EVALUATION OF EFFECTIVENESS PARAMETERS ON GAS DEHYDRATION PLANT

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SUPERVISOR DECLARATION

"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Chemical Engineering (Gas Technology)."

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In the name of ALLAH, Most Gracious, Most Merciful

To my beloved my father, mother, and

brothers.

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EVALUATION OF EFFECTIVENESS PARAMETERS ON GAS DEHYDRATION PLANT

ABSTRACT

Natural gas in either from natural production or storage reservoirs contain water, which condensed and form solid gas hydrates that can cause trouble to the pipeline, increases the operating pressure and potential damage to the equipment. Thus dehydration of natural gas is important to ensure smooth operation of gas transmission line. This study focused on the dehydration by the absorption of liquid desiccant. The purpose of this study was to evaluate the effectiveness parameters used in Triethylene Glycol unit. Water need to be removed from the Natural Gas to meet a water dew point requirement of sale gas contract specification range from $32.8 \text{ to } 117 \text{ kg} / 10^6 \text{ standard m}^3$. The evaluation of effectiveness parameters on gas dehydration plant used Aspen HYSYS. Peng-Robinson Equation of State has been chosen because the process involved hydrocarbon and water. The simulation was carried out to identify the effect of the parameter of column operating pressure, gas flow rate, inlet gas temperature and number of theoretical stages of the absorber. The optimum conditions of gas dehydration was at 7000 kPa with 100 mmscfd gas flow rate at 30 °C and 8 column theoretical stages.

PENILAIAN KEBERKESANAN PARAMETER PADA LOJI DEHIDRASI GAS

ABSTRAK

Gas asli sama ada daripada penghasilan semula jadi atau dari kolam simpanan, mengandungi air yang terkondensasi dan membentuk hidrat gas yang boleh mendatangkan masalah di dalam paip, meningkatkan kadar tekanan dan berpotensi untuk memusnahkan peralatan. Oleh itu proses penghidratan adalah penting untuk melancarkan operasi penghantaran gas. Kajian ini memfokuskan pada penghidratan secara penyerapan menggunakan cecair pengering. Tujuan kajian ini dijalankan adalah untuk mengenal pasti parameter yang efektif pada unit Triethylene Glycol. Kandungan air yang disingkirkan dari gas asli harus menepati keperluan tahap minimum kandungan air dalam gas yang telah ditetapkan oleh spesifikasi kontrak jualan gas iaitu dari 32.8 to 117 kg/ 10⁶ m³. Penilaian keberkesanan parameter pada pelan penghidratan gas dilaksanakan menggunakan Aspen HYSYS. Persamaan Peng-Robinson digunakan selari dengan proses yang melibatkan hidrokarbon dan gas. Proses simulasi dijalankan untuk mengenal pasti kesan parameter iaitu kadar operasi tekanan di dalam kolum, kadar aliran gas, suhu gas, dan bilangan dulang kolum. Keadaan penghidratan gas yang optimum berlaku pada 7000 kPa, 100 mmscfd, 30 °C and 8 dulang kolum.

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LIST OF SYMBOLS

Р	Pressure
V	Molar Volume
Т	Temperature
R	Universal Gas Constant (8.314 J.K ⁻¹ .Mol ⁻¹)
T _c	Critical Temperature
Pc	Critical Pressure
A	Alpha Function of Reduced Temperature

LIST OF ABBREVATIONS

TEG	Triethylene Glycol
PFD	Process Flow Diagram
BTEX	Benzene, toluene, ethylbenzene, xylenes
VOC	Volatile organic compound

CHAPTER 1

INTRODUCTION

1.0 Research Background

Natural gas is an environmentally friendly clean fuel and very safe source of energy. The lowest of carbon dioxide emissions makes this superior environmentally qualities over crude oil and coal. This can helps to reduce problems of acid rain, ozone layer depletion, or greenhouse effect.

Over thousands years ago, the uses of natural gas is specific for ignition only. In Persia, Greece, or India, they used the eternal flame for their religion's ritual until in 900 BC, the ancient Chinese were the first discovered and use natural gas. By the end of 1970s Japan was the world's largest importer of natural gas. Natural gas has been used mostly in North America, Europe, and Asia Pacific. North America has been largest self-sufficient with Canada as their exporter. In Saudi Arabia, natural gas reserves were estimated at 5.8 trillion m³ in January 1999. Most known reserves are in the form of associated gas. Nowadays, there are approximately 130 Underground Gas Storages (UGSs) inside the European Union. Their total maximum technical storage capacity is around 95 BCM. According to the largest update, over 70 BCM of additional storage capacity will come on stream in Europe till 2020.

There are two basic reasons why storing natural gas is an interesting idea. First it can decrease the dependency on supply. Second it can exploit the maximum capacity at distribution level. Natural gas is used as a fuel and raw material in manufacturing. It is used in home furnaces, water heating, and cooking stove.

Natural gas is a gaseous fossil fuel that are essentially the degradation of plants and animals and microorganism that lived millions years ago. Two main mechanisms are responsible for this degradation arebiosenic and thermosenic. Biosenic that is almost contained methane, formed at shallow depths and low temperature by anaerobic bacteria decomposition of sedimentary organic matter into organic matter. In contrast, thermosenic that formed at the deeper depths by the thermal cracking of sedimentary organic matter into hydrocarbon liquid and gas and thermal cracking of oil at high temperature into gas and pyrobitumen. Normally thermosenic consist ethane, propane, butane and other heavier hydrocarbons.

Natural gas produced from geological formations comes in a wide array of compositions. The varieties of gas compositions can be broadly categorized into three distinct groups: (1) non-associated gas, (2) associated gas and (3) continuous. Non-associated gas, sometimes called 'gas well gas' is produced from geological formations. It is typically do not contain much amount of methane but also can

contain carbon dioxide and hydrogen sulphide. Associated gas is the gas that associated with crude oil that produced during crude oil production.

1.1 Problem Statement

Natural gas that comes from oil wells consist primarily methane is not totally pure but there are contaminants or mixture gas that typically contained water vapor, carbon dioxide, hydrogen sulphide, helium, nitrogen, and others. To get higher impurities of the gas, there are several process need to be done. The water contained in the gas can result in gradual plugging of the pipeline by the hydrates formation and also corrosion. These problems will affect the efficiency of gas transmissions and distributions.

1.2 Objectives

- 1.2.1 To evaluate the effectiveness parameters such as absorber operating pressure, number of theoretical stages, gas flow and inlet gas temperature on Natural Gas Dehydration Plant
- 1.2.2 To optimize the plant parameters of Triethylene Glycol (TEG) dehydration unit by using ASPEN HYSYS.

1.3 Scope of Research Work

The scope of the study was to study the optimum parameters of Triethylene Glycol, which were number of theoretical stages, pressure, gas flow rate and inlet gas temperature. Optimization of parameters will be made based on the performance of drying agent which is Triethylene Glycol. Absorption dehydration involves the use of the Triethylene Glycol to remove water vapor from gas.

CHAPTER 2

LITERATURE REVIEW

2.1 Natural Gas Composition

Natural gas that originated from underground comes from the decaying plants and animal that suspended a million years ago (Rebecca et. al., 1999). Natural gas is primarily in methane and along with heavier, more complex hydrocarbons such as ethane, propane, and butane (Mohan, 2008). Often, natural gas also contain impurities such as CO_2 (acid gas), hydrogen sulphide (sour gas), and water as well as nitrogen, helium, and other traces gases. All these contaminants must be removed to maintain the quality of gas before it is being sold.

In natural gas, the most common undesirable contaminant impurity is water that is either in a form of liquid or/and vapor. The amount of water content in the natural gas is varied depend on the pressure and temperature of the gas. The water content in the gas should be removed to the level of the allowable water content in the natural gas, 7 lb/MMscf at 4 Mpa (Michal, 2011). Determination of water content in natural gas is important in evaluating and/or designing the gas dehydration system. Mcketta and Wehe chart (GPSA, 2004) provides the standard for water content determination (Saied et. al., 2006). This chart can be used to predict the saturated water content of sweet, pipeline quality natural gas. An appropriate method has been introduced by Wichert and Wichert that provides good estimations of the equilibrium water vapor content of natural gas.

Components	Typical Analysis	Range
	(mol %)	(mole%)
Methane	94.9	87.0 - 96.0
Ethane	2.5	1.8 - 5.1
Propane	0.2	0.1 - 1.5
i-Butane	0.03	0.01 - 0.3
n-Butane	0.03	0.01 - 0.3
i-Pentane	0.01	Trace - 0.14
n-Pentane	0.01	Trace - 0.04
Hexanes	0.01	Trace - 0.06
Nitrogen	1.6	1.3 - 5.6
Carbon Dioxide	0.7	0.1 - 1.0
Hydrogen Sulphate	1.0	0.1 - 5.0
Oxygen	0.02	0.01 - 0.1

 Table 2.1 Component of natural gas

A reasonable detailed summary of the water vapor problem in natural gas and various means which has been proposed for removing water vapor from natural gas is disclosed in (Athur et. al, 1997).

Natural Gas in the right condition can combine with liquid or free water to form solid-ice like crystal called hydrates (Kasiri, 2004). Hydrates can block pipeline, valves, and other process equipment. Moreover, that water contaminant can increase the corrosivity especially when the acid gasses are present. In order to remove the water content, gas dehydration is the most prominent unit operations in natural gas industry.

