SUSTAINABILITY CONSIDERATIONS IN MODELING AND IMPROVEMENT OF ACID GAS REMOVAL UNIT IN GAS PROCESSING PLANT

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ABSTRACT

Natural gas from wells contains significant amount of Hydrogen Sulfide and Carbon Dioxide which known as acid gas. Acid gas should be removed as the sulfur compound in hydrogen sulfide is extremely harmful and corrosive. The main process in Acid Gas Removal Unit (AGRU) is absorption, where the selection of the solvent is based on its capability to absorb or removing acid gas. Benfield Process is a chemical absorbing process by using Benfield solvent that consist of 30% Potassium Carbonate (K_2CO_3), water, DEA as activator and corrosion inhibitor. Solvent foaming is a contributor factor to the problem in the Benfield process due to degradation of DEA. The degradation will reduce the tendency of solvent absorption and also reduce the efficiency of absorption column. This research is carried out to simplify the AGRU process by reducing the number of equipment. A new simplified process has successfully constructed by replacing flash drum with a cooler to liquefied the solvent. Simulation using Aspen Hysys is then performed to study the modified process by using Peng-Robinson as property package. From the simulation on simplified PFD , the capital cost of the process is reduced due to the reduction of equipment used in the process. Moreover, the objective of this research is to increase the efficiency of absorption process using Piperazine to replace DEA as activator in the Benfield solvent. As the conclusion, modified PFD with Piperazine in Benfield Solvent found can reduce the energy consumption, capital cost and give high efficiency absorption process.

ABSTRAK

Gas asli daripada telaga mengandungi jumlah ketara Hidrogen Sulfida dan Karbon Dioksida, yang juga dikenali sebagai asid gas. Acid Gas perlu dibuang kerana sebatian sulphur dalam hidrogen sulfida yang amat menghakis dan berbahaya. Proses utama dala Unit Pemindahan Gas Asid (AGRU) adalah penyerapan, Di mana pemilihan pelarut adalah berdasarkan keupayaan khas pelarut itu menyerap atau mengeluarkan asid gas. Proses Benfield adalah satu proses kimia dengan menggunakan pelarut Benfield untuk menyerap, pelarut itu terdiri daripada 30% Kalium Karbonat (K2CO3), air, dan DEA sebagai perencat kakisan dan penggerak. Pelarut berbuih adalah factor penyumbang kepada masalah dalam proses Benfield yang disebabkan degradasi DEA. Kemerosotan akan mengurangkan kecenderungan penyerapan pelarut dan juga mengurangkan kecekapan ruang penyerapan. Kajian ini dijalankan untuk memudahkan proses. dengan mengurangkan bilangan peralatan dalam proses AGRU. Satu proses baru dipermudahkan telah berjaya dibina untuk mengganti Flash Column dengan penyejuk untuk cecair pelarut. Simulasi menggunakan Aspen Hysys kemudiannya dijalankan kajian proses dengan menggunakan Peng Robinson yang diubahsuai. Dari simulasi adalah PFD yang dipermudah, kos modal dalam proses ini berkurangan. disebabkan pengurangan peralatan yang digunakan dalam proses. Objektif kajian ini adalah untuk meningkatkan kecekapan proses penyerapan menggunakan piperazine menggantikan DEA sebagai penggerak dalam pelarut Benfield. Sebagai kesimpulan itu, PFD yang diubah suai dengan Piperazine Benfield sebahagai pelarut ditemui boleh mengurangkan penggunaan tenaga, kos modal dan memberi kecekapan yang tinggi dalam proses penyerapan acid gas.

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LIST OF ABBREVIATIONS

H_2S	Hydrogen Sulfide
CO_2	Carbon Dioxide
K_2CO_3	Potassium Carbonate
LNG	Liquefied Natural Gas
CNG	Compress Natural Gas
GTL	Gas To Liquid
GTS	Gas To Solid
GTP	Gas To Power
GTC	Gas To Commodity
MEA	Monoethanolamine
DEA	Diethanolamine
TEA	Triethanolamine
DGA	Diglycolamine
DIPA	Diisopropanolamne
MDEA	Methyl- Diethanolamine
MVR	Mechanical vapor recompression

CHAPTER 1

INTRODUCTION

1.1 NATURAL GAS

Natural gas is a combustible mixture of hydrocarbon gases consisting primarily of methane. Natural gas also consist small range of ethane, propane, butane, pentane, and hexane. Before natural gas can be used as a fuel it is processed in order to eliminate the sulphur, carbon dioxide, water vapour, helium, and nitrogen.

