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Research Article

UTILIZATION OF ASPEN HYSYS SIMULATION TO DETERMINE THE OPTIMUM ABSORBER WORKING PRESSURE NEEDED TO ACHIEVE MORE THAN 0.99 METHANE PURITY FROM EGYPTIAN BIOGAS

***Sameh Tawfik Abd Elfattah, Yehia A. Eldrainy and Abdelhamid Attia**

Department of Mechanical power, Faculty of Engineering, Alex University, Egypt

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ABSTRACT

Egypt has many sources that can be utilized in renewable energy generation, for example, agricultural waste, sewage waste and livestock production, which can be utilized in biogas generation. Biogas is not only one of the promising renewable energy sources in Egypt, but also it can be used in Industrial and research purposes. However, using biogas in industrial and research purposes needs to use an advanced technique for purification and enrichment in order to achieve high methane purity more than 99%.Whatever the purpose of biogasapplication, it is essential to clean it from acidic gases before using it.Biogas contains mainly two acidic gases they are CO_2 and H_2S, whichmust be minimizedin biogas total composition before pumping it in natural gas pipelines in order to insure the compatibility between biogas composition and natural gas network quality standards. In case of using biogas in industrial and research purposes such as X-ray metal analyzer the biogas CO_2 and H_2S contents must be equal to zero in order to achieve methane purity 99 % or more. This article aims to upgrade the Egyptian biogas to achieve 99 % methane purity by removing the acidic gases CO_2 and H_2S completely from Egyptian biogas composition. In order to make a proper design of biogas acidic gascleaning plant, Aspen HYSYS software can be used as one of numerical simulation programs.Using the typical acidic gas treating plant which plugged in Aspen HYSYS 8.6 library, and used for natural gas treating, it is possible to simulate the biogas treating process, but after taking in consideration the differences between partial pressures of CO_2 and H_2S in both of natural gas and biogas. This Partial pressure difference leads to study the relation between inside treating gas treating cycle main equipment, and both of CO_2, H_2S and methane volume contents of the final sweetening gas product.After drawing relation curves it is easy to determine the optimum working pressure, whichcan be used to achieve methane purity more than 99 % from Egyptian biogas. The natural gas treating process was done inside Pressure Swing Absorber (PSA) where the feed sour gas enters the absorber atthe CO_2 contents of 0.025,H_2S contents of 0.007, a temperature of 37 °C, a pressure of 30 bars, a flow rate of 13 m3/hour,Diethanolamine (DEA) concentration of 0.3 and 20 stages PSA has atray diameter of 1.7 m.Then the final methane purity can be obtained from natural gas is 96 %.Using the same cycle with the same conditions, but after the regulation of the PSA working pressure to be suitable for Egyptian biogas treating, a 20 bar PSA working pressure will be obtained as the optimum pressure needed to achieve 99 % methane purity from Egyptian biogas.

INTRODUCTION

In fact, it is possible to overcome the energy crises in Egypt by converting the agricultural, industrial and sewage waste to biogas (El-Dorghamy and Zahran, 2012) in order to generate a large amount of energy. Not only that but also it is possible to use this biogas in industrial and scientificresearchpurpose, such as X-ray metal analyzer ,which used in determination of metallic contents of alloys, after achieving pure methane has more than 0.99 % purity.

****Corresponding author: SamehTawfikAbd Elfattah,***
Department of Mechanical power, Faculty of Engineering, Alex University, Egypt.

The methane purity more than 99% is needed for biogas extracted methane to be suitable for mixing with argon gaswhich also is essential for X-ray metal analyzer application. SourEgyptian biogas contains other acidic components(CO_2 and H_2S) where they must be removed before pumping it into the natural gas network to meet the standards of these networks (Ryckebosch *et al*., 2011; Deublein and and Steinhauser, 2011; Poeschl *et al*., 1782). In addition, as mentioned before it is possible to obtain a high -purity methane from the biogas that used for other expensive purposes other than energy and power generation such as industrial , scientific research applications, and calibration for sophisticated devices which (Persson *et al*., 2006; McKendry, 2002).