In this operations, natural gas need to meet a sale gas contract and specification for water content in range from 32.8 to $117 \text{ kg/10}^6 \text{ stdm}^3$ (Gandhidasan et. al., 2000) .The water content of NG at saturation is dependent on temperature and pressure. With increasing pressure of the gas the water content decreases, and with increasing temperature the water content in the gas increases. This is well presented in Figure No. 20-3, Chapter 20, in the GPSA Data Book, 11^{th} Edition. The water content of the gas can be calculated using the equation 1.1.

$$W_{water} = 593335 \exp(0.05486 t_G) P_G^{-0.81462}$$
 (2.1)

Where w_{water} is in kilograms of water per 10⁶ms³ of NG, t_G is temperature of NG in °C, and P_G is pressure of NG in MPa.

2.2 Dehydration

Dehydration of natural gas is the removal of water content that associated with water in vapor form which is accomplished by lowering the dewpoint of the gas at which water vapor will condense from the gas (Gandhidasan et. al., 2000). Removing water content may maintain the efficiency of gas transmission and all at once save the maintenance cost of pipeline.

There are three different techniques employed for dehydrating natural gas which are absorption by liquid desiccants, adsorption by solid desiccant, and direct cooling (Gandhidasan et. al., 2000). Two of more prominent methods that are current use in industry are absorption and adsorption (Dan, 2009). Several other dehydration technologies are membranes, vortex tube, and supersonic process are used less commonly.

2.3 Dehydration by Adsorption

Solid desiccant dehydration systems basically work on the principle of adsorption (Saied et. al., 2006). Adsorption is purely a surface phenomenon which is, degree of adsorption is a function of operating temperature and pressure. Adsorption increase with pressure increased and decreased with the temperature increased (Gandhidasan et. al., 2000) .In this method H₂O usually adsorbed by a molecular sieves, silica gel or alumina (Michal, 2011).

Property	Silica gel	Alumina	Molecular sieves
Surface area	750-830	210	650-800
Pore volume	0.4-0.45	0.21	0.27
Pore diameter	21-23	26	11.4
Bulk density	721	801-881	689-721
Specific gravity	1.2	1.6	1.1
Specific heat	0.92	0.24	0.2

 Table 2.2 Properties of solid desiccant

2.3.1 Desiccant Selection

There are varies of solid desiccant available for the specific applications. The preferable characteristics for choosing solid desiccant with particular reference to dehydration of natural gas are, the solid desiccants must have large surface area for high capacity and high mass transfer rate. They must also pose a high bulk density and activity for the components to be removed. They must easily and economically regenerated (Gandhidasan et. al., 2000).

Silica gel used for natural gas drying should be of the Sorbead type because this is the water stable silica gel type. Silica gel thus having a longer lifetime, high adsorption capacity for water low dewpoint, and are not catalytic for sulphur conversion reactions. Silica gel also has a higher capacity for pentane. Their longer lifetime can reduce the operating cost while their high performances enhance the operating safety of natural gas treatment plants compared to others. The problem with silica is its tendency to shatter when contacted with liquid water. Molecular sieve are crystalline alkali metal alumino silicates comprising three dimensional interconnecting networks of silica and alumina tetrahedral. Because of its uniform structure, molecular sieve will not giving up moisture into the package in case if the temperature rise (Hasan et. al, 2011) A molecular sieve is the most versatile because it can be manufactured for a specific pore size depending on the application. However, it is more expensive than silica but offers greater dehydration (Saied et. al., 2006).

Alumina is the least expensive adsorbent that is activated by driving off some of water associated with it in its hydrate form by heating. It produces an excellent dew point depression values but require more heat for regeneration. The most efficiency adsorbents are molecular sieves (Dan, 2009).

The final choice of desiccant must be based on the equipment cost, service and applicability to process needs. In most adsorption plant proper design and operation is more critical than choosing the adsorbents (Gandhidasan et. al., 2000).

2.4 Adsorption Unit

In most common configuration, adsorption unit is equipped with at least two beds. Commercially one bed is for adsorption cycle and another one is for regeneration (Michal, 2011). The wet gas flow downward trough the tower in the absorption cycle. Then all the gas is adsorbed at different rates depend on their chemical nature, size of molecules and the size of pores in solid material (Saied et. al., 2006; Gandhidasan et. al., 2000).

2.4.1 Design Consideration

The following considerations are good approximation for estimation of the adsorption dehydration behaviour.

- Allowable gas velocity
- Bed length to diameter ratio
- Desiccant capacity
- Breakthrough time

2.4.2 **Process Descriptions**

Water molecule are adsorbs first in the top layers of desiccant bed and all at once hydrocarbon gasses also being adsorbed. Then, the upper layer of the desiccant bed becomes saturated with water. The lower layer begins to see wet gas and adsorbing is begun. The tower must switch from the adsorption cycle to regeneration cycle before the bed has become completely saturated with water.

For the regeneration, gas flows to trough the adsorbents into a cooler and then further into the separator. Natural gas is flow downwards through adsorption column and regeneration is performed by counter current flow in order to provide complete regeneration from bottom of the column. (Michal, 2011).

Therefore, operational problem that may occur are of poor design, operation and maintenance. Sometimes operators faced problem with the support grid and leakage of molecular sieve. As the result, it is needed to replace the whole bed. Figure 2.1 shows the flow diagram for dehydration by using adsorption methods.



Figure 2.1 Flow diagram adsorption dehydration unit

2.5 Dehydration by Absorption

Absorption is the most common technique where the vapor in the gas stream become absorbed by using liquid desiccant in an absorber (also called contactor) (M.Saied et. al, 2006). The rich glycol must be regenerated before it can be reuse in the contactor. The regeneration is done by distilling the glycol thus removing the water (L. Dan, 2009).

Although many liquids possess the ability to absorb water from gas the liquid desiccant is most desirable to use for commercial purposes when it possess the following properties : (Muhamadbeigy, 2008)

- Strong affinity for water to minimize the required amount of absorbent
- Low affinity for amount of hydrocarbon to minimize hydrocarbon losses during dehydration
- Low volatility at the absorption temperature to minimize vaporization losses
- Low tendency to form and emulsify to avoid reduction in gas handling capacity and minimize losses during absorption and regeneration
- Good thermal conductivity to prevent decomposition
- Non-corrosive and non-toxic
- Easy and economic regeneration

Inhibitor used in a gas treatment plant can be either an alcohol or one of the glycol types. Determination of amount and concentration of inhibitor and their distribution in different phases are very important for practical purposes and industrial applications. Therefore in order to determine the required amount and concentration of this inhibitor, several thermodynamic models for hand and rigorous calculation have been developed and incorporated into the computer software (Muhamadbeigy , 2008)

Glycols are the common name for diols with the two alcohols substance have a higher affinity of water (Dan, 2009). Glycol liquid is widely used, as they approximate the properties that meet commercial application criteria. Several glycols have been found suitable for commercial application.

Common Available Glycol	Characteristics		
Monoethylene Glycol (MEG)	 High vapor equilibrium with gas Tend to lose to gas phase in the contactor Use as hydrate inhibitor where it can be covered from gas by separation at temperature below 		
Diethylene Glycol (DEG)	 High vapor pressure leads to high losses in contactor Low decomposition temperature (315 to 340 F) Cannot get pure enough for most applications 		
Triethylene Glycol (TEG)	 Most common glycol Reconcentrate at 340-500F for higher purity At contactor temperature in excess of 120F there is a tendency to high vapor loses Dewpoint depressions up to 150F are possible with stripping gas 		
Tetraethylene Glycol (TREG)	 More expensive than TEG but less loss a high gas contact temperatures Reconcentrate at 400-430F 		

 Table 2.3 Characteristics of Glycols

Therefore TEG by far is the most common liquid desiccant used in natural gas dehydration. It exhibits most of the desirable criteria at commercial suitability listed below:

- i. TEG is regenerated more easily to a concentration at 98-99% in an atmospheric stripper because of its high boiling point and decomposition temperature
- TEG has an initial theoretical decomposition temperature of 404 °F whereas that of diethylene glycol (DEG) is only 328°F
- iii. Vaporization losses are lower than monoethylene glycol (MEG). Therefore the TEG can be regenerates easily to the high concentrations needed to meet pipeline water dewpoint specifications.
- iv. Capital and operating costs are lower

Glycol	MEG	DEG	TEG	TREG
Formula	HOC ₂ H ₄ OH	HO(C ₂ H ₄ O) ₂ H	HO(C ₂ H ₄ O) ₃ H	HO(C ₂ H ₄ O) ₄ H
Molecular mass	62.07	106.12	150.17	194.32
Boiling point 101	197	245	287	327
kPa (°C)				
Freezing point (°C)	-13	-8	-7.2	-6.2
Density 20 °C	1113	1116	1123	1246
(kg/m^3)				
Viscosity °C	20.9	35.7	47.9	60.0
(mPa.s)				
Degradation	163	162	206	226
temperature °C				

Table 2.4 The Properties of Glycols.

In the Table 2.4 the important values are the normal boiling point, vapor pressure, viscosity, maximum recommended regeneration temperature and the onset of decomposition.

The normal boiling point and vapor pressure has an influence in distillation. The greater the differences for these properties between the top and the bottom product, the easier to separate the components. The separation of glycol and water is important because the water content in the lean glycol determine the amount of water can be removed from the gas.

2.6 Simulation Model

When a dehydration plant is simulated it is important to know the operating parameters and unit required in the dehydration plant. With this design determine it is easy to create HYSYS simulation (Dan, 2009).