1.1.1 History of Natural Gas

Natural gas generally considered as fossil fuel which has been formed from the dead sea animals and plants 400 million years ago. The layer of the dead animals and plants turned into sedimentary rock. Under the sea pressure and heat from the earth, the organic mixture reacts and changed into petroleum and natural gas. The natural gas is trapped in the porous rock deep underground.

As conclude in National Energy Education Development (NEED), Natural gas is believed to have been first discovered in China about 2500 years ago. In 1821, the first natural gas well was drilled about 27feet deep and transported through wooden and lead pipe. In 1920, the modern seamless steel pipe was installed. With the modern technology, natural gas now can be transported in the liquid form. The natural gas was cooled in the liquefaction process known as Liquefied Natural Gas (LNG). Compare to natural gas in gas form, LNG is easier to store and transport because the volume of natural gas reduced 600 times.

1.1.2 World Natural Gas Demand

The worldwide energy demand has rapidly increased during the recent years and the available resources are becoming insufficient. Referring to the U.S. Energy Information Administration (EIA), natural gas consumption could increase from 104 trillion cubic feet in 2005 to 158 trillion cubic feet in 2030.As show in Figure 1.1.2, electric power sector and the industrial sector are the major demand of natural gas with 24% and 32% respectively. Natural gas use in residential is about 22% and commercial with 14% followed by 8% in others sector. According to EIA, electric power sector consumption expected will increase about 2.8% and 1.5% for industrial sector by year. With the advantage clean burning process of natural gas, the demand of natural gas in transportation also expected to be increased.

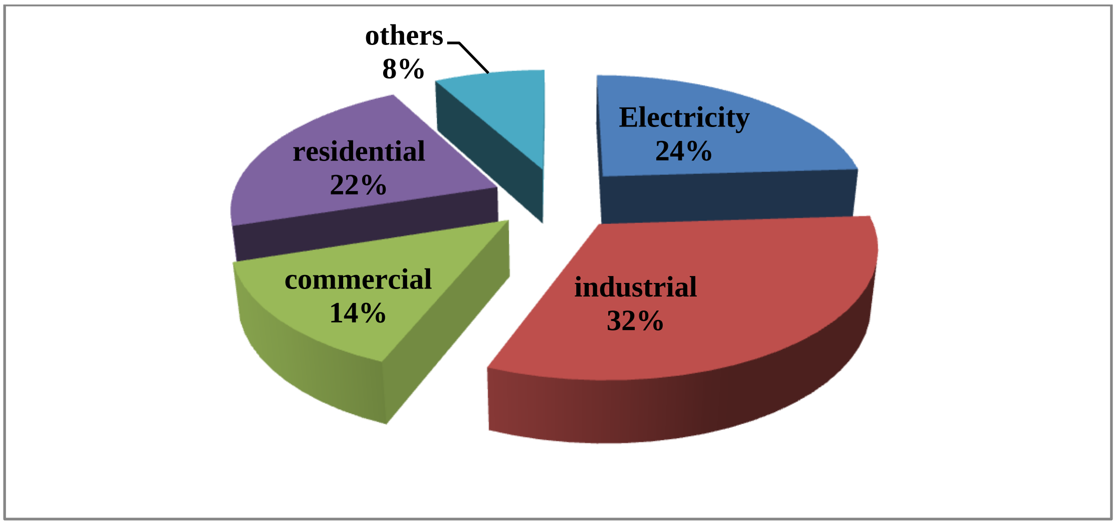

Figure 1.1.2: Natural Gas Used by Sector

Source: U.S. Energy Information Administration (EIA)

1.2 ACID GASES

Engineering standard for process design of gas treating unit defined acid gas present in most natural gas streams mainly hydrogen sulfide and carbon dioxide. Natural gas from the wells contains significant amounts of hydrogen sulfide and carbon dioxide an also known as sour gas (Speight, 2007). Because of the extremely corrosive and toxicity of sulfur compound, the acid gas should be removed and the process removal also known as sweetening and treating process.