Biogas sweetening is the process in which CO_2 and H_2S are removed in order to protect the pipelines network and power engines from corrosion due to acidic effect, and to raise the calorific value of the treated biogas (Ryckebosch *et al.*, 1645; Belmabkhout *et al.*, 2009; Bioenergy *et al.*, 1999; Zhao *et al.*, 2010; Rodriguez, 2014). Most of biogas researches in Egypt focused only on biogas production from local resources and using it in thermal energy generation (El-Shinnawi, 1989; Halwagi *et al.*, 1986; Abou Hussein *et al.*, 2010; El-Shimi *et al.*, 1995; El-Din, 1982), however there are only few researchers concentrate on the biogas quality enrichment.The numerical simulation plays an important role in facilitating the proper design of sweetening cycle and sizing of its equipment especially the absorber (Krischan *et al.*, 2012; Gawel, 2012; Nuchitprasittichai and Cremaschi, 2011). Aspen HYSYS 8.6 simulation software program is one of the most important and accurate programs that have been used in the design of gas treatment process (Alfadala *et al.*, 2009; Bruno *et al.*, 2009; Yulin *et al.*, 2011; Shuxia, 2011).

Therefore, this article aims to determine the optimum PSA working pressure to achieve the highest purity of the Egyptian biogas using Aspen HYSYS 8.6 simulation program. The detailed discussion of the ways of biogas upgrading to remove acidic contents (CO_2 and H_2S) to match the universal standard of engines and power stations and intensive study in using the simulation programs in the purification process of acid gases have been done (Øi, 2007;p Peters, 2011; ErikØi, 2012; Gabrielsen, 2006; Mandal, 2001). However, these previous literatures did not provide a specific method to determine the optimum absorber dimensions to extract pure methane from biogas.

stage consists of one tray as having construction looks like a sieve as shown in Figure . The acid gas fluid package which contains DEA is also selected. The feed NG gas which has the composition as mentioned in enters the absorber at atemperature of38°C, pressure of 20 bar and volume flow rate of 13.5m^3/hr from the bottom of the absorber column. The lean amine (DEA) enters at the top of the column at conditions of 43°C, 36barand 54m^3/hr.

The amine DEA can absorb CO_2 and H_2S from the feed NGgas simultaneously. The sweet feed gas, which is free from CO_2& H_2S, exits from the top of column, and the rich amine, exits from the bottom of the absorber. Then the rich amine passes through the expansion valve in order to expand to 46 °Cand5 bars and then it enter the separator.Rich amine exits from the separator by the same fore mention conditions to enter a Lean amine /Rich amine heat exchanger (L/R) . The L/R heat exchanger transfers heat from lean amine into rich amine. The hot rich aminewhich exits from the exchangerenters a regeneration column to extract CO_2 from the rich amine to lean it for reusing it.

While the lean amine enters a make-up tank at 87°C and 2.3 bar which is above atmospheric pressure by 1.3 bar and exits from it at also 87°C and 2.3 bars which equal the same inlet conditions of the make-up tank.Then it is pumped to 88^{0}C and 36 bars successively it is cooled at constant pressure process to 43°C to be sent toa recycler.Lean amine exits from recycler at 43°C and36 bars. Finally, a sweet gas is obtainedfrom the absorber after removing both CO_2& H_2S and has a composition as mentioned in Table .