2.6.1 Simplified Model

When the process plant on an offshore platform is simulated the dehydration unit is often a problem. The dehydration plant solves simple problem, removing the water but it can be difficult to simulate. There is an alternative to simulating an entire dehydration plant, namely to insert a component splitter.

A component splitter is a non-thermodynamic separator, where the composition of the output streams is determined by the programmer (Dan, 2009). Some accuracy input data for the unit must be known before inserting the component splitter. The input data must be calculated by simulation if data for the actual unit is not available. With input data from dehydration unit, the effect of the component splitter is equal to simulating the entire dehydration plant.

By using the component splitter instead of a dehydration unit is much faster. There are may be a small error if the input data in the component splitter comes from calculation with a different gas composition. The simulation of the dehydration plant is often neglected when the process plant on an offshore platform is simulated. It is also possible to create a new dehydration plants from the empirical data from existing plant without simulations. But simulations are necessary when dehydration plants are optimized or otherwise the actual split needs to be calculated for the component splitter.

For the purpose of analysis, thermodynamic behaviour of the dehydration system was represented by means of Peng-Robinson equation of state. The models guarantee good phase equilibrium predictions over a wide range of temperature and pressure (Dan, 2009).

The Peng-Robinson equation is written as:

$$P = \frac{RT}{V-b} - \frac{a\alpha}{V(V+b) + b(b-V)}$$
(2.2)

Where $a = 0.45724 \frac{R^2 T_c^2}{P_c}$, b = 0.07780, P = pressure, V = molar volume, $T = \text{temperature} \frac{RT_c}{P_c}$, $R = \text{universal gas constant (8.314 J.K^{-1}.mol-1)}$, $T_c = \text{critical temperature}$, $P_c = \text{critical pressure}$, $\alpha = \text{alpha function of reduced temperature } T_r = T/T_c$,

$$\left[1 + (0.37464 + 1.54226\omega - 0.26992\omega^2) \left(1 - \left(\frac{\tau}{\tau_{c}}\right)^{0.5}\right)\right]^2$$
(2.3)

$$\omega = -\log\left(\frac{p}{p_c}\right) - 1 \tag{2.4}$$

The Peng-Robinson equation is universally used for hydrocarbons and related components over a wide range of temperature and pressure.

2.6.2 Complex Unit (Dehydration and Regeneration)

The glycol dehydration process can be classified into two section which is first lean glycol dried the inlet wet gas, thereby making the glycol rich with water. The second section is the process of removing water from the rich glycol and making it lean once again.

Regeneration is the one of the important process in the dehydration unit which effected upon the efficiency of the glycol to absorb the water in the gas. It is a key to successful and economical operation of the dehydration of natural gas (Gandhidasan, 2003). There are three points to answer what is the function of glycol regeneration system:

- To obtain the optimal pressure and temperature conditions for regeneration of the rich glycol
- 2. For glycol regeneration
- Readjust glycol temperature and pressure for optimal dehydration conditions in the contactor.

Three main points need to consider when designing a dehydration plant:

- 1. Installing a flash separator before the regeneration column. This separator removes the majority of the hydrocarbons in the dissolved in the glycol.
- 2. Filtering the rich glycol if there is solid particle or liquid hydrocarbon in the glycol
- 3. Integrating the heat exchangers so the lean glycol is cooled by heading the rich glycol thus minimizing the energy consumption
- 4. Glycol make up to replace the glycol loss

2.6.3 Parameter Considerations

In order to design suitable dehydration for natural gas using TEG as the liquid desiccant, one must know the effectiveness parameter of this dehydration process to improve the efficiency of water absorbed (Gandhidasan, 2003)

- 1. Flow rate of TEG entering the contactor
- 2. Temperature of TEG
- 3. Inlet gas temperature
- 4. Lean glycol concentration
- 5. TEG circulation rate
- 6. Number of equilibrium stages (no of trays)
- 7. Operating pressure
Dewpoint is the temperature and pressure at which the first drop of water vapour condenses into a liquid. Dewpoint indirectly indicates the water content of a natural gas and is defined as the temperature at which vapor begins to condense into a liquid at a particular system pressure (Kumar, 1987). A natural gas stream shows both hydrocarbon and water dewpoints. Sometimes the dewpoints is only a metastable condition. In the stable condition the condensed material is a solid ice commonly known as hydrates occurring at the higher temperature.

Dew point depression is the differences between the original dew point and the dew point achieved after some of the water vapour removed (Kumar S., 1987). It is used to describe the amount of water needed to be removed from the natural gas to establish specific water vapour content. Dewpoint depression is dependent on TEG circulation rate (gallons per pound of water in the gas), lean TEG concentration, number of equilibrium stages (number of trays) in the absorber, contact temperature and pressure.

Dew point depression is especially sensitive to inlet gas temperature. TEG dehydration units yield a higher dew point depression with an increase in temperature and correspondingly a lower dew point depression with a decrease in inlet gas temperature. This performance change is primarily due to the change in gas-glycol contact efficiency in relation to temperature.

Even though the dew point depression increases with an increase in inlet gas temperature, the outlet gas dewpoint will be higher. For the lowest obtainable outlet dew points it is desirable to have a low inlet gas temperature. Normal operating temperatures range from 50 to 135 °F. 50 °F is considered to be the minimum operating temperature due to the high viscosity of glycol at lower temperatures. 135 °F is the upper practical temperature limit for TEG dehydrators because of the increased TEG vaporization losses at higher temperatures.



Figure 2.2 Effect of contactor temperature to dewpoint

Since absorption is an exothermic process, increasing input TEG temperature decreases water absorption rate. In real dehydration plants temperature of TEG entering the absorption tower is kept at 5-6°C more than entering gas temperature (Kasiri et. al., 2004). Water absorption rate as a function of TEG temperature is represented in the following figure:



Figure 2.3 Effect of TEG temperature on water absorption rate

Usually the glycol absorber contains 6-12 trays that provide an adequate contact area between the gas and the glycol (Saied et. al., 2006). With increasing number of trays, the greater the dew point depression for a constant glycol circulation rate and lean glycol concentration. On the contrary, specifying more trays with the same TEG concentration, a lower circulation rate is required. By specifying more trays, fuel savings can be realized because the heat duty of the reboiler is directly related to the glycol circulation rate. Also, calculated tray efficiency values depend on the TEG/water equilibrium data used.

Increasing number of equilibrium stages increases water absorption rate as well as manufacture and maintenance costs (Kasiri et. al., 2004). As number of stages increases, glycol circulation rate decreases. Percentage of water removal as a function of number of equilibrium stages in absorber is represented in the following figure:



Figure 2.4 Effect of number of stages in absorber

Pressure appears to have little effect on dew point depression in the dehydration process. Existing data indicates that the dew point depression is essentially constant over a range of 0 to at least 3000 psig. Pressure does however

affect the water vapor capacity of the gas. At lower pressures the gas can absorb more water per unit volume.

At a constant temperature, the water content of the inlet gas decreases with an increasing pressure. Less water is removed if the gas is dehydrated at a higher pressure (Mohamadbeigy, 2008). At lower pressure, wall thickness required is lesser. Therefore, an economic trade-off exists between operating pressure and contactor cost.



Figure 2.5 Effect of pressure on the percentage of water removal

The higher the concentration of glycol will result the greater dewpoint depression at particular glycol circulation rate and number of trays. Figure shows that the increasing the lean glycol concentration can have a much greater effect on dewpoint depression that increasing the circulation rate. The lean glycol concentration is determined by the temperature of the reboiler, the gas stripping rate and the pressure of the reboiler. Glycol concentration of 98 % to 99% are common apply in natural gas industry.



Figure 2.6 Effect of TEG circulation rate to dewpoint depression

When the number of absorber trays and lean glycol concentration are fixed, the dewpoint depression of a saturated gas is a function of the glycol circulation rate. The more glycol contact with the gas the more efficiency of water removed. The minimum circulation rate can lead to a good glycol-gas contact. Typical standard for contactor are design for approximately three gallons of glycol per pound of water removed.

2.7 **Process Descriptions**

For the process of absorption using liquid desiccant (specifically known as TEG dehydration and regeneration unit), wet natural gas enters an inlet cooler to lower the inlet gas temperature to desired temperature in the contacts. Dehydration is more efficient at low temperature (Dan, 2009).In a typical glycol dehydration plant, a glycol steam containing about 1-5 % water by weight is contacted with natural gas in a counter current column (Gavilin et. al., 1998). The rich natural gas then flows into the inlet scrubber (separator) to remove almost all liquid hydrocarbons from the gas stream (Saied et. al., 2006).Removing liquid water in the scrubber decrease the amount of water has to be removed in the contactor.

After leaving the scrubber, the wet gas is flow into the glycol contactor (a tray column of packed bed) where it is contacted counter currently with the TEG and dried by TEG (Michal, 2011).TEG also absorbs volatile organic compound that vaporize with the water in the reboiler (Saied et. al., 2006).The dry natural gas then leaves the top of the glycol contactor and it is fed either to pipeline or to a gas plant.



Figure 2.7 shows the flow diagram for dehydration using triethylene glycol.

Figure 2.7 Typical flow diagram glycol dehydration unit

After leaving the glycol contactor enriched TEG is then flows to the internal heat exchanger which is incorporated at the top of the still column. It is then flows into the flash drums where the flash gases are released and separated from the stream (Michal, 2011). The flash gas can be used as process gas in plant. Without separator the gas in the glycol will be released together with water in the generator and this can reduce the water removal efficiency.