1.3 GAS PROCESSING PLANT (GPP)

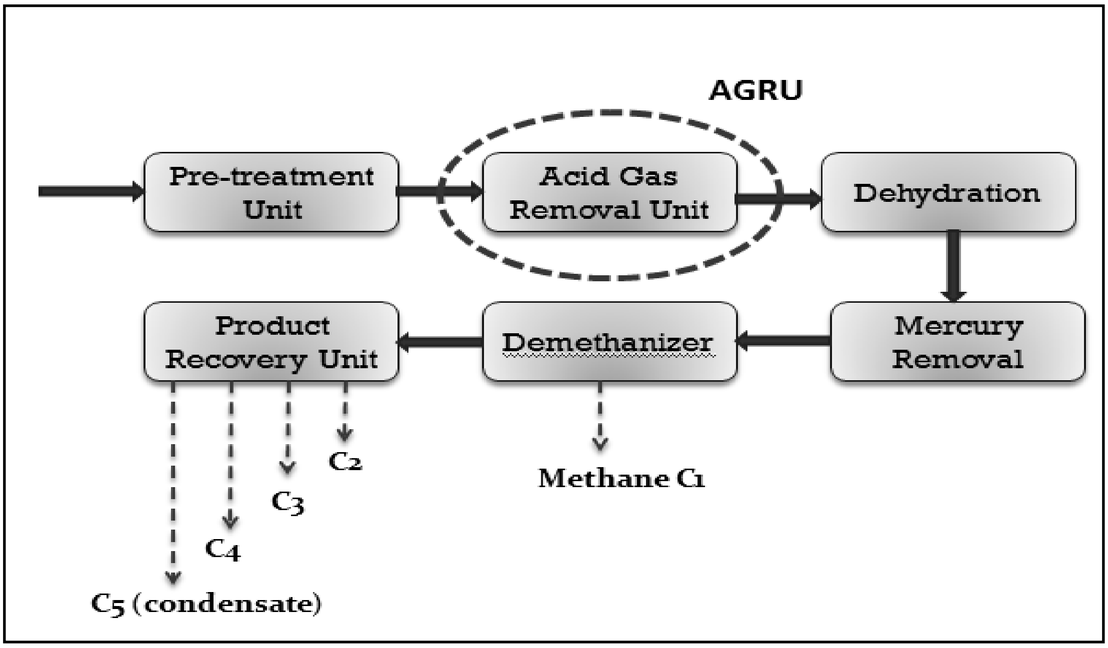

Figure 1.3: Process flow of gas processing plant

Figure 1.3 shows the several processes involved in gas processing plant. The processes in the gas processing plant are acid gas removal, dehydration, mercury removal and product recovery unit which are hydrocarbons separation based on their group. Raw gas from the offshore is transported by pipeline to the separation process to separate between the oil, gas and water at pre-treatment unit. In the pre-treatment unit, contaminant is removed and the clean gas is transferred to the AGRU.

In the AGRU, acid gas is removed and the treated gas will proceed with the dehydration process. Dehydration is the removal of the water. It is necessary to ensure smooth operation of gas transmission lines. Dehydration prevents the formation of gas hydrates and reduces corrosion. The next step is mercury removal by using adsorption processes before the gas fed into distillation in a demethanizer fractionating column. After methane was separated, the gas is continuously processed in the product recovery unit which consist of three distillation tower is series called a deethanizer, a depropanizer and a debutanizer. The product from the gas processing plant enters a compressor station where it is pressurized for transmission (Chakma, 1997). Methane is usually transported by pipeline as commercial gases. Other group of hydrocarbon (ethane, propane, butane) will be distributed to industry, consumers and domestic use.

1.4 ACID GAS REMOVAL UNIT (AGRU)

As show in figure 1.3, acid gas removal unit is the process after pre-treatment unit. In the pre-treatment unit, slugs, waters and others contaminants is remove before the gas transferred to the acid gas removal unit. Contaminants in the acid gas will disturb the process in acid gas removal. In the acid gas removal unit, the acid gas will be remove to meet the specification. Acid gas removal unit is the earlier process in the gas processing plant can avoided corrosion and hydration problem when the gases undergo others process. In the acid gas removal unit, there many process to remove acid gas. There two general processes in removal acid gases, by absorption and adsorption (McCain *et al*, 1997).

