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Design Simulation Analysis and Enhancement of Nigeria Biogas to Connect That of Natural Gas Netting Capacity and Model

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Abstract: In Nigeria, biogas is a viable renewable energy source. This study's goal was to filter raw biogas of acidic gases CO_2 and H_2S before connecting it to the natural gas netting standard. The biogas acidic gas treatment plant was designed and numerically modelled using Aspen HYSYS 8.6. The simulation's primary goal is to find the optimal operating pressure that can make Nigerian biogas as pure as natural gas. The biogas treatment was carried out in a 20 stage PSA with a tray diameter of 1.7 m and a CO_2 content of 0.25, H_2S content of 0.0004, temperature of 30 C, pressure of 1.1 bar, flow rate of 13 m^3/h, and DEA concentration of 0.3. A PSA operating pressure of 5 bars is necessary to achieve 95% pure methane biogas.
Keywords: Nigerian biogas; Methane enhancing; Aspen HYSYS; Biogas purification

I. INTRODUCTION

In reality, transforming agricultural, industrial, and sewage waste to biogas [1] may help Nigeria solve its energy crisis. The CO2 and H2S in sour Nigerian biogas must be eliminated before pumping it into the natural gas netting to fulfill the standards of these nettings [2–5]. Biogas sweetening removes CO2 and H2S from treated biogas to protect pipelines and engines from corrosion and increase calorific value [6–9]. Most biogas research in Nigeria focuses on producing biogas from local resources and utilizing it to generate thermal energy [10–14], but few researchers focus on biogas capacity enrichment. Numerical simulation aids in the design of sweetening cycles and size of equipment, particularly the absorber [15–17]. The Aspen HYSYS 8.6 simulation software is one of the most accurate and critical programs used in gas treatment process design [18–21].

Using the Aspen HYSYS 8.6 modeling tool, this paper determined the optimal PSA operating pressure to ensure methane purity in Nigerian biogas.

The investigation of employing simulation programs in the purification process of acid gases has been done [22–26]. No precise technique was provided to establish the optimal PSA operating pressure to extract pure methane from biogas. Thus, the current research intended to improve Nigerian biogas netting capacity. 2.

Fig. 1 depicts a typical full acid gas removal cycle (sweetening cycle) used for natural gas upgrading and purification [27].

The absorber column was chosen from the Aspen HYSYS model pallet (Fig. 2), which has an internal architecture of 20 stages, each level consisting of one tray. The DEA-containing acid gas fluid package is chosen [29].

The feed Nigerian biogas enters the absorber at 30°C, 1.1 bar pressure, and a flow rate of 13 m3/h from the absorber column's bottom. The lean amine (DEA) enters at 30 C, 20 bars, and 5.45 104 m3/h. DEA can concurrently absorb CO2 and H2S from Nigerian biogas. The sweet feed gas escapes at the top of the column, while the rich amine exits at the bottom of the absorber. The rich amine then travels through the expansion valve to reach 43 C and 1.4 bars before entering the separator. Rich amine leaves the separator under the same circumstances to enter an L/R heat exchanger. Lean amine is heated using the L/R heat exchanger. The hot, rich amine departs the exchanger and enters a regeneration column to absorb CO2 from it to lean it for reuse, while the lean amine enters a make-up tank at 74 C and 1.04 bar (0.027 bar above atmospheric pressure) and exits it at 74 C and 1.04 bar (0.027 bar above atmospheric pressure). Then it's pushed to 74.5 C and 1.1 bars, then cooled to 30 C using a continuous pressure technique. 1.1 bar lean amine recycler exit [30].

II. RESULTS AND DISCUSSION

The simulation process was done to optimize PSA working pressure using Aspen HYSYS. The removal cycle's temperature, pressure, and inlet gas flow rates were all calculated numerically to maximize methane purification from Nigerian biogas.