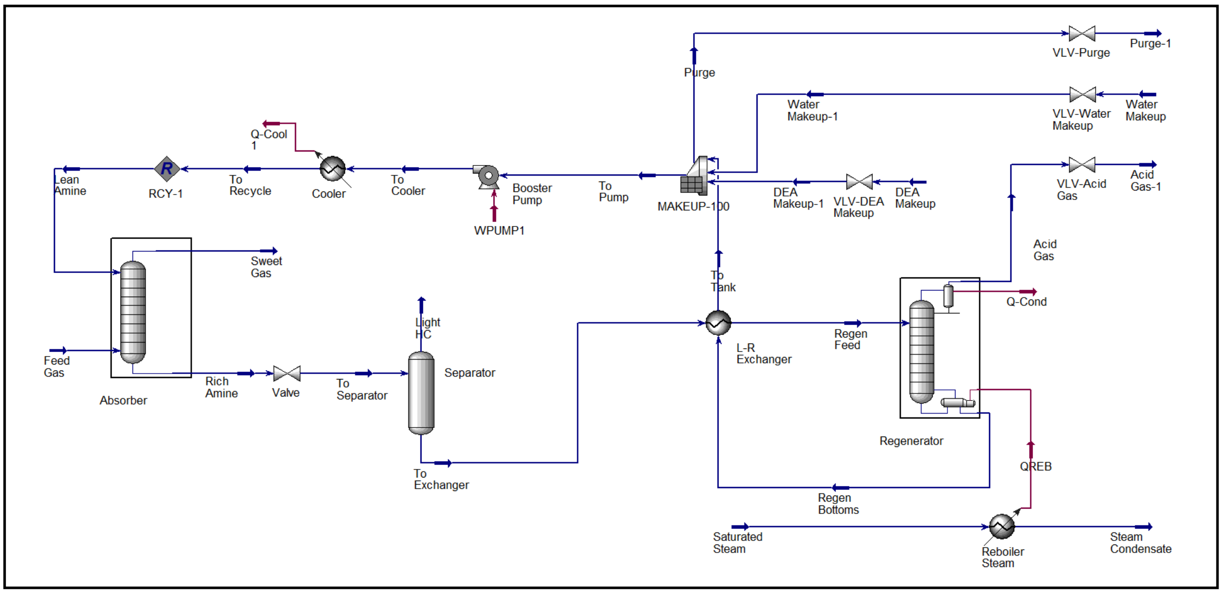

Figure 1. Complete Acid Gases Removal Cycle (sweetening Cycle) (Elfattah *et al.*, ?)

MATEIALS AND METHODS

Figure 1 describes the typical complete acid gases removal cycle (sweetening cycle) which plugged in Aspen HYSYS 8.6 library and used for natural gas NG upgrading and purification (Elfattah, ?) in which the acid gas removal steps are performed.

The absorber column was selected from Aspen HYSYS model pallet as shown in Figure 2 which has the internal construction as shown in Figure 3 and Table 3. and containing 20 stages each

After recording the NG sweetening cycle initial conditions and final results, and repeating the same steps but using the Egyptian biogas composition as mentioned in **Error! Reference source not found.** instead of NG ,The results which are recorded in Table will be obtained. The simulation cycle was run to insure absorber conversion using Aspen HYSYS for the purpose of PSA working pressure optimization.The optimum PSA working pressure needed for Egyptian biogas cleaning from acidic gaseswas found20 bars.

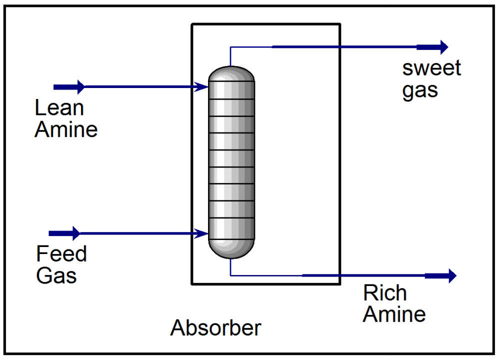

Figure 2. The Absorber column

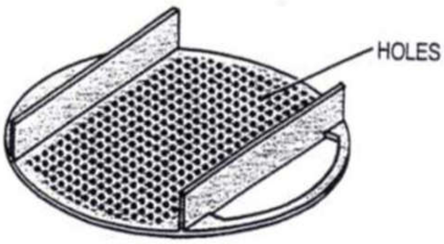

Figure 3. Absorber column tray (sieve) construction (Ludwig, 1994)