1.5 WHY NEED TO REMOVE ACID GAS

Acid gases, mainly hydrogen sulphide and carbon dioxide need to be removed at specific level due to transportation and safety requirement.

1.5.1 Transportation Requirement

Natural gas main transportation is by using pipeline. Others than that, it is also can be transported by using liquefied Natural Gas (LNG), compress natural gas (CNG), gas to solid (GTL), gas to solid (GTS), gas to power (GTP), and gas to commodity (GTC) (Mokhatab, S. et al., 2006).

Commonly steel is a material using as a medium transportation of natural gas. One of common problems in the transportation of natural gas by pipeline is corrosion. Corrosion is defined as the deterioration of material, usually metal, due to some reaction. The corrosion can cause by water, impurities, or acid gases in the gas. H_2S is extremely corrosive gas that found in the natural gas. As the reason, this gas should be removed in safe composition in the natural gas to avoid the corrosion problem (Bhide, *et. al*, 1997). Also stated in his book as an internal corrosion protection, chemical corrosion inhibitor can be used but it is most practically used in small scale transportation.

Removal acid gases also is a prevention of hydration in pipeline. A gas hydrate is an ice-like crystalline solid called clathrate (Speight, 2007). The exact temperature and pressure at which hydrate form depends on the composition of the gas and the water. Besides that, with present of acid gas, it will increase the tendency to form hydrate. As the pressure increase, the hydrate formation temperature also increases. Lowering the temperature of gases also will increase the tendency of form hydration. Foaming of hydration in pipeline will block the flow of natural gas in the pipeline.

To overcome the hydrate problem in pipeline, Baillie-Wichert chart is used for estimating hydrate formation condition. This chart shows the effect of presence of hydrogen sulphide (up to 50mol %) and propane up to10%. Figure 1.5.1 below shows the Baillie-Wichert chart. Using the chart, the hydrate formation can be predicted by its acid gas composition at given pressure. Carrol, (2009) states in his book the calculation method by using this chart is used to calculate hydrate formation temperature. From the calculation using this chart, increasing the composition of H_2S will lower the boiling point of hydration formed. It is important to remove the H_2S to the specific composition to avoid hydrate in the pipeline.