A. Impact of Nigerian PSA working pressure on CO_2 concentration of biogas

As shown in Fig. 3, the relationship between PSA working pressure and CO_2 percent in Nigerian biogas is inverse. The CO_2 percentage is 0.0084 when the absorber PSA operating pressure is 5 bar. If the PSA operating pressure is beyond 5 bar, there is negligible (non-economic) influence on CO_2 levels. To keep the lowest starting cost for absorber construction, the PSA operating pressure does not need to exceed 5 bar.

B. Impact of Nigerian PSA working pressure on H_2S concentration of biogas

In Fig. 4, the relationship between PSA working pressure and H_2S percent in Nigerian biogas is reversed. At 1.1 bar pressure, H_2S may be entirely eliminated from Nigerian biogas. Thus, the 5 bar pressure required to clear CO_2 from Nigerian biogas cleans both CO_2 and H_2S concurrently.

C. PSA Working Pressure on Nigerian biogas end Product Pure Methane

Fig. 5 demonstrates the impact of PSA operating pressure on final biogas methane purity. The methane purity tends to be 95% at the absorber PSA operating pressure of 5 bar, which is sought by most NG nettings. More than 5 bar PSA operating pressure has a greater influence on methane purity.

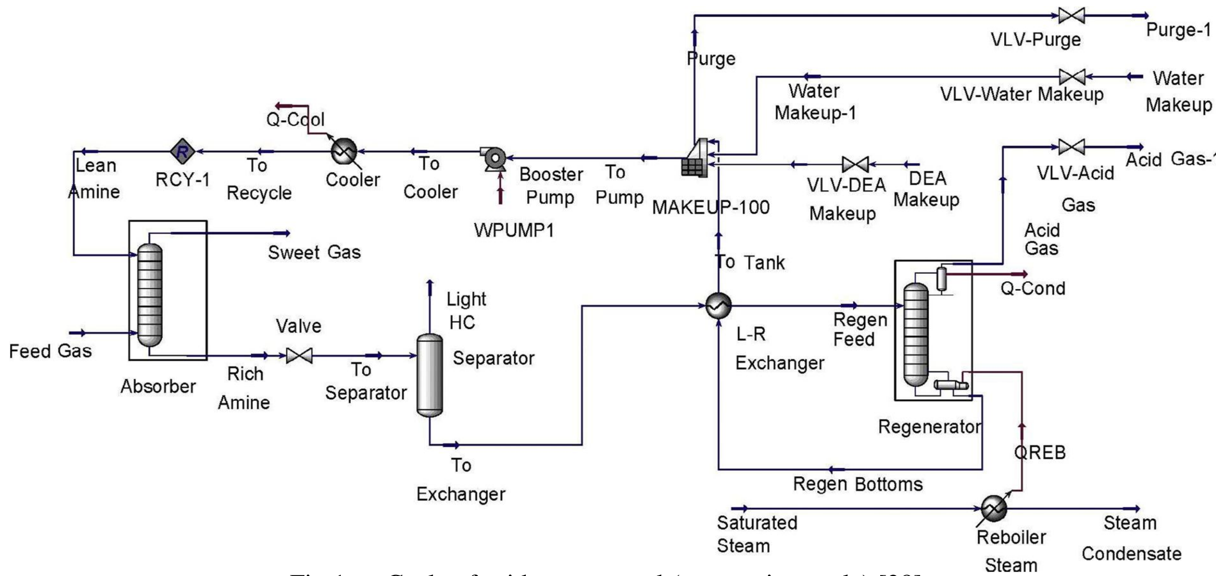

Fig 1. Cycle of acid gas removal (sweetening cycle) [28].