Then the rich glycol runs to the cold side of the TEG heat exchanger. Just afterwards TEG is filtered to remove solid particles and liquid hydrocarbons. However the filtration does not have any impact in terms of simulation. TEG then sprayed into the still column. After that TEG enter the reboiler which H₂O is boiled out of the TEG. Regenerated TEG is then pumped back to the hot side of TEG/NG and NG/TEG heat exchanger at the top of the contactor. Although the absorption process is the most popular method to dehydrate the natural gas however there are several operational problems with this liquid desiccant. The main operating problems are upon the absorber are insufficient dehydration, foaming and hydrocarbon solubility in glycol (Gandhidasan, 2003). One problem with known process for dehydration of natural gas is the undesirable tendency of the drying agent to absorb aromatic compound which may be present in the natural gas (Gavilin et. al., 1998)

2.8 Description of Contactor Design

Glycol contactor also known as absorption tower is the most important section of dehydration unit (Kasiri et. al., 2004). Glycol contactor sizing involves specifying the correct contactor diameter and number of trays, which establishes its overall height, selecting glycol circulation rate and lean glycol concentration and calculating the reboiler heat duty. As previously explained, the number of trays, glycol circulation rate and lean glycol concentration are all related. Figure bellows will show the relation of those parameters.



Figure 2.8 Effect of TEG rate with various purity to fraction of water removed

Various configurations of contactor design are possible, for this research, typical type of bubble cap trays is chosen. This type of trays have proved to be the effective, reliable and have good gas and liquid turn down ratio. Bubble cap trays efficiency between 25 % – 40 % has normally been recommended (Lars, 2002). A large variety of bubble caps designs are available. The performance of the trays in glycol contactor is not dependent on the type of bubble cap installed. The following criteria should be fulfilled to ensure the optimum performance on the trays;

- 1. The column diameter should be sufficient for the vapor flow
- The downward liquid velocity in the top of the down comer and/or the downcomer pipes should less than 0.07 m/s under maximum flow conditions. This is to prevent choking

- 3. The downcomer area should be a minimum of 11% of the column crosssectional area might be lead to misdistribution of liquid, which in turn could cause a drop in efficiency.
- 4. An outlet weir of 100 mm height should be used. Lower weir heights will result in reduced efficiency
- 5. Back-up in the downcomer should be sufficiently low to prevent premature flooding. This is not usually a problem for a properly designed column.
- 6. The glycol inlet to the top tray should be carefully positioned in order to ensure good distribution

2.9 Absorption as The Best Method

By far the current methods for dehydration in the industry are by using adsorption of solid desiccant and absorption of liquid desiccant. Each of the methods presented here has its advantages and disadvantages

Generally the absorption method of absorption by using glycol is the preferable dehydration method because it is more economical than adsorption this is due to the following differences between adsorption and absorption:

- Adsorbent is more expensive than glycol
- It requires more energy to regenerate adsorbent than glycol
- Replacing glycol is much cheaper than replacing an adsorption bed

• Glycol can be changed continuously, while changing an adsorption bed requires a shutdown

CHAPTER 3

MATERIALS AND METHODS

3.0 Research Methodology

3.1 Introduction

This chapter will discuss the research methodology that was used in the study. This project will be carried on based on the three main stages which will be shown in research procedures and the study involves the simulation of parameters performance via ASPEN HYSYS. Many researchers have been done and the problems have been identified. In order to solve the problems and upgrading the recent technology in dehydration, since there are rooms to be improved. This research entitled as "Evaluation of Effectiveness Parameters on Gas Dehydration Plant" and aims to overcome and accomplished to the objectives of chapter 1 by using aspen HYSYS simulation method.

3.2 Research Design

3.2.1 HYSYS Simulation Approach of Dehydration

ASPEN HYSYS is usually used for modelling of a dehydration process. It was used for steady state simulation, design, performance monitoring and optimization of oil and gas production, gas processing and petroleum refining industries (HYSYS User Guide, 2005). HYSYS simulator is the main tool in this analysis.

In HYSYS, all necessary information pertaining to pure component flash and physical property calculations is contained within the Fluid Package, therefore choosing the right Fluid Package is essential. For the given composition of natural gas flowing through the dehydration unit, different Fluid Packages were checked, and Peng-Robinson equation of state was chosen, as an ideal model for process calculations (HYSYS User Guide, 2005) because it is suitable to handle system containing hydrocarbon, and water.

Material streams were used to stimulate the material travelling in and out of the simulation boundaries and passing between unit operations. For the material stream, the main properties and composition has to be defined. The parameters necessary are the temperature, pressure, molar flow, and composition. Energy streams were used to stimulate the material travelling in and out and it allows user to define stream parameters, view objects to which the stream is attached and specify dynamic information. The main parameters for the energy streams is heat flow (HYSYS User Guide, 2005). Separator is a unit to separate feed into constituent part, with one or multiple feeds, one vapor, and one liquid product stream. Every separator may be provided with some common features and the user can choose between various heating types, which determined the way in which heat is transferred to the vessel operation (HYSYS User Guide, 2005).

3.2.2 Details on Feed Natural Gas

Natural gas processing begins at the wellhead. The compositions of the raw natural gas extracted from the producing well are depend on the type, depth, and location of the underground deposit and the geology of the area. In this research, the composition is based on the Sabah Oil & Gas Terminal (SOGT) project .Mole fraction of typical gas fields mixed natural gas is given as below:

CO ₂	0.0199
N ₂	0.0015
Methane	0.9019
Ethane	0.0424
Propane	0.0186
i-Butane	0.0039
n-Butane	0.0046
i-Pentane	0.0018
n-Pentane	0.0012
n-Hexane	0.0012
Mcyclopentan	0.0004
Benzene	0.0002

 Table 3.1 Table of gas composition

Cyclohexane	0.0003
n-Heptane	0.0007
Toluene	0.0002
n-Octane	0.0002
e-Benzene	0.0000
n-Nonane	0.0000
123-mbenzene	0.0000
n-Decane	0.0001
o-xylene	0.0000
TEGlycol	0.0000
H ₂ 0	0.0008
Methanol	0.0000

3.2.3 Liquid desiccants dehydration unit



Figure 3.1 Typical glycol dehydration unit

Figure 3.1 schematically shows a process flow diagram of TEG dehydration unit .Wet natural gas enters the bottom of the glycol contactor and

flowing upward through the absorber theoretical trays. The lean and dry TEG enters the top of glycol contactor and flows down through the tower. In this tower, TEG contact counter-currently with wet gas that will absorb water vapour in the gas due to the dewpoint depression.

Dehydrated natural gas exit the absorber and cools the incoming lean TEG in the gas to glycol heat exchanger while the rich TEG will proceed to the regeneration process. It passes through two heat exchanger to heat up the temperature from 30.15°C to 80°C. Next, it will flow to flash separator to decrease the amount of flash gases in the material stream. This will help to reduce the venting of BTEX to the atmosphere. The glycols then moves to component splitter which remove the solid particles in the TEG. Then it enters a glycol-glycol heat exchanger that heats it up to 160°C.

Next, it enter the distillation column as regenerator where glycol and water is separated. For process requiring gas with very low water dew points, a stripping vapour will most likely be needed to aid the regeneration process. The condenser at the top of the column will provide reflux ration of 0.2 to improve the separation of glycol and water. The temperature of the condenser is 100°C. The energy required for the separation process is supplied by the reboiler at the bottom of the stripper. The operating temperature at this reboiler is 204°C . The TEG then flow to the stripping column to achieve the high purity of TEG up to 99.9%. Then TEG is pumped from 105 kPa to 7130 kPa and enter the glycol-lean gas heat exchanger to cool down to 30°C before entering back to the top of the contactor.

3.2.4 Details on TEG Dehydration Unit

Glycol has been used to dehydrate sweet and sour natural gas over a wide range of operating conditions. The system sizing involves specifying the minimum glycol mass flow, specific glycol circulation rate, and number of theoretical stages. The following table shows the TEG Dehydration Unit specification, which is used for simulation and modelling of dehydration unit.



Figure 3.2 TEG Absorption Column

Specifications	Natural Gas, in	TEG, in
Vapor Fraction	1	0
Temperature (°C) 30,40,50,60,70		35
Pressure (kPa)	7000,8000,9000,10000,11 000	0.00756
Gas Flow (MMSCFD) 100,200,300,400,500		100,200,300,400,500
Number of Theoretical Stages of Absorber	2,4,6,8,10	2,4,6,8,10

Table 3.2 Inlet stream used in TEG Dehydration Unit

3.3 Research Procedure



Figure 3.3 Flow of Research Procedure

3.4 HYSYS SIMULATION

3.4.1 To Create a New Simulation

To start a new case, from the menu bar, select file, then select new and then case. The simulation basis manager will be appeared which all the components and properties will be specified.

Simulation Bas Component Lists	is Manager	Databank Selectio HYSYS Databa C Aspen Properti <u>A</u> dd	n anks es				
		Delete		rt			
		⊻iew		ort			
	Fluid Pkas	<u>H</u> efresh	Dil Manager	Beactions	Component Maps	User Properties	
components			Extend Simula	ion Basis Man	ager	Enter Simulatio	on Environment

Figure 3.4 Simulation Base Manager

Then from the tools menu bar select tools and then preferences. The sessions preferences property will appear. The HYSYS default settings were save in Preferences file named HYSYS .pfr.