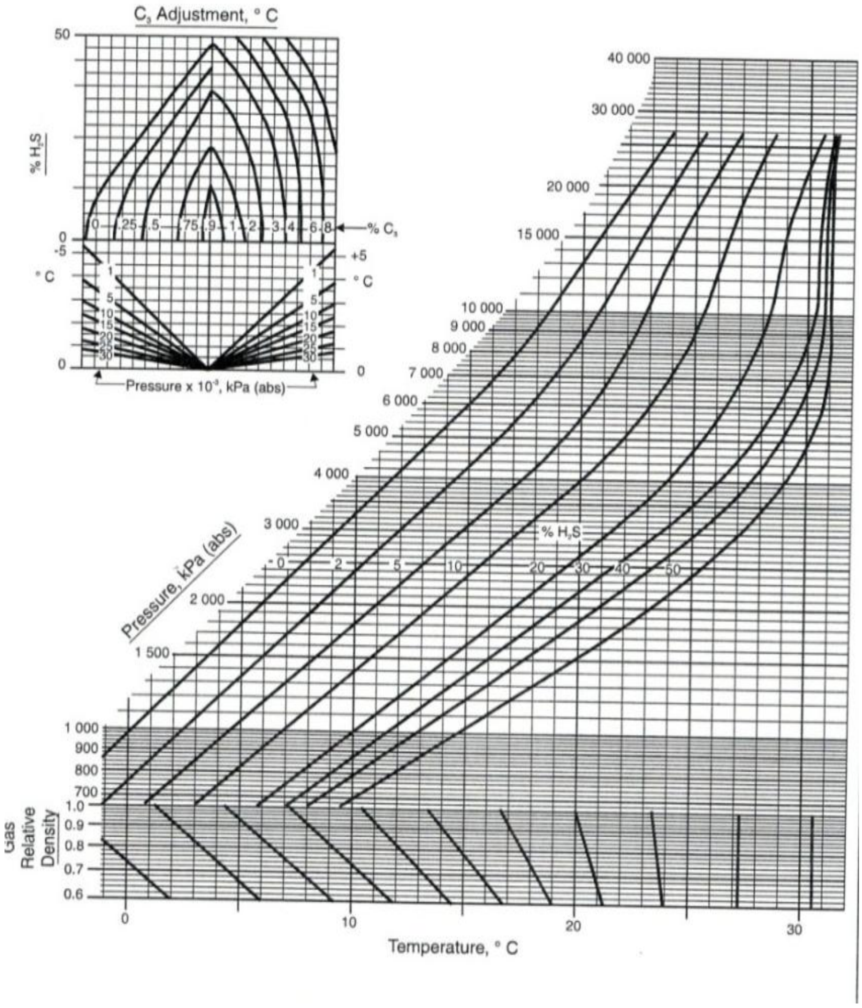

Figure 1.5.1: Hydrate Chart for Gases Containing H_2S

Source: (Carrol, 2009)

1.5.2 Safety Requirement

H_2S is a very toxic gas and affects to human at low level of exposure. The H_2S should be remove due to safety aspect to the persons in their working area that involve in H_2S and also as a safety requirement to the consumers. Table 1.5.2 below is the level exposure of H_2S and its effect to human body

Table 1.5.2: Level exposure of H_2S and its affect to the human.

Level exposure	Effects
0.03 ppm	Can smell and only safe for not exceed than 8 hours exposure
4 ppm	Cause eye irritation.
10 ppm	Maximum exposure 10 minutes and violently with dental mercury amalgam fillings.
20 ppm	Exposure for exceed than 1 minute causes severe injury to eye nerves.
100 ppm	Respiratory paralysis in 30 to 45 minutes and will become unconscious quickly.
200 ppm	Serious eye injury and permanent damage to eye nerves and throat.
300 ppm	Loses sense of reasoning and balance. Respiratory paralysis in 30 to 45 minutes
500 ppm	Breathing problems are observed and death can be expected in minutes.
700 ppm	Permanent brain damage may result unless rescued promptly and for more than 700ppm death will occurs immediately

1.6 PROCESS IN ACID GAS REMOVAL

Acid gas can be treated in many processes, Mokhatab S. *et al.*, (2006). There are several factor must be considered in selected the process in removal acid gas. The factors are the types and concentration of contaminants in the feed gas, degree of contaminant desired, the specification of acid gas, temperature, pressure, volume and the composition of the feed gas.

Generally the process of removal acid gas used is by absorption and adsorption. Absorption process is divided in two classes, absorption based on chemical solvent and physical solvent. This process is depends on physical solubility and chemical reaction in the liquid phase. Most common absorbent used in the removal acid gases process is water, aqueous amine, caustic, and sodium carbonate. However, the solvent must be selected by considering several factors to get the best result in the process.

1.6.1 Amine Process

Amine process is a one of the absorption based on chemical solvent. Depending on the composition of the feed gas, different group of amine need to select to match the criteria of best solvent. James G. Speight (2007), was highlighted in his book six types of amine that usually used as solvent in the amine process. Table 1.6.1 are listing the group of amine and its properties.

Table 1.6.1: Properties of Amine Solvent

Name	**Derive Name**	**Mole. weight**	**Specific Gravity**	**Melting Point** ℃	**Boiling Point** ℃	**Flash Point** ℃	**Relative Capacity %**
Monoethanolamine	MEA	61.08	1.01	10	170	85	100
Diethanolamine	DEA	105.14	1.097	27	217	169	58
Triethanolamine	TEA	148.19	1.124	18	335, d	185	41
Diglycolamine	DGA	105.14	1.057	-11	223	127	58
Diisopropanolamne	DIPA	133.19	0.99	42	248	127	46
Methyl-Diethanolamine	MDEA	119.17	1.03	-21	247	127	51

Source: James G. Speight (2007)