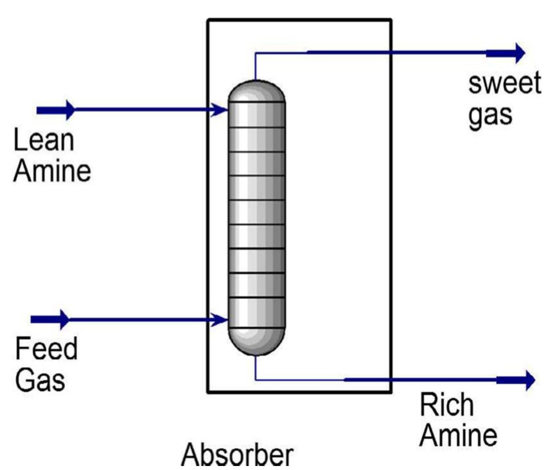

Fig 2. absorbing column [29].

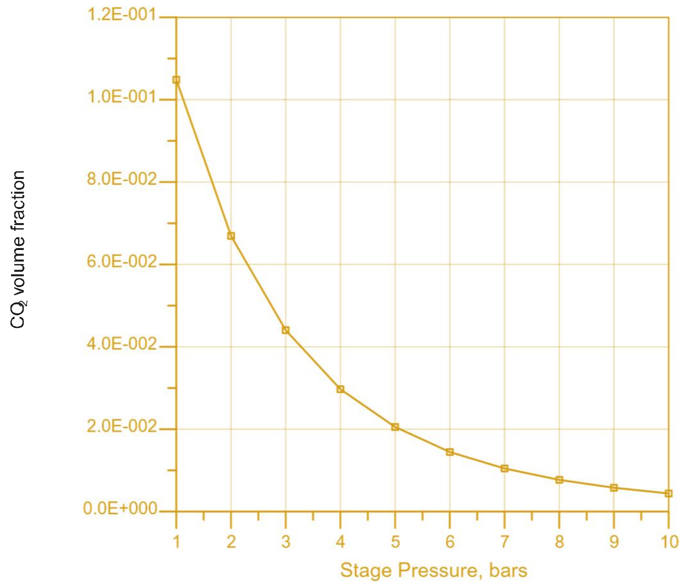

Fig 3. Impact of Nigerian PSA working pressure on CO_2 concentration of biogas.

Table 1. Feed Nigerian biogas mole fraction [30].

Component	Mole fraction	Volume fraction
Methane (CH_4)	0.7466	0.7468
Carbon dioxide (CO_2)	0.2523	0.2523
Hydrogen sulfide (H_2S)	0.0005	0.0005
Water vapor (H_2O)	0.0005	0.0002
Hydrogen (H_2)	0.0002	0.0002
Nitrogen (N_2)	0.0003	0.0003
Oxygen (O_2)	0.0003	0.0003

It is clear from the preceding graphs that the optimal PSA operating pressure for achieving 95% methane purity from Nigerian biogas is 5 bar. If the pressure is too low, the biogas treatment cycle might yield less pure methane.

The partial volume of a given gas in a combination is the volume of one element of the combination, according to Amagat's law of cumulative volume [31]. Tables 2 shows the partial pressures of acidic gases.

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

The term (P_x/P_{tot}) is directly proportional to V_x, therefore if (P_x/P_{tot}) is tiny, then V_x is little as well. This means that increasing total pressure may enhance methane purity according to Amagat's law of additive volume..

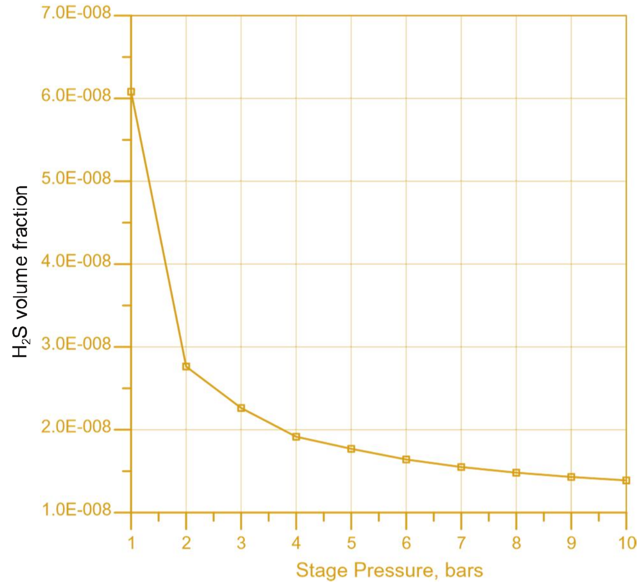

Fig 4. Impact of Nigerian PSA working pressure on H_2S concentration of biogas.