Table 1. Feed Natural Gas Composition In Mole and Volume Fraction (Control *et al*., 2000)

Component	Mole fraction	Volume fraction	Range of volume fraction
Methane	0.9500	0.9500	87.0 - 96.0
Ethane	0.0025	0.0025	1.8 - 5.1
Propane	0.0020	0.0020	0.1 - 1.5
I - Butane	0.0003	0.0003	0.01 - 0.3
N - Butane	0.0003	0.0003	0.01 - 0.3
I - Pentane	0.0001	0.0001	Trace - 0.14
N - Pentane	0.0001	0.0001	Trace - 0.04
H_2S	0.0001	0.0001	Trace - 0.06
Nitrogen	0.0016	0.0016	1.3 - 5.6
CO_2	0.0070	0.0070	0.1 - 1.0
O_2	0.0002	0.0002	0.01 - 0.1

Table 2. Final Natural Gas Composition after CO_2 and H_2S Removing (Control *et al*., 2000)

Component	Mole fraction	Volume fraction
Methane	0.9670	0.9670
Ethane	0.0092	0.0092
Propane	0.0074	0.0074
I - Butane	0.0011	0.0011
N - Butane	0.0011	0.0011
I - Pentane	0.0004	0.0004
N - Pentane	0.0007	0.0007
H_2S	0	0
N2	0.0059	0.0059
CO_2	0	0
O_2	0.0007	0.0007

Table 3. Feed Egyptian biogas composition in mole fraction Mohamed, 2015

Component	Mole fraction	Volume fraction
Methane (CH_4)	0.7464	0.7466
Carbon dioxide (CO_2)	0.2522	0.2522
Hydrogen sulfide (H_2S)	0.0004	0.0004
Water vapor (H_2O)	0.0004	0.0001
Hydrogen (H_2)	0.0001	0.0001
Nitrogen (N_2)	0.0002	0.0002
Oxygen (O_2)	0.0003	0.0003

The final composition of sweeteninggas whichobtained from Egyptian bio gas will be as mentioned inTable.

Table 4. Composition of final sweetening Egyptian Biogas

Component	Mole fraction	Volume fraction
Methane (CH_4)	0.9949	0.9949
Carbon dioxide (CO_2)	0	0
Hydrogen sulfide (H_2S)	0	0
Water vapor (H_2O)	0.0042	0.0042
Hydrogen (H_2)	0.0001	0.0001
Nitrogen (N_2)	0.0003	0.0003
Oxygen (O_2)	0.0004	0.0004

RESULTS AND DISCUSSION

Effect of NG PSA Working pressure on NG final product CO_2 Contents

It can be noted from Figure that there is a reverse proportion between PSA working pressure and CO_2% in the NG final product gas. At the point, which the absorber PSA working pressure to 36 bar, the CO_2 percentage tends to be 0.0.

There is very little effect of PSA working pressure on the CO_2 contents if the pressure is more than 36 bar. Therefore there is no need to increase the PSA working pressure to more than 36 bar to maintain the optimum initial cost for absorber construction.