8 Session Prefere	nces (Aspen HYSYS V7.PRF)	
Simulation	Allow Multiple Stream Connections	Use Input Experts
Options	View New Streams upon Creation	Confirm Deletes
Errors	📃 🔲 Use Modal Property Views 🔽	Confirm Mode Switches
Desktop	Record Time When Notes Are Modified	Enable Single Click Action
Naming	🔽 Enable Cross Hairs On PFD 🔽	Enable Cell Edit Button
Tool Tips	🔽 🔽 Save XML Fluid Package To User Defined File 🔽	Show Tip of the Day
Dynamics		
Performance	Show Property Package Warning	
Licensing	Show Property Package Warning	
RTi Server	-Stream Property Correlations	
Column	Activate Property Correlations (Standard Black Oil	Electrolute)
Status Window	Confirm Before Adding if Active Correlations are Pre	ent
Trace Window		.30/ IK
Cut/Copy/Paste		
Simulation V	ariables Reports Files Resources Extensions	Dil Input jay Sizing
Save Preferenc	e Set	Load Preference Set

Figure 3.5 Session Preferences

To create a new unit set, select variables tab in the session preferences property view and select the unit in the variable column. In available unit set group, SI is selected and makes it as an active set. The clone button is clicked and a new unit set named NewUsers appears.

ধ্যে Session Preferer	ces (Aspen HYSYS V7.PRF)		
Variables Units	Available Unit Sets		Clone
Formats	Field NewUser SI		Delete
	Unit Set Name NewUs	ser	View <u>U</u> sers
	Display Units		
		Unit	<u>∕</u> iew
	Acidity	mg KOH/g	
	Act. Gas Flow	ACT_m3/h	A <u>d</u> d
	Act. Vol. Flow	m3/h	Delete
	Actual Liquid Flow	m3/s	
	Actual Mass Density	kg/m3	A
	Angle	deg	2*
	API Fire Equation Constan	Btu/hr-ft1.64	
	Area	m2	
	AreaPerVolume	m2/m3	_
Simulation Va	riables Reports Files R	esources Extensions (Dil Input Jay Sizing 🌖
Sa <u>v</u> e Preference	Set		Load Preference Set

Figure 3.6 Creating a New Unit Set

In the display units table, the unit of specification will be selected.

3.4.2 Adding components to the simulation

The first step in establishing the simulation basis is to insert the chemical components. Then add button is selected in the components tab. Then the list of the components available in HYSYS will be appear. After that the desired components for the simulation are selected by double click on the components name or by

clicking the add pure. Then simply clicked the X button and will be returned back to the simulation basis manager.

3.4.3 Selecting a fluid package

Once the components have been specified the particular fluid package must be selected for the simulation. The fluid package is used to calculate the fluid or thermodynamics properties of the components and mixture in the simulation. In this simulation Peng-Robinson fluid package is selected.

Add Component	Selected Components	_	-Components Availa	able in the Component Library—		
Components			<u>M</u> atch		View Filters	
Hypothetical			C Sim Name	 Full Name / Synonym 	C Formula	
		< <u>A</u> dd Pure	Methane Ethane Propane	C1 C2 C3	CH4 C2H6 C3H8	
		<- <u>S</u> ubstitute->	i-Butane n-Butane i-Pentane	i-C4 n-C4 i-C5	C4H10 C4H10 C5H12	
		<u>R</u> emove>	n-Pentane n-Hexane n-Heptane	n-C5 C6 C7	C5H12 C6H14 C7H16	
		Sort List	n-Octane n-Nonane n-Decane	C8 C9 C10	C8H18 C9H20 C10H22	
		⊻iew Component	n-C11 n-C12 n-C13	C11 C12 C13	C11H24 C12H26 C13H28	-
			🔽 Show Synonyi	ms 🔽 Cluster		
Selected Compo	nent by Type					

Figure 3.7 Selecting the Gas Component

Selected Components		
C02	- A	
Nitrogen		
Methane		
Ethane		
Propane		
i-Butane		ZavAdd Dura
n-Butane		
i-Pentane		
n-Pentane		Z.Substitute.S
n-Hexane		
Mcyclopentan		
Benzene	=	Remove
Cyclohexane		<u>H</u> emove
n-Heptane		
Toluene		Sort List
n-Octane		
E-Benzene		
n-Nonane		View Component
123-MBenzene		Tiew component
n-Decane		
o-Xylene		
TEGlycol		
H20		
Methanol	-	

Figure 3.8 Complete Gas Component List

4 Simulation Basis Manager				
Current Fluid Packages		Flowsheet - Fluid Pkg As	sociatio <u>n</u> s	
	<u>∀</u> iew	Flowsheet	Fluid Pkg To Use	
	<u>A</u> dd	Case (Main)	<empty></empty>	
	Delete			
	Сору			
		Default Fluid Pkg		•
	Import	Fluid Pkg for New Sub-Fl	lowSheets	
	CZPOIL	 Use Default Fluid F Use Parent's Fluid 	Pkg Pkg	
Components Fluid Pkas Hupotheticals	Dil Manager	Beactions Component N	Aans User Properties	
	<u>Extend Simula</u>	tion Basis Manager	Enter Simul	ation Environment

Figure 3.9 Selecting Fluid Package

👙 Fluid Package: Basis-1	_ • ×
HYSYS C Aspen Properties C COMThermo	
Property Package Selection Grayson Streed Kabadi-Danner Lee-Kesler-Plocker Margules MBWR NBS Steam NRTL OLL Electrolyte Progerty Package Filter Package Filter C All Types C EOSs C Activity Models C Chao Seader Models C Vapour Press Models PR-Twu PRSV Sour PR Sour SRK SRK	
Component List Selection Component List - 1 View	
Set Up Parameters Binary Coeffs StabTest Phase Order Rxns Tabular Notes Delete Name Basis-1 Property Pkg Peng-Robinson Ec	dit Properties

Figure 3.10 Selected Fluid Package

3.4.4 Enter the simulation environment

After the necessary input data are completed, next enter the simulation environment. A PFD view will be appear as shown in Figure 3.10.



Figure 3.11 Entering Simulation Environment

3.4.5 Adding material streams

Material streams are used to transport the material components from processes units in the simulation. A material stream can be added by to the flow sheet by clicking the blue arrow button on the object pallet. Then, the stream is clicked twice to add the information such as compositions, temperature, pressure, and molar flow rate.

Worksheet	Stream Name	18		
····· Conditions	Vapour / Phase Fraction	1.0000		
Properties	Temperature [C]	29.60		
Composition	Pressure [kPa]	7080		
Composition	Molar Flow [kgmole/h]	6.245e+004		
K Value	Mass Flow [kg/h]	1.157e+006		
User Variables	Std Ideal Lig Vol Flow [m3/h]	3517		
Notes	Molar Enthalpy [kJ/kgmole]	-8.453e+004		
Cost Parameters	Molar Entropy [kJ/kgmole-C]	148.2		
	Heat Flow [kJ/h]	-5.279e+009		
	Lia Vol Flow @Std Cond [m3/h]	<emptv></emptv>		
	Fluid Package	Basis-1		
	Utility Type			
	▲ _	Þ		
Worksheet Attachments Dynamics				
Delete	Define from Other Stream	+ +		

Figure 3.12 Inserting Data on Feed

3.4.6 Installing Unit Operations

To install the necessary unit operations for processing the gas, click on the workbook icon to reach the workbook property view and click on the Unit Ops tab. To add a unit, click Add unit ops button. The Unit Ops property view appeared and select the unit needed. Next, an absorber is added to the pfd. The inlet and outlet stream is labelled. The specification such as number of stages, and pressure of the absorber need to be specified.

" Column: T-100 /	COL1 Fluid Pkg: Basis-1 / Peng-Rob	inson	
Design Connections Monitor	Column <u>N</u> ame T-100	Sub-Flowsheet Tag COL1	0⊻hd Vapour Outlet Glycol Contactor 0/L 💌
Specs Specs Summary Subcooling Notes	Top Stage Injet Lean Glycol IL Contac Optional Inlet Streams Stream Inlet Stage Stream >> Bottom Stage Inlet 19	$ \begin{array}{c} 1\\ \underline{Num of}\\Stages\\n = 10\\ \underline{n-1}\\n\end{array} \end{array} Pn $ 7070 kPa	Optional Side Draws Stream Type Draw Stage << Stream >>
	Top Down C Bottom Up Edit Trays		Bottoms Liguid Outlet Rich Glycol O/L Contz -
Design Param	eters Side Ops Rating Workshee	et Performance Flowsheet	Reactions Dynamics
Delete	Column Environment Run	<u>R</u> eset Conv	rerged 🔽 🔽 Update Outlets 🔲 Ignored

Figure 3.13 Entering Data of an Absorber

🏽 E-101-2		
Design	<u>N</u> ame E-101-2	
Connections		
Parameters	Inlet Energy	
User Variables	104-2 💌 104e-2 💌	
Notes	Outlet Fluid Package Basis-1	
Design Rating	Worksheet Performance Dynamics	
Delete	OK	🔲 🧾 🔤

Then, insert a reboiler. The temperature out and pressure drop must be specified.

Figure 3.14 Data of a Reboiler

The heated glycol then enter a flash tank. A flash tank is added to the pfd.