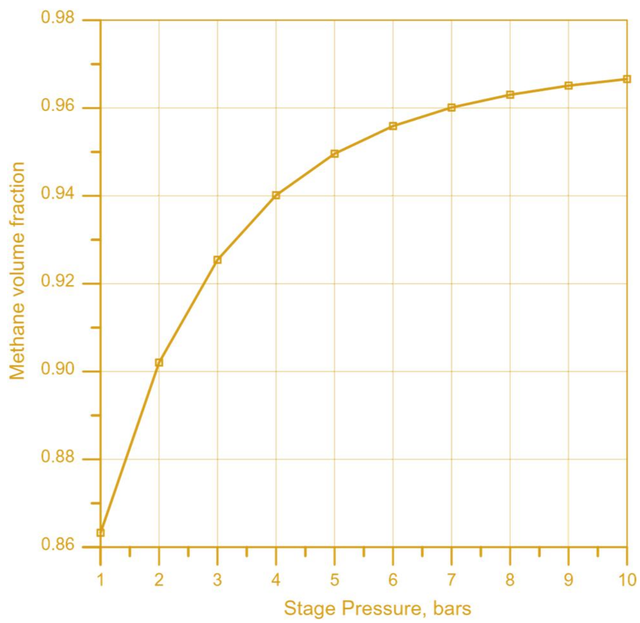

Fig 5. PSA working pressure on Nigerian biogas end product Pure Methane.

Table 2. CO_2 and H_2S partial pressure in Nigerian biogas.

Acidic component	Partial pressure
CO_2 partial pressure	0.2774 bar
H_2S partial pressure	$4.455\ 10^4$ bar

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Table 3. Sweetening Nigerian biogas composition.

Component	Mole fraction	Volume fraction
Methane (CH_4)	0.9557	0.9785
Carbon dioxide (CO_2)	0.0085	0.0087
Hydrogen sulfide (H_2S)	0	0
Water vapor (H_2O)	0.0353	0.0122
Hydrogen (H_2)	0.0002	0.0002
Nitrogen (N_2)	0.0003	0.0003
Oxygen (O_2)	0.0004	0.0004

The ideal PSA operating pressure for cleaning acidic gases in Nigerian biogas is 5 bars. Table 3 shows the final sweetening gas composition derived from Nigerian biogas.

III. CONCLUSION

The optimal PSA operating pressure was determined by numerical simulation utilizing Aspen HYSYS simulation software. CO_2 0.25, H_2S 0.0004; 30 C; 1.1 bar pressure; and 13 m3/h flow rate were fed to the PSA. Simultaneous CO_2 and H_2S removal using DEA amine solvents. The simulation revealed that a DEA concentration of 0.3 and 20 steps PSA with a tray diameter of 1.7 m were optimal for biogas treatment. The best PSA operating pressure for obtaining 95% pure methane from Nigerian biogas is discovered to be 5 bar.

