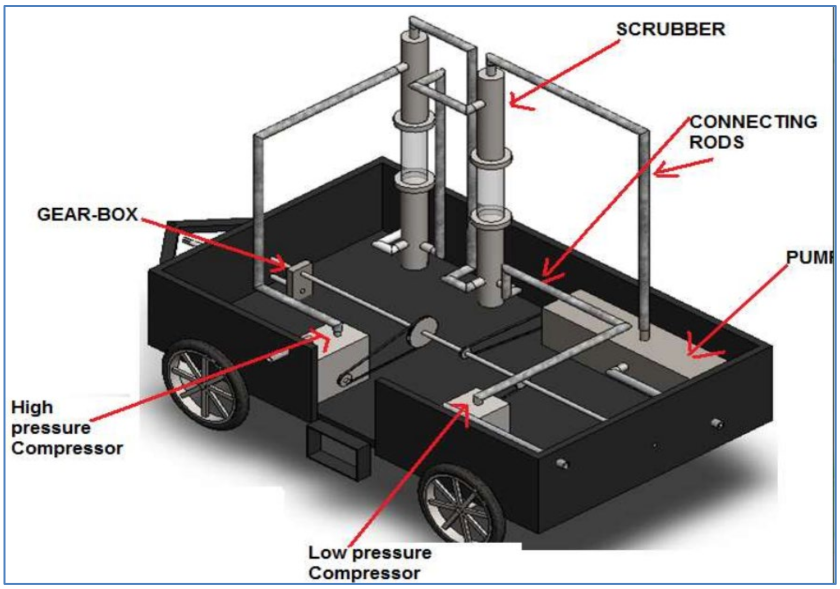

Figure 6 Illustration of a water scrubbing unit on a vehicle (Vijay, 2018)

Chemical/Amine Scrubbing

The use of reactive systems for removing CO_2 form biogas. Use a reagent that chemically binds to the CO_2 molecule, removing it from the biogas. A water solution of amines (molecules of carbon and nitrogen) is commonly used due to the molecular or ion form.

Operationally, the process of chemical scrubbing is the same as the process for water scrubbing. You would use chemical scrubbing instead of water scrubbing by choosing chemicals that have a stronger affinity to the unwanted constituents resulting a lower amount of methane absorbed into the off gas, a higher methane recovery, and a lower methane slip.

Although the high capacity and high selectivity of the selected chemical is highly effective during the adsorption phase, it can be a drawback during the regeneration phase when the unwanted constituents are released from the chemical. The process often requires a significantly increased amount of energy. The loaded solution will need to be heated up to around 160 degrees C in order to release the unwanted constituent.

Common solvents include aqueous solutions of Monoethanolamine MEA, Diethanolamine DEA and Methyldiethanolamine MDEA. (bio.methan.at, 2013)

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