Liquefaction of Biogas

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Abstract:

The liquefaction of biogas appears to be an appropriate solution in cases where logistics constraints arise due to the absence of a transportation network. In liquid form, bio methane is easy to transport to its point of use. **DWSIM**, computer-aided process design programs, widely used in academics and chemical and thermodynamic process industries, in this study liquefaction process of biogas was simulated in DWSIM with the aim to at assess the technology using cryogenic process to liquefy the biogas and obtain the **liquefied bio methane and CO2** as a by-product through the simulation results. The parameters such as biogas feed, temperature and pressure are obtained from the case study from **Havys Biogas Power Plant** owned by Cenergi Sdn. Bhd. Hence, with a working principle of cryogenic process, a simulation of the process of liquefaction of biogas was simulated in DWSIM simulation environment where it consists of three stages, which are pre-cooling stage, liquefaction stage and sub-cooling stage. As a result, with a biogas feed of 1,500 m3/h consists of 60% CH4 and 40% CO2 at 200 kPa and 35°C, liquefied bio methane were obtained from the design of the simulation with a purity of 99% and liquid CO2 was also obtained as a by-product of the liquefaction process.

Process Description:

For production of liquefied bio methane, the biogas is cooled down to temperature of -162 °C. In this case, the gas turned to an odorless and transparent liquid. In this study, nitrogen is used as refrigerants for the liquefaction of biogas due to the boiling points of nitrogen which is at -197 °C. Before entering the cryogenic distillation column, which is the important unit operation for liquefying biogas, the biogas need to be cooled first to avoid freezing in the cooling step. The biogas feed at the temperature of 35 °C and pressure at 200 kPa is compressed to 2 MPa and cooled down to temperature of -48 °C to freeze out of possible impurities. LNG exchanger is used for cooling the cool biogas to -162 °C. Three stage exchangers used for this purpose. The first stage which is precooling stage is as mentioned before where the biogas is cooled down to -48 °C. In second stage which is liquefaction stage, biogas is cooled to -120 °C. Finally, in the third stage which is sub cooling stage, the biogas is cooled down to -162 °C to obtain liquefied bio methane. In precooling stage, the cooler has been used to decrease the temperature of the biogas. Inlet biogas feed is in temperature 35 °C and the pressure of 200 kPa. In this stage, the temperature is reduced to -40°C after being compressed. In liquefaction stage, liquefied natural gas (LNG) exchanger with two streams is used. The first stream is nitrogen which used as a refrigerant with the temperature set at -130°C. This stream is a part of stage which includes a compressor and cooler. In this stage, the temperature of biogas is reduced to -120°C. The temperature cannot be reduced to lower than the stated temperature using nitrogen. The second stream is "cool biogas" cooled in the LNG exchanger for using in third exchanger which is sub cooling stage as a "cold biogas". In this stage also, the first stream which is "coolant in" enters to the compressor for increasing its pressure, then it enters into a cooler for the reduction of its temperature. At last, it enters back into the LNG exchanger. In the third stage, the cold biogas enters pump for increasing its pressure, then it enters the cryogenic distillation column. The cryogenic distillation process is the important process for the overall process because this process performs the actual liquefaction of biogas into liquefied bio methane. The operation in the column at one (1) bar is a good compromise for an acceptable low temperature of the liquid. The heat duties of the reboiler of the low-pressure column and heat duties of the condenser of the high-pressure column are different to obtain two various products which is liquid bio methane at high pressure and solid carbon dioxide at low pressure. At the end of the process, liquid bio methane is obtained by condensing the biogas to -162 °C. The carbon dioxide will enter the reboiler and left the distillation column as liquid carbon dioxide.

Results:

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Object	Bio Gas feed	Coolent(N2)In	Liquid BioMethane	Liquid CO2	
Temperature	35	25	-161.755	-45.7981	C
Pressure	2	1.01325	1	8	bar
Mass Flow	3206.15	7500	1133.43	2072.76	kg/h
Molar Flow	117.746	267.729	70.6478	47.0985	kmol/h
Volumetric Flow	1500	6547.98	160.312	1.81953	m3/h
Molar Enthalpy (Mixture)	317.038	-7.78767	-12558.3	-17707.9	kJ/kmol
Molar Entropy (Mixture)	1.65357	-0.022309	-88.71	-92.7901	kJ/[kmol.K]
Molar Flow (Vapor)	117.746	267.729	17.6619	0.000780839	kmol/h
Volumetric Flow (Vapor)	1500	6547.98	158.306	0.0016565	m3/h
Molar Fraction (Vapor)	1	1	0.25	1.65789E-05	
Molar Fraction (Mixture) / Methane	0.6	0	0.999967	1.82027E-05	
Molar Flow (Mixture) / Methane	70.6478	0	70.6454	0.000857321	kmol/h
Mass Flow (Mixture) / Methane	1133.36	0	1133.33	0.0137535	kg/h
Molar Fraction (Vapor) / Methane	0.6	0	0.999999	0.000435077	
Molar Fraction (Mixture) / Carbon dioxide	0.4	0	3.30066E-05	0.999982	
Molar Flow (Mixture) / Carbon dioxide	47.0985	0	0.00233184	47.0977	kmol/h
Mass Flow (Mixture) / Carbon dioxide	2072.78	0	0.102623	2072.74	kg/h
Molar Fraction (Mixture) / Nitrogen	0	1	0	0	

Reference: **Journal homepage:** www.akademiabaru.com/arbb.html

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https://www.researchgate.net/publication/327857990_Design_of_Liquefaction_Process_of_Biogas_using_Aspen_HYSYS_Simulation