Design	<u>N</u> ame V-100-2	
Connections Parameters User Variables Notes	Injets I Rich Glycol I/L Flz << Stream >> Energy (Optional)	∑apour Outlet 107-2 ▼
Design Reaction	Vessel Fluid Package Basis-1 ns Rating Worksheet Dynamics	Liquid Outlet

Figure 3.15 Inserting a Separator

Next, installed a component splitter and labelled it's inlet and outlet stream

💶 X-100-2	
Design Connections Parameters Splits TBP Cut Point User Variables	Name 100.2 Injets Overhead Outlet V Stream >> V Stream >> Software S
Design Rating	qe 110-2 << Stream >> Fluid Pkg Worksheet Dynamics

Figure 3.16 Inserting Component Splitter

The heat exchanger is added to the PFD as it will heat up the rich glycol before entering a distillation column. The heat exchanger property will be appear. The inlet, outlet, and energy stream were labelled. Next, the parameters suh as temperature outlet, heat duty, and pressure drop must be specified. Then, a valve with 50% openings is added.



Figure 3.17 Designing Shell and Tube Heat Exchanger

Next, the distillation column is added to the PFD. The details and specifications needed as shown in the figure were specified.

🖐 Column: T-101-2	/ COL4 Fluid Pkg: Basis-1 / Peng-Ro	obinson	
Design	Column Name T-101-2	Sub-Flowsheet Tag COL4	Condenser O Total O Partial O Full Reflux
Connections Monitor Specs Specs Summary Subcooling Notes	Condenser Energy Stream 114c-2 Injet Streams Stream Injet Stage I14-2 I_Mair << Stream >> Stage Numbering	0 1 2 P cond 105.0 kPa n = P reb 105.0 kPa n = P reb	Delta P 115-2 Delta P 0.0000 kPa Oyhd Vapour Outlet Optional Side Draws Stream Type Comparison Reboiler Energy Stream
	Top Down O Bottom Up Edit Trays		Bottoms Liguid Outlet
Design Parame	eters Side Ops Rating Workshee	et Performance Flowsheet	Reactions Dynamics
Delete	Colu <u>m</u> n Environment R <u>u</u> n	<u>R</u> eset Conve	erged 🔽 🔽 Update Outlets 🗌 Ignored

Figure 3.18 Designing the Distillation Column

A pump is installed after the regeneration column. The duty and outlet pressure needed is inserted as in figure.

🖅 P-101	
Design	<u>N</u> ame P-101
Connections	
Parameters	Outlet
Curves	Inlet
Links	
User Variables	((-))
Notes	
	7e Tulu <u>rackage</u>
Design Bating	Worksheet Performance Dynamics
Delete	OK. 🔽 On 🗌 Ignored

Figure 3.19 Entering Data for a Pump

As we recycle back the glycol from the absorber, the recycle block is added after the pump as before it enter to the absorber back. A recycle block is used to control the recycled flow to the absorber.



Figure 3.20 Connecting A Recycle Block

Finally, after all of the unit operations completed the PFD, the simulation can be started to run. The green indicator indicates that the system is converged. If the systems are not converged, identify the errors by the notifications given. The simulation is repeated by manipulating different number of theoretical stages, operating pressure, gas flow rates and inlet gas temperature.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents all the expected results that will be obtained according to the respective parameters involve. The main objectives of this study is to determine the most effective parameters of dehydration process using Triethylene Glycol (TEG). The simulation should be run using the best software for the natural gas dehydration which is Aspen HYSYS.

There are several parameters involved in the simulation process that has been discussed in previous chapter. The main objective of this research is to determine the most effective parameters in gas dehydration process by using Triethylene Glycol. In order to establish the objective of this study, Aspen HYSYS has been choose as the best software for the modelling of the dehydration of natural gas as it has a special thermodynamic package for dehydration process. The parameters that have to pay attention as mentioned.

- 1. Number of theoretical stages
- 2. Inlet gas temperature
- 3. Natural gas volumetric flow rate
- 4. Absorber's pressure

All the data of simulation were analyse and discussed.

4.2 Result of Water Removal Efficiency

Table 4.1 Percentage of Water Removal on Gas Flow Rates and Pressures at 2Theoretical Stages in Absorber

Gas Flow Rate	Percentage of Water Removal				
(MMSCFD)	7000kPa	8000kPa	9000kPa	10000kPa	11000kPa
100	58.88	58.06	57.08	57.08	54.31
200	57.12	56.34	56.32	55.21	51.67
300	56.11	54.8	53.47	52.08	49.39
400	54.76	53.47	51.84	50.31	47.29
500	53.67	40.07	37.99	35.87	31.77

Table 4.2 Percentage of Water Removal on Gas Flow Rates and Pressures at 4

 Theoretical Stages in Absorber

Gas Flow Rate	Percentage of Water Removal				
(MMSCFD)	7000kPa	8000kPa	9000kPa	10000kPa	11000kPa
100	94.03	92.92	91.81	90.56	88.19
200	93.4	92.22	90.90	89.44	86.45
300	77.59	75.97	74.26	72.50	68.94
400	91.84	90.07	88.09	85.97	81.39
500	90.78	85.90	82.59	79.79	73.02

Gas Flow Rate	Percentage of Water Removal				
(MMSCFD)	7000kPa	8000kPa	9000kPa	10000kPa	11000kPa
100	94.17	93.19	92.08	90.97	88.61
200	94.03	92.99	91.88	90.69	88.33
300	93.43	92.18	90.74	89.26	86.02
400	93.78	92.67	91.35	89.93	86.74
500	93.61	90.42	88.54	86.39	81.35

Table 4.3 Percentage of Water Removal on Gas Flow Rates and Pressures at 6Theoretical Stages in Absorber

Table 4.4 Percentage of Water Removal on Gas Flow Rates and Pressures at 8

 Theoretical Stages in Absorber

Gas Flow Rate	Percentage of Water Removal				
(MMSCFD)	7000kPa	8000kPa	9000kPa	10000kPa	11000kPa
100	94.17	93.19	92.08	90.83	88.61
200	94.03	92.99	91.88	90.69	88.40
300	93.98	92.91	91.76	90.56	88.00
400	93.92	92.90	91.81	90.66	88.19
500	93.89	91.04	89.50	87.85	85.69

Table 4.5 Percentage of Water Removal on Gas Flow Rates and Pressures at 10Theoretical Stages in Absorber

Gas Flow Rate	Percentage of Water Removal				
(MMSCFD)	7000kPa	8000kPa	9000kPa	10000kPa	11000kPa
100	94.17	93.19	92.08	90.83	88.61
200	94.03	92.99	91.88	90.69	88.40
300	93.98	92.96	91.85	90.69	88.29
400	93.96	92.92	91.81	90.66	88.19
500	93.92	91.15	89.72	88.19	85.69



Figure 4.1 Percentage of Water Removal versus Gas Flow Rate at 2 Theoretical Stages in Absorber



Figure 4.2 Percentage of Water Removal versus Gas Flow Rate at 4 Theoretical Stages in Absorber



Figure 4.3 Percentage of Water Removal versus Gas Flow Rate at 6 Theoretical Stages in Absorber



Figure 4.4 Percentage of Water Removal versus Gas Flow Rate at 8 Theoretical Stages in Absorber



Stages in Absorber

4.2.1 Pressure Variations

Figure 4.1 shows that at constant temperature, the percentage of water removal of the inlet gas decreased with the increasing pressure thus less of water removed if the gas is dehydrated at the higher pressure. Figure 4.1 also shows that the most highest efficiency of dehydration was at 7000kPa, followed by 8000kPa, 9000kPa, 10000kPa and the lowest efficiency of dehydration was 12000kPa. Figure 4.2, 4,3, 4.4 and 4.5 show an identical pattern of graphs generated which also shows that at 7000kPa, the highest dehydration occurred followed by 8000kPa, 9000kPa, 10000kPa.

Ken Arnold and Maurice Stewart (1999) stated that by increasing pressure, there was less contact between natural gas and TEG in the absorber. At lower pressure less wall thickness of absorber is required to contain the pressure in a given diameter absorber. Thus, it is more economical which lowered the cost of contactor. It can be explain more that the amount of water removed is less if the operating pressure is higher. At the lower pressure, wall thickness required lesser. The result obtained for these simulations identical to the theory.

4.2.2 Gas Flow Rates

Figure 4.1 shows that the percentage of the water removal in the inlet gas was increased when the flow of the inlet gas was decreased. From this Figure, it shows that the highest was water removal in the contactor was 100MMSCFD, followed by 200MMSCFD, 300MMSCFD, 400MMSCFD and 500MMSCFD. By referred to Figure 4.2, 4.3, 4.4 and 4.5, results from Figures 4.2, 4.3, 4.4 and 4.5 have the same trends with 100MMSCFD of gas inlet flowrate as the highest water efficiency remove. However, Figure 4.2 shows that the lowest percentage of water removal was at 300MMSCFD.

At the constant flow of TEG and the higher flow rate of the gas inlet, the contact time between TEG and inlet gas was higher. Thus, more water from the gas will be absorbed by the TEG. This hypothesis can be related to the variations of the TEG flowrate and constant gas flow rate. According to Mohamadbeigy, (2008) the higher TEG flowrate will increase the water dehydration efficiency. The condition
was the same as the natural gas flow decreased and the TEG flow rate kept constant. Thus all the result obtained was identically to the theory.

4.2.3 Number of Theoretical Stages

Refer to Figure 4.1; the contactor with 2 theoretical stage has the lowest efficiency of water that have been removed. By increasing the number of stages to 4, 6, 8 and 10, the amount of water removed was slightly increased. Thus, same case occurred as in Figure 4.2, 4.3, 4.4 and 4.5.