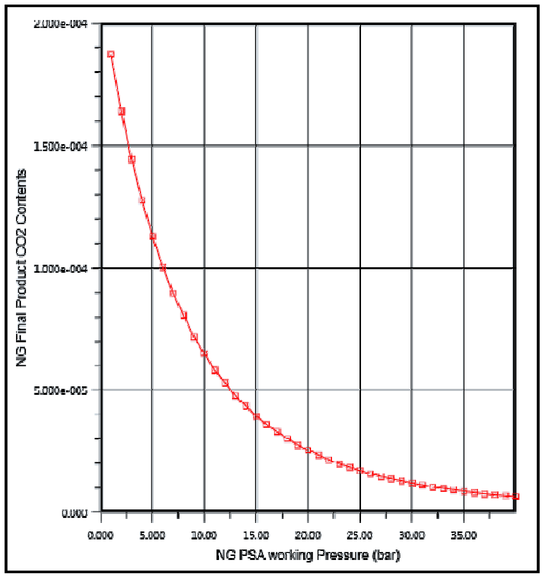

Figure 4.Effect of NG PSA Working pressure on NG final product CO_2 Contents

Effect of NG PSA Working pressure on NG final product H_2S Contents

It can be noted from Figure 2 that there is a reverse proportion between PSA working pressure and H_2S% in the NG final product gas. The H_2S contents can be vanished completely from NG final product At the pressure of 5 bar. That leads to say that the pressure value of 36 bar which needed to clean CO_2 from NG is sufficient to clean the CO_2 and H_2S simultaneously.

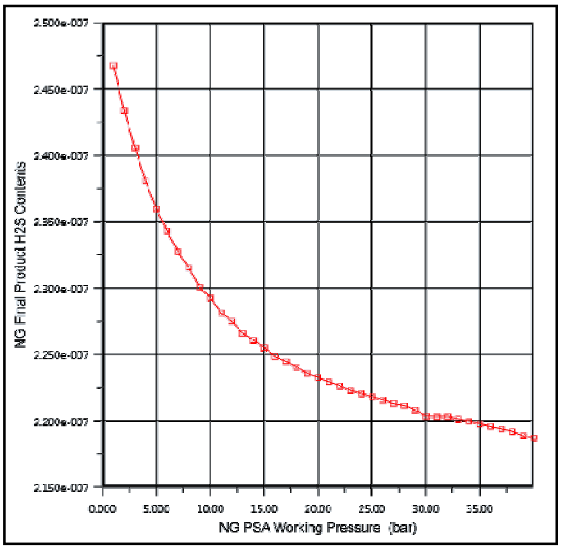

Figure 2. Effect of NG PSA Working pressure on NG final product H_2S Contents

Effect of NG PSA Working pressure on NG final product Methane purity

It can be noted from Figure 3 that there is a direct proportion between PSA working pressure and methane purity in the NG final product gas. At the point, which the absorber PSA working pressure to 36 bar, the methane purity tends to be 96 % which is the maximum value can be obtained. There is very little effect of PSA working pressure on the methane purity if the pressure is more than 36 bar. Therefore there is no need to increase the PSA working pressure to more than 36 bar to maintain the optimum initial cost for absorber construction.

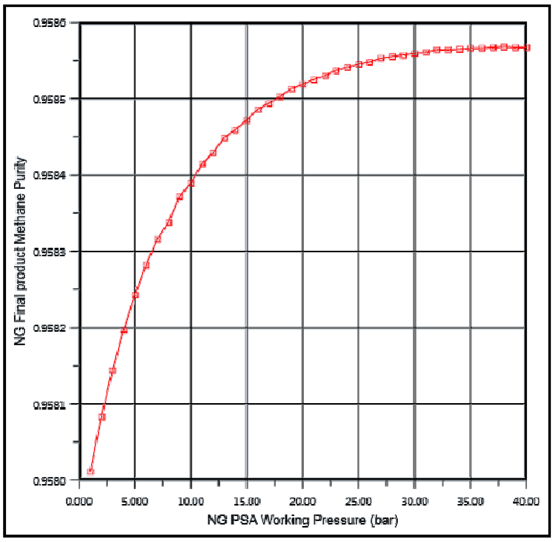

Figure 3. Effect of NG PSA Working pressure on NG final product Methane purity

Effect of Egyptian Biogas PSA Working pressure on Biogas Final product CO_2 contents

It can be noted from Figure 4 that there is a reverse proportion between PSA working pressure and CO_2% in the Egyptian biogas final product gas. At the point, which the absorber PSA working pressure to 20 bar, the CO_2 percentage tends to be 0.0. There is very little effect of PSA working pressure on the CO_2 contents if the pressure is more than 20 bar. Therefore there is no need to increase the PSA working pressure to more than 20 bar to maintain the optimum initial cost for absorber construction.