A. Nomenclature

Cond	condenser
DEA	diethanolamine
L/R	Lean/Reach
NG	natural gas
PSA	Pressure Swing Absorber total
ptot	pressure of the gas mixture
p_x	partial pressure of an individual gas component (X) in the mixture
RCY	recycler
REB	reboiler
VLV	valve
V_{tot}	total volume of the gas mixture
V_x	partial volume of an individual gas component (X) in the mixture

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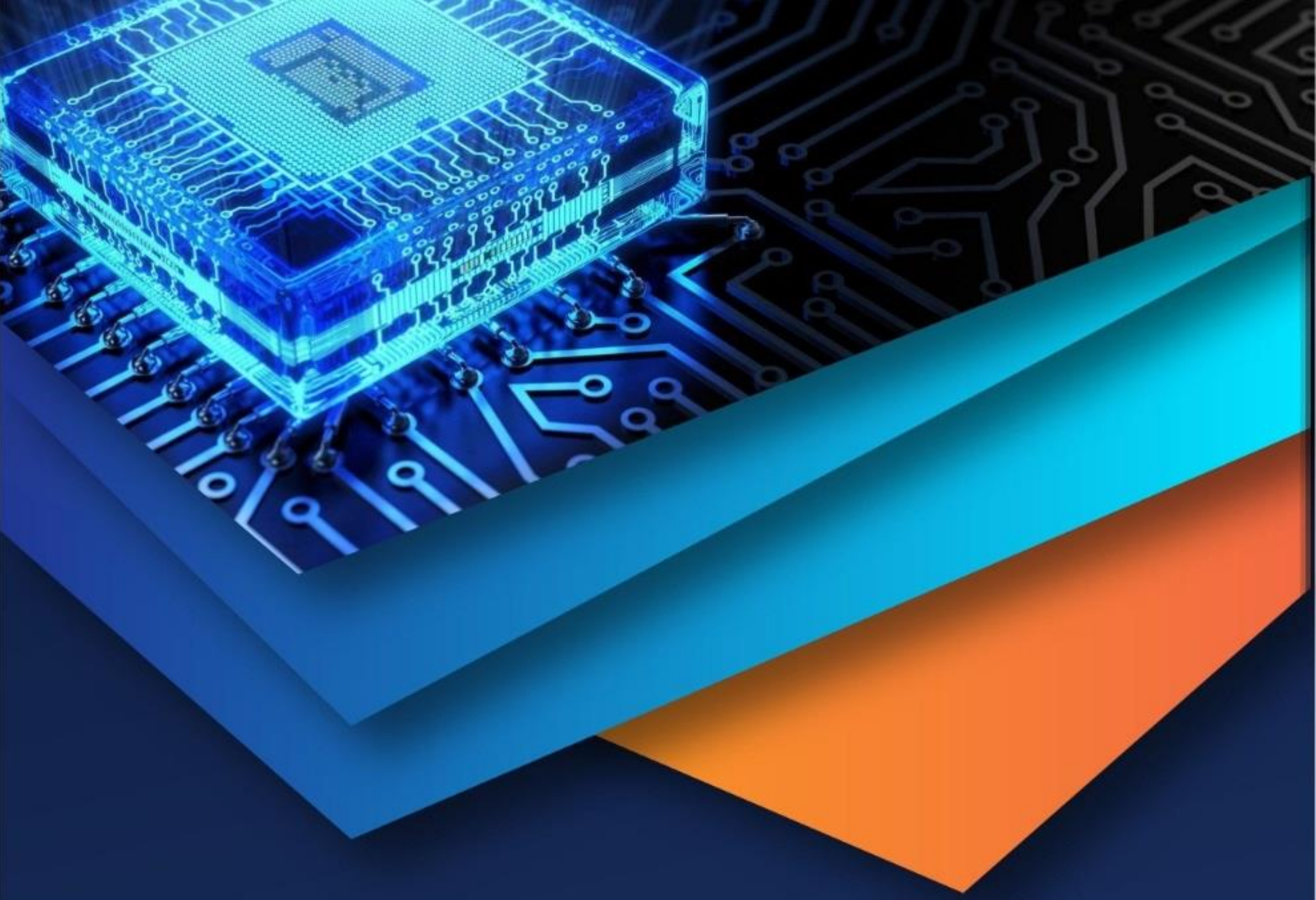

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