In the past research by the Lars Eric (2002), the increased number of the theoretical trays with constant TEG concentration lowered the circulation rate of TEG. It can be explained by at the higher number of the theoretical stages, lower circulation rate of TEG makes the increasing of water removal percentage. The more trays, the greater the dewpoint depression for a constant TEG circulation rate and lean TEG concentration (Vincente, 2006). As mentioned by the Mohamadbeigy, (2008), increasing number of trays will increase the percentage of water removal and at the same time allow the gas to approach equilibrium with the lean glycol at a lower circulation rate.

4.2.4 Inlet Gas Temperature

	Percentage of Water Removal										
Gas Temperature (°C)	2	4	6	8	10						
30	56.11	93.15	93.94	94.48	94.03						
40	56.06	92.73	93.94	93.98	93.98						
50	56.02	92.69	93.89	93.98	93.98						
60	55.97	92.64	93.84	93.94	93.94						
70	55.93	92.59	93.89	93.89	93.94						

Table 4.6 Percentage of Water Removal on inlet gas temperature and TheoreticalStages in Absorber at 7000 kPa



Absorber

From the Figure 4.6, the graph shows that at 7000kPa, the gas temperature of 30°C shows the highest efficiency of water removed in the absorber. This is followed by 40°C, 50°C, 60°C, and 70°C. Previous studies state that at constant pressure, the water content of the inlet gas increase as the inlet gas temperature increase. At higher

temperature, TEG need to remove about 3 times greater than a standard volume. Plus, by increasing gas temperature may result in an increase of diameter of the contactor. Thus all the result obtained was identically to the theory.

4.3 Optimization

A new method to determine the optimum performance of natural gas processing plant has been developed. Most of the natural gas industry used the Aspen HYSYS as their modelling simulator as it has the special package in this field. This advantages technology helps to achieve a certain demand by evaluating the most optimize parameters that must be controlled In order to have the highest efficiency in the process. This also can brought to an economical trade off by determining the set of economically optimum operating conditions. Moreover, the optimization is important to control the amount of BTEX emissions in the dehydration process which is release from the regeneration column along with water vapor.

From this research and study, the parameter that have been chosen to be optimize are as below:

Pressure in Contactor (kPa)	7000
Gas inlet flowrate (MMSCFD)	300
Number of Theoretical stages	8
Gas inlet temperature (°C)	30

 Table 4.7 Optimized parameter

Pressure of 7000 kPa has been chosen instead of 8000,9000,10000 and 12000 Kpa. The resultsfrom this study relatively showed that at this pressure the efficiency of the water removed was the highest. Gas flowrate of 300 MMSCFD has been chosen. When the gas was travelled at 100 MMSCFD, the water being removed was high, but it is lower to the requirement that is not feasible. At 300 MMSCFD, the water content have been reduced from 38.75 lb/mmscf to 3.2 lb/mmscf that is meet the sale gas specification range from 2 to 7 lb/mmscf. Since glycol circulation rate is determine by the gas flow rate, the lower glycol circulation rate will is needed. This will lower the amount of BTEX and hydrocarbons venting to the atmosphere. Table shows the amount of venting emissions from the stripper

Benzene	0.15483 kgmole/h
Toluene	0.20450 kgmole/h
Ethylbenzene	2.7123e- ³ kgmole/h
o-Xylene	0

 Table 4.8 BTEX emissions from striper

For the number of theoretical stages in the contactor, 8 number of trays has been chosen. According to the theory by, it is discuss that the efficiency of dehydration will be increase with the number of theoretical stages. By referring to this study, the number of stages of 8 and 10 has the same efficiency. Thus, 8 theoretical stages was chosen for both the economical and effectiveness. Increasing the number of theoretical tray allow the gas to approach equilibrium with the lean glycol at lower glycol circulation rate. Operating temperature of inlet gas has been set to 30°C as it shows the highest efficiency of water removed. This is because, the higher gas temperature require more glycol circulation rate since:

- 1. There is an exponential increase in the water vapour content of the saturated feed gas
- 2. The higher inlet dewpoint requires a higher dewpoint depression
- 3. There is an increase in the contacting temperature which increase the equilibrium water content of gas in contact with the glycol, hence reduces the dehydrating driving force.

4.4 **Problem Faced**

The most problem occurred in the simulation by using HYSYS is convergence problem. It is important to not too over specified in each of the unit inserted. HYSYS cannot read and calculate the certain value and the simulation cannot be proceed. Most of the problem occurred at the distillation column. The distillation column cannot be easily inserted by assuming the value of the parameter such as reflux ratio, overhead outlet flow and also bottom outlet flow. This must be design properly by doing a calculation and by specifying the actual reflux ration. This part is important because distillation column is the main of regeneration process of the TEG. Failure to design distillation column will affect overall plant. The second problem is the result get is not same as the theory. At first, the gas flow rate is set to 1000 m³/hr., 2000 m³/hr., 3000m³/hr., 4000m³/hr. and 5000m³/hr. When these flowrate is set to the simulation plant, there are no changes in the amount of water in the inlet and outlet of the gas. However, when the gas flow is changes to 100 MMSCF to 500 MMSCF, the simulation shows the changes in the amount of water removed. It is also important to make sure that the PFD plotted is correct

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

There are several process involved in purification of natural gas. One of the most important process is gas dehydration which the water present can cause a corrosion and hydrates. This paper presents the evaluation on effectiveness parameters on natural gas dehydration plant using absorption by liquid desiccant. Triethylene glycol (TEG) is chosen as the desiccants as it has most desirable criteria at commercial suitability. The main purpose of this study is to determine the optimum parameters in the gas dehydration plant that tend to remove water at higher efficiency.

Process simulations are conducted by evaluating the parameter that is inlet gas flow rate, number of theoretical stages, the glycol contactor pressure and inlet gas temperature. Aspen HYSYS was selected as the simulator while Peng-Robinson was selected as fluid package. As the result, the most optimise parameter have been decided that is 7000 kPa pressure of glycol contactor, 300 MMSCFD flow rate of inlet gas in the contactor, 8 number of theoretical stages of contactor and 30° C of inlet gas temperature. At this condition, the efficiency of water removed achieved is 93.98%.

5.2 **RECOMMENDATIONS**

Although the project objectives have been fully achieved, several recommendations have been considered for the good of the future, as stated below:

- Optimization of process parameters for glycol unit to mitigate the emission of BTEX/VOCs.
- Considering the other parameter that are listed in literature review that are flow rate of TEG entering the contactor, temperature of TEG Lean glycol and concentration TEG circulation rate.

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Figure A.1 McKetta and Wehe Water Content in Natural Gas Chart

APPENDIX B



Figure B.1 Process Flow Diagram

APPENDIX C

Operating Conditions at 7000 Kpa, 300 MMSCCFD, 30 ^OC, 8 Number Of Theoretical Stages