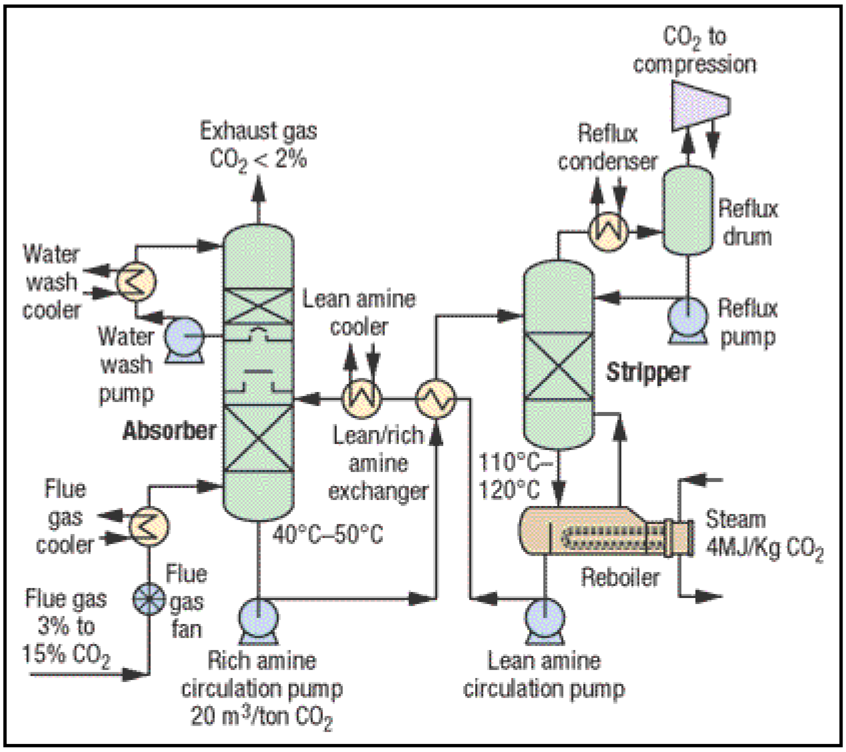

Figure 1.6.1: Process Flow Diagram for Amine Process

Source: W.I Echt. (1997)

Figure 1.6.1 shows the general amine process flow diagram. The feed gas will enter at the bottom of absorber column and flows up and contacted countercurrent with the amine solution. Treated gas which also known as sweet gas will exit at the top of absorber column. At the bottom of absorber column, rich amine solution will exit and go through the flash tank. In the flash tank, the hydrocarbon that may have dissolved or condensed will be recovered. The process is continued with rich amine will regenerate at the regenerator column. The regeneration process operates at low pressure and high temperature. Reboiler is added at the bottom of column in order to maintain the temperature inside the regenerator. Acid gas will separate from the amine and the acid gas leave at the top column and go to the condenser. Lean amine from the bottom regenerator will pumped through the lean-rich amine heat exchanger and cooler before enters the absorber column. The process is close loop process where the solvent is recycled (UOP, 2007).

1.6.2 Adsorption Process

Adsorption is a physical-chemical phenomenon where the gas is concentrated on the surface of the solvent to remove the impurities Then, the acid gas will be desorbed at the desorption column. Adsorbent used usually granular solids with large surface area per unit mass. Increasing the surface area of solid will increase the quantity of the compound adsorb. Figure 1.6.2 shown the mechanism of adsorption process in removal CO_2 from the natural gas. This process is suitable for high pressure gas, low concentration of heavy hydrocarbon gas, high composition of acid gas and desired hydrogen sulphide and carbon dioxide selectivity.