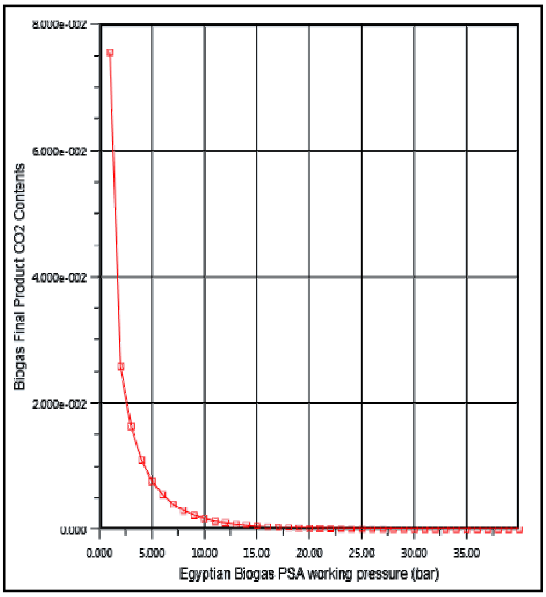

Figure 4. Effect of Egyptian Biogas PSA Working pressure Biogas final product CO_2 contents

Effect of Egyptian Biogas PSA Working pressure on Biogas Final product H_2Scontents

It can be noted from

Figure 5 that there is a reverse proportion between PSA working pressure and H_2S% in the Egyptian biogas final product. The H_2S contents can be vanished completely from Egyptian biogas final product at the pressure of 3 bar. That leads to say that the pressure value of 20 bar which needed to clean CO_2 from Egyptian biogas is sufficient to clean the CO_2 and H_2S simultaneously.

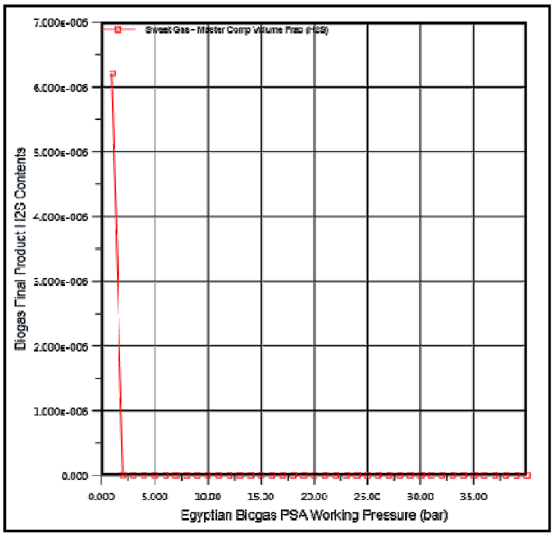

Figure 5 Effect of Egyptian Biogas PSA Working pressure Biogas final product H_2S contents

Effect of Egyptian Biogas PSA Working pressure on Biogas Final product Methane purity

It can be noted from Figure 9 that there is a direct proportion between PSA working pressure and methane purity in the NG final product gas. At the point, which the absorber PSA working pressure to 36 bar, the methane purity tends to be 96 % which is the maximum value can be obtained. There is very little effect of PSA working pressure on the methane purity if the pressure is more than 36 bar. Therefore there is no need to increase the PSA working pressure to more than 36 bar to maintain the optimum initial cost for absorber construction.