Inlet gas pressure7000kPaInlet gas flow300 MMSCFDInlet gas composition	Inlet gas temperature	30°C
Inlet gas flow300 MMSCFDInlet gas compositionCO20.0199N20.0015Methane0.9019Ethane0.0424Propane0.0186i-Butane0.0039n-Butane0.0046i-Pentane0.0012n-Pentane0.0012Mcyclopentan0.0002Gyclohexane0.0002r-Hotane0.0002r-Decane0.0002r-Decane0.0001r-Decane0.0001r-Borgene0.0001r-Borgene0.0001r-Borgene0.0002r-Borgene0.0002r-Borgene0.0002r-Borgene0.0002r-Borgene0.0001r-Borgene0.0001r-Borgene0.0001r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.0008r-Borgene0.008r-Borgene0.008r-Borgene0.008r-Borgene0.008 <th>Inlet gas pressure</th> <th>7000kPa</th>	Inlet gas pressure	7000kPa
Inlet gas composition CO2 0.0199 N2 0.0015 Methane 0.9019 Ethane 0.0424 Propane 0.0186 i-Butane 0.0039 n-Butane 0.0046 i-Pentane 0.0012 n-Pentane 0.0012 n-Hexane 0.0012 Mcyclopentan 0.0001 Benzene 0.0002 Cyclohexane 0.0002 n-Octane 0.0002 n-Decane 0.0001 o-xylene 0.0000 H2O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 105 kPa Equilibrium trays in contactor 8	Inlet gas flow	300 MMSCFD
CO20.0199N20.0015Methane0.9019Ethane0.0424Propane0.0186i-Butane0.0039n-Butane0.0046i-Pentane0.0012n-Pentane0.0012Mcyclopentan0.0002Benzene0.0003n-Heptane0.0002Cyclohexane0.0002n-Octane0.0002n-Decane0.0001TeGlycol0.0000H2O0.0008Lean glycol temperature35°CRich glycol flash pressure7080 kPaEquilibrium trays in contactor8	Inlet gas composition	
N2 0.0015 Methane 0.9019 Ethane 0.0424 Propane 0.0186 i-Butane 0.0039 n-Butane 0.0046 i-Pentane 0.0012 n-Pentane 0.0012 n-Hexane 0.0002 Kyclopentan 0.0003 n-Heptane 0.0002 Cyclohexane 0.0002 n-Octane 0.0002 n-Decane 0.0001 o-sylene 0.0001 H2O 0.0000 H2O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa	CO ₂	0.0199
Methane 0.9019 Ethane 0.0424 Propane 0.0186 i-Butane 0.0039 n-Butane 0.0046 i-Pentane 0.0012 n-Pentane 0.0012 n-Hexane 0.0012 Mcyclopentan 0.0002 Cyclohexane 0.0003 n-Heptane 0.0002 n-Octane 0.0002 n-Decane 0.0001 o-xylene 0.0001 H2O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa	N_2	0.0015
Ethane 0.0424 Propane 0.0186 i-Butane 0.0039 n-Butane 0.0046 i-Pentane 0.0012 n-Pentane 0.0012 n-Hexane 0.0012 Mcyclopentan 0.0004 Benzene 0.0002 Cyclohexane 0.0003 n-Heptane 0.0007 Toluene 0.0002 n-Decane 0.0001 o-xylene 0.0001 TEGlycol 0.0000 H_2O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa	Methane	0.9019
Propane 0.0186 i-Butane 0.0039 n-Butane 0.0046 i-Pentane 0.0018 n-Pentane 0.0012 n-Hexane 0.0012 Mcyclopentan 0.0004 Benzene 0.0002 Cyclohexane 0.0003 n-Heptane 0.0002 n-Octane 0.0002 n-Decane 0.0001 TEGlycol 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa	Ethane	0.0424
i-Butane 0.0039 n-Butane 0.0046 i-Pentane 0.0018 n-Pentane 0.0012 n-Hexane 0.0012 Mcyclopentan 0.0004 Benzene 0.0002 Cyclohexane 0.0003 n-Heptane 0.0007 Toluene 0.0002 n-Decane 0.0002 n-Decane 0.0001 TEGlycol 0.0000 H ₂ O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa Equilibrium trays in contactor 8	Propane	0.0186
n-Butane 0.0046 i-Pentane 0.0012 n-Pentane 0.0012 n-Hexane 0.0012 Mcyclopentan 0.0004 Benzene 0.0002 Cyclohexane 0.0003 n-Heptane 0.0007 Toluene 0.0002 n-Octane 0.0002 n-Decane 0.0001 TEGlycol 0.0000 H2O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 105 kPa Equilibrium trays in contactor 8	i-Butane	0.0039
i-Pentane0.0018n-Pentane0.0012n-Hexane0.0012Mcyclopentan0.0004Benzene0.0002Cyclohexane0.0003n-Heptane0.0007Toluene0.0002n-Octane0.0002n-Decane0.0001o-xylene0.0000TEGlycol0.0000H₂O0.0008Lean glycol temperature35°CRich glycol flash pressure7080 kPaRegenerator pressure105 kPaEquilibrium trays in contactor8	n-Butane	0.0046
n-Pentane 0.0012 n-Hexane 0.0012 Mcyclopentan 0.0004 Benzene 0.0002 Cyclohexane 0.0003 n-Heptane 0.0007 Toluene 0.0002 n-Octane 0.0002 n-Decane 0.0001 o-xylene 0.0000 TEGlycol 0.0000 H_2O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa Equilibrium trays in contactor 8	i-Pentane	0.0018
n-Hexane 0.0012 Mcyclopentan 0.0004 Benzene 0.0002 Cyclohexane 0.0003 n-Heptane 0.0007 Toluene 0.0002 n-Octane 0.0002 n-Decane 0.0001 o-xylene 0.0000 TEGlycol 0.0000 H ₂ O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa	n-Pentane	0.0012
Mcyclopentan 0.0004 Benzene 0.0002 Cyclohexane 0.0003 n-Heptane 0.0007 Toluene 0.0002 n-Octane 0.0002 n-Decane 0.0001 o-xylene 0.0000 TEGlycol 0.0000 H ₂ O 0.0008 Kean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa	n-Hexane	0.0012
Benzene 0.0002 Cyclohexane 0.0003 n-Heptane 0.0007 Toluene 0.0002 n-Octane 0.0002 n-Decane 0.0001 o-xylene 0.0000 TEGlycol 0.0000 H ₂ O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa Equilibrium trays in contactor 8	Mcyclopentan	0.0004
Cyclohexane 0.0003 n-Heptane 0.0007 Toluene 0.0002 n-Octane 0.0002 n-Decane 0.0001 o-xylene 0.0000 TEGlycol 0.0008 H ₂ O 0.0008 Kean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa Equilibrium trays in contactor 8	Benzene	0.0002
n-Heptane 0.0007 Toluene 0.0002 n-Octane 0.0002 n-Decane 0.0001 o-xylene 0.0000 TEGlycol 0.0000 H ₂ O 0.0008 Kich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa Equilibrium trays in contactor 8	Cyclohexane	0.0003
Toluene 0.0002 n-Octane 0.0002 n-Decane 0.0001 o-xylene 0.0000 TEGlycol 0.0000 H2O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa Equilibrium trays in contactor 8	n-Heptane	0.0007
n-Octane 0.0002 n-Decane 0.0001 o-xylene 0.0000 TEGlycol 0.0000 H2O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa Equilibrium trays in contactor 8	Toluene	0.0002
n-Decane 0.0001 o-xylene 0.0000 TEGlycol 0.0000 H ₂ O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa Equilibrium trays in contactor 8	n-Octane	0.0002
o-xylene 0.0000 TEGlycol 0.0000 H ₂ O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa Equilibrium trays in contactor 8	n-Decane	0.0001
TEGlycol 0.0000 H ₂ O 0.0008 Lean glycol temperature 35°C Rich glycol flash pressure 7080 kPa Regenerator pressure 105 kPa Equilibrium trays in contactor 8	o-xylene	0.0000
H2O0.0008Lean glycol temperature35°CRich glycol flash pressure7080 kPaRegenerator pressure105 kPaEquilibrium trays in contactor8	TEGlycol	0.0000
Lean glycol temperature 35° CRich glycol flash pressure 7080 kPaRegenerator pressure 105 kPaEquilibrium trays in contactor 8	H ₂ O	0.0008
Rich glycol flash pressure7080 kPaRegenerator pressure105 kPaEquilibrium trays in contactor8	Lean glycol temperature	35°C
Regenerator pressure105 kPaEquilibrium trays in contactor8	Rich glycol flash pressure	7080 kPa
Equilibrium trays in contactor 8	Regenerator pressure	105 kPa
	Equilibrium trays in contactor	8

13	GLYCOL VAPOUR TO OVERHEAD VENT CONDENSER	Vapour	109	100.00		1.0000	38.25	719		719.47	0.77	0.66	18.809	0.012		I	I	I	
12	LEAN GLYCOL FROM P-2380A/E TO GLYCOL COOLER	Liquid	10381	87.90		0.0000	67.80	10000		1	:	I		1		10000	9.1923	1087.87	5 A)
11	LEAN GLYCOL TO P-2380A/B	Mixed	101	91.01		0.0000	67.80	10000		0.04	0.00	0.62	18.527	0.013		10000	9.3811	1065.97	00 V
10	LEAN GLYCOL TO SURGE DRUM	Mixed	105	91.03		0.0003	67.79	9666		0.32	0.00	1910	18.463	0.013		9666	9.3772	1065.95	A 08
6	LEAN GLYCOL TO E-2370	Mixed	110	124.75		0:0001	67.79	9666		0.11	0.00	0.63	19.026	0.015		9666	9.6343	1037.52	212
8	LEAN GLYCOL TO E-2360	Liquid	115	204.00		0.0000	67.79	9666			:			-		9666	10.3569	965.14	0.57
L	RICH GLYCOL TO REGENERATOR	Mixed	265	160.00		0.0023	86.74	9#201		4.97	0:00	1.83	24.743	0.014		10341	10.3500	999.09	117
9	VAPOUR OUTLET GLY COL FLASH VESSEL	Vapour	320	80.01		1.0000	3.25	74.05		74.05	0:07	2.50	22.77	0:01				I	:
5	HC CONDENSATE OUTLET FLASH VESSEL	Liquid	320	80.01		0.0000	TRACES	TRACES			:					TRACES	TRACES	672.07	95 U
4	RICH GLYCOL TO FILTER	Liquid	320	80.01		0.0000	86.74	10346		00:0	00:0	2.50	22.775	0.013		10346	9.6552	1071.51	6 M
3	RICH GLYCOL TO FLASH VESSEL	Mixed	370	80.00		0.0354	89.99	10420		72.15	0.06	2.87	22.642	0.013		10348	9.6573	1071.47	5 99
2	RICH GLYCOL TO WARM GLYCOL/GLYCO L HEAT EXCHANGER	Mixed	420	46.28		0.0341	89.99	10420		68.44	0:06	3.57	22.323	0.012		10351	9.4110	1099.91	13.02
Ļ	RICH GLYCOL FROM GLYCOL CONTACTOR	Liquid	10181	40.11		0.0000	89.99	10420		1	1					10420	9.4022	1108.22	14 40
STREAM NUMBER DESCRIPTION	5		кРа	D0			kgmole/h	kg/h		kg/hr	MMSCFD	kg/m ³		сР		kg/hr	m ³ /h	kg/m ³	đ
	Phase	Pressure	Temperature	Overall	Vapour Fraction	Total Flow	Mass Flowrate	Vapour	Vapour Mass Flow	Vapour Std Gas Flow	Vapour Density	Vapour Molecular Weight	Vapour Viscosity	Liquid	Liquid Mass Flow	Liquid Actual Flow	Liquid Density	Lionid Viscosity	

APPENDIX D

 Table D.1 Heat and Material Balance