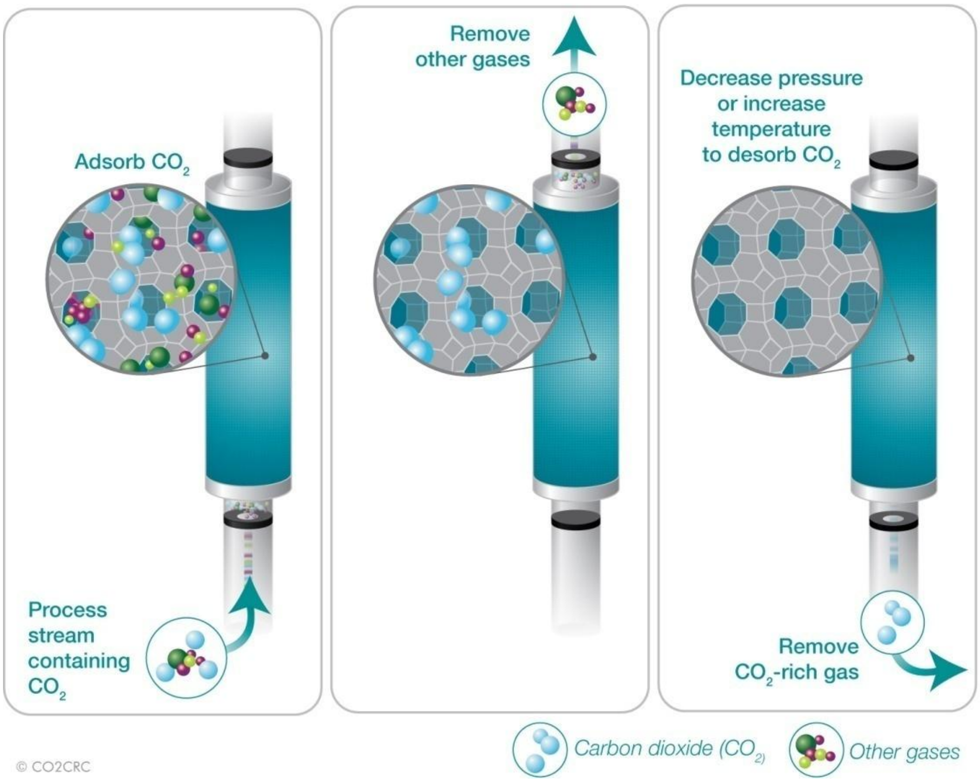

Figure 1.6.2: Mechanism of adsorption process

1.6.3 Gas Permeation

Gas permeation is a process already applied in industry to remove the acid gas. The advantages of this process are low methane loss in permeate, and cost effective due to its single stage operation (Rojey et al., 1997). In this process, the acid gas separated by using membrane which is usually polymeric or organic membranes. For a gas to permeate through a membrane surface, the gas must first dissolve in the high pressure side of membrane, diffuse across the membrane wall and evaporate from the low pressure side (Ahmad *et al*, 2010). Figure 1.6.3 is the mechanism of the gas permeation process.

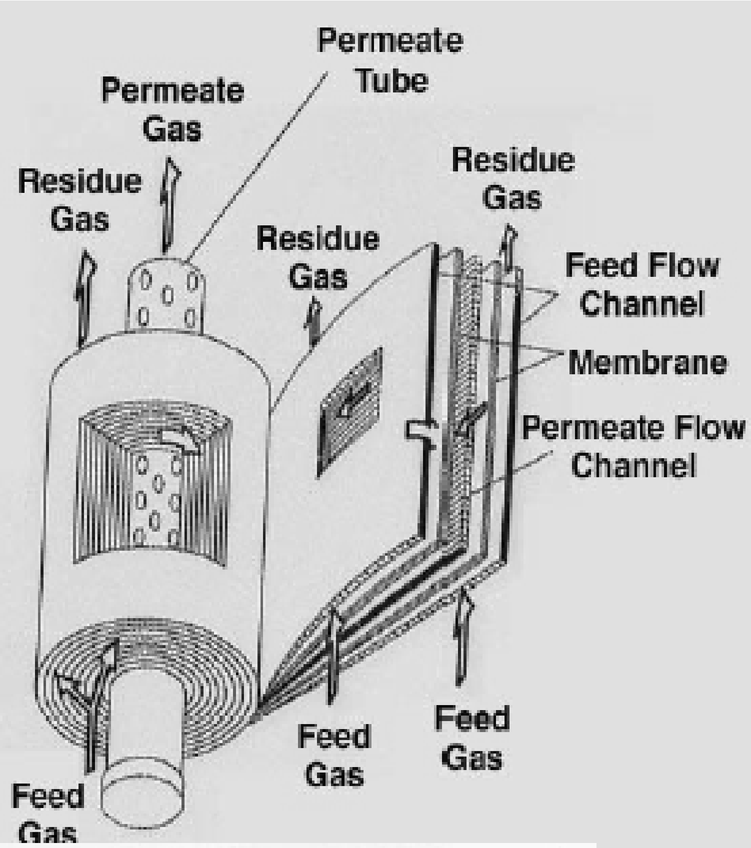

Figure 1.6.3: Gas Permeation Mechanism

Source: Ahmad *et al*, (2010)