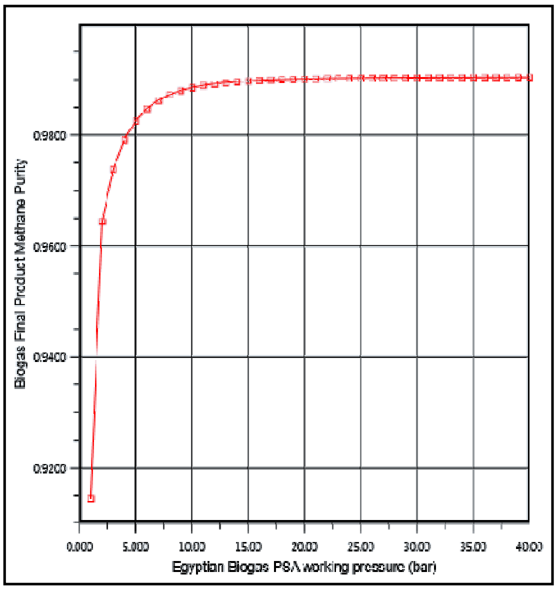

Figure 6. Effect of Egyptian Biogas PSA Working pressure Biogas final product Methane purity

From the abovecurves which describe the relation between PSA working pressure and methane purity for all NG and Egyptian biogas, it is obvious that is the optimum pressure which needed to achievehighest methane purity from NG is 36 bar while the optimum pressure which needed to achieve highest methane purity from Egyptian biogas is 20 bar. If the pressure is lower than that value the biogas treating cycle can producemethane has lower purity in range between 85% to 98 % which can be used in power generation but cannot be used in scientific research applications. This difference between the PSA working pressure needed for removing CO_2 and H_2S from natural gas composition and the PSA working pressure needed to remove the same gases from Egyptian biogas composition because the difference between partial pressure of CO_2 and H_2S in both NG and Egyptian biogas as shown in Table

According to (Amagat's law of additive volume) which deals with Partial volume (Jump up, 2005), The partial volume of a particular gas in a mixture is the volume of one component of the gas mixture

Table 5. partial pressure of CO_2 and H_2S in Both of NG and Egyptian Biogas

Natural Gas		Egyptian Biogas	
CO_2 Partial pressure	0.5 bar	CO_2 Partial pressure	0.2522 bar
H_2S Partial pressure	0.1431 bar	H_2S Partial pressure	4.05×10^{-4}

$$V_X = V_{tot} \times \frac{p_x}{p_{\ tot}}$$

-V_x….is the partial volume of an individual gas component (X) in the mixture.
-V_{tot} ……is the total volume of the gas mixture.
-p_x ……..is the partial pressure of gas (X).
-p_{tot} …….is the total pressure of the gas mixture.

At the same total volume ther is a direct propotion between Vx and the term of (P_x/P_{tot}), ther fore if the term (P_x/P_{tot}) is very small then the term Vx is very small also.In otherwords the Amagat's law of additive volumean elain clearly the increasing of pressure huger than 36 bar in natural gas case and 20bar in biogas case has very little effect (which can be neglected) in methane purity

The main reason of this Partial pressure difference because of NG has many other components other than methane, CO_2 and H_2S such as Butane and Ethane, while Egyptian biogas has mainly Methane, CO_2, H_2S and very little traces of other gases which can be neglected. That leads to possibility of obtaining pure methane has purity higher than the methanepurity whichobtained from natural gas at lower PSA working pressure. All the previous conditions of temperatures, pressures and feed gas flow rates of the removal cycle are a result of running many simulation trials in order to get the highest methane purity from Egyptian biogas.

Conclusion

Aspen HYSYS simulation program was used to determine the optimum PSA (Pressure Swing Absorber) working pressure in order to achieve the highest methane purity from Egyptian Biogas. DEA amine solvent with different 0.3 strength was used to remove the CO2 and H2S simultaneously from an amount of feed biogas with total volume flow rate about 13 m3/h. 20 stage PSA . It is found that the optimum PSA working pressure to obtain pure methane of 99 % purity from the Egyptian biogas is 20 bar.

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