1.7 PROBLEM STATEMENTS

Acid gas removal in this research involves stripper column as main equipment. Besides that, in order to complete this process others equipment such as, reboiler, flash column, cooler, and pump is added. However, this process is highly energy consumption to remove the acid gases. The operating cost of this process also increases in order to supply the energy. For Benfield process, foaming of solvent is a common problem in the absorption process. Foaming of solvent will reduce the tendency of solvent to absorb acid gases. Thus, it will decrease the efficiency of the absorption process overall.

1.8 RESEARCH OBJECTIVES

This research contains two main objectives. The first objective is to minimize the energy consumption in Acid Gas Removal Unit (AGRU) in gas processing plant by reducing number of equipment that consume energy in the process. The second objective is to increase the efficiency of the absorption process in acid gas removal unit by solving the foaming problem in the absorber column.

1.9 SCOPE OF RESEARCH

This research will be focusing on simulation using Aspen Hysys, which is will be done based on the industrial Acid Gas Removal process flow sheet that use Benfield Solution. Comparisons between AGRU which used Benfield solution with DEA as activator and Benfield with Piperazine activator are being compared in terms of absorption column removal efficiency. The structural modification on AGRU design will be compared with the existing process in terms of power consumption, process duty and capital cost.

1.10 RATIONAL AND SIGNIFICANCE OF RESEARCH

In this research, the new activator will increasing the efficiency of absorption process with no foaming problem and thus increases the efficiency of absorption process. Since typical AGRU with DEA as activator has operational problems such as solvent losses and degradation, foaming and corrosion, the selection of solvent with suitable activator is therefore very important. Reducing the number of equipments is a contribution factor to reduce the energy consumption and capital investment in the AGRU and reduce the operating cost of the process.

CHAPTER 2

LITERATURE REVIEW

2.1 BENFIELD PROCESS

First basic Benfield Process was developed by Benson and Field in 1950s. Benfield process is then improved with the new technology by adding activator in the potassium carbonate solvent to increase reaction rate of the process. Benfield Process is applicable to the removal of H_2S and CO_2 from natural gas in gas processing plant. This process also used to remove CO_2 in ammonia plant and it is well known around the world for CO_2 removal for many chemical plant industries. Francais S. Manning stated in his book, Benfied Process have three basic process flowsheet, that is single stage absorber, split flow absorber, and two stage absorber as shown in Figure 2.1, (a),(b),(c) respectively.

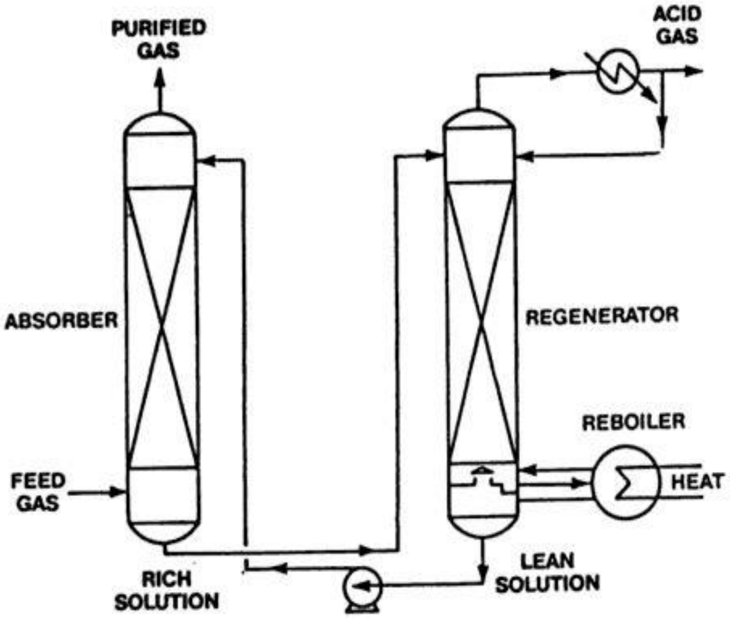

Figure 2.1(a): Single Stage Absorber