NATURAL GAS DEHYDRATION USING TRIETHYLENE GLYCOL (TEG)

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Date :

NATURAL GAS DEHYDRATION USING TRIETHYLENE GLYCOL (TEG)

AHMAD SYAHRUL BIN MOHAMAD

Submitted to the Faculty of Chemical & Natural Resources Engineering
in partial fulfillment of the requirements for the degree of Bachelor of
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Faculty of Chemical & Natural Resources Engineering
University Malaysia Pahang

APRIL 2009

I declare that this thesis entitled "Gas Dehydration using Triethylene Glycol (TEG)" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Name	: AHMAD SYAHRUL BIN MOHAMAD
Date	: 21 APRIL 2009

Dedicated, in thankful appreciation for support,
encouragement and understanding to my beloved family,
friends and my supervisor

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Assalamualaikum wbt…

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Wassalam

ABSTRACT

Dehydration of natural gas is the process removal of the water that is associated with natural gases. The objectives of this experiment is to remove water content in natural gas by using triethylene glycol (TEG).The mixtures of water in natural gas can cause the problems for the production operation, transportation, storage and use of the gas. The four major methods of dehydration are absorption, adsorption, gas permeation and refrigeration. The process of dehydration by using TEG is absorption, involves the use of a liquid desiccant to remove water content from the gas. This research focused on the effect of operating pressure and volumetric flowrate of natural gas. Before that, the engineering works was applied in order to make dehydration unit for the experimental of dehydration such as designing, fabricate and testing. From the result of experimental, the highest amount water content was removed when the operating pressure at lowest and the volumetric flowrate at highest. Higher amount of water content can be removed in the future study by carrying out the better dehydration unit.

ABSTRAK

Penyahhidratan gas asli adalah proses penyingkiran air yang telah bersatu dengan gas asli.Objektif experimen ini adalah untuk membuang air yang terkandung di dalam gas asli dengan menggunakan triethylene glycol (TEG).Penyatuan air dengan gas asli ini boleh memberi masalah terhadap operasi pengeluaran,pengangkutan,penyimpanan dan kegunaan gas itu sendiri.Empat kaedah yang utama yang digunakan dalam penyahidratan adalah penyerapan, penjerapan, penelapan gas dan pendiginan. Proses penyahhidratan yang menggunakan TEG ini adalah proses penyerapan,melibatkan pengunaan cecair penyerap untuk membuang air daripada gas.Kajian ini tertumpu terhadap kesan tekanan operasi dan kadar aliran gas asli.Sebelum itu,kerja-kerja kejuruteraan telah diaplikasikan di dalam pembuatan sebuah unit pengdehidratan yang telah digunakan dalam experimen penyahhidratan seperti mereka bentuk ,membina dan menguji.Daripada hasil kajian yang diperolehi,kandungan air yang tertinggi telah dapat disingkirkan apabila pada tekanan operasi yang paling rendah dan kadar aliran gas yang paling tinggi. Lebih banyak kandungan air dapat disingkirkan pada kajian akan datang dengan menggunakan unit pengdehidratan yang lebih baik.

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LIST OF ABBREVIATION

CH_4	-	Methane
H_2S	-	Hydrogen sulfide
$Al_2 O_3$	-	Aluminum oxide
SiO_2	-	Silicon dioxide
TEG	-	Triethylene glycol
EG	-	Ethylene glycol
DEG	-	Diethylene glycol
TREG	-	Tetraethylene glycol
MEG	-	Monoethylene glycol
C_2H_6	-	Ethane
C_3H_8	-	Propane
C_4H_{10}	-	Butane
CO_2	-	Carbon dioxide
O_2	-	Oxygen
N_2	-	Nitrogen
PFR	-	Plug flow reactor

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Today, natural gas is one of the most important fuels in our life and one of the principle sources of energy for many of our day-to-day needs and activities. It is important factor for the development of countries that have strong economies because its source of energy for household, industrial and commercial use, as well as to generate electricity. Natural gas, in itself, might be considered a very uninteresting gas - it is colorless, shapeless, and odorless in its pure form, but it is one of the cleanest, safest, and most useful of all energy sources. Natural gas is a gaseous fossil fuel. Fossil fuels are essentially, the remains of plants and animals and microorganisms that lived millions and millions of years ago. It consisting primarily of methane but including significant quantities of ethane, propane, butane, and pentane. Methane is a molecule made up of one carbon atom and four hydrogen atoms, and is referred to as CH_4. Natural gas is considered 'dry' when it is almost pure methane, having had most of the other commonly associated hydrocarbons removed. When other hydrocarbons are present, the natural gas is 'wet'[1].

The natural gas used by consumers is composed almost entirely of methane. However, natural gas found at the wellhead, although still composed primarily of methane, is by no means as pure. Raw natural gas comes from three types of wells: oil wells, gas wells, and condensate wells. Natural gas that comes from oil wells is typically termed 'associated gas'. This gas can exist separate from oil in the formation (free gas), or dissolved in the crude oil (dissolved gas). Natural gas from gas and condensate wells, in which there is little or no crude oil, is termed nonassociated gas. Gas wells typically produce raw natural gas by itself, while condensate wells produce free natural gas along with a semi-liquid hydrocarbon condensate. Whatever the source of the natural gas, once separated from crude oil it commonly exists in raw natural gas or sour gas [2].The raw natural gas contains water vapor, hydrogen sulfide (H_2S), carbon dioxide, helium, nitrogen, and other compounds .In order to meet the requirements for a clean, dry, wholly gaseous fuel suitable for transmission through pipelines and distribution for burning by end users, the gas must go through several stages of processing, including the removal of entrained liquids from the gas, followed by drying to reduce water content [3].

In order to remove water content, dehydration process is used to treat the natural gas. Dehydration (hypohydration) is the removal of water from an object. In Physiologic terms, it entails a relative deficiency of water molecules in relation to other dissolved solutes. Gas dehydration is one of the most prominent unit operations in the natural gas industry. In this operation water content is removed from natural gas streams to meet sales specifications or other downstream gas processes such as gas liquid recovery. In particular, water content level in natural gas must be maintained below a certain threshold so as to prevent hydrate formation and minimize corrosion in transmission pipelines . The lifetime of a pipeline is governed by the rate at which corrosion occurs which is directly linked with presented of water content in gas that causing the formation of hydrates can reduce pipeline flow capacities, even leading to blockages, and potential damage to process filters , valves and compressors. That may prevented by lowered the content of water in natural gas and all at once save maintenance cost of pipeline [4].

The types of dehydration process used are absorption, adsorption, gas permeation and refrigeration. The most widely dehydration processes used are which usually involves one of two processes: either absorption, or adsorption. Absorption occurs when the water vapor is taken out by a dehydrating agent. Adsorption occurs when the water vapor is condensed and collected on the surface [5].

1.2 Problem Statement

Natural gas that comes from oil wells is not totally pure but there are contaminants or mixtures in gas or typically termed 'associated gas' like water vapor, hydrogen sulfide (H_2S), carbon dioxide, helium, nitrogen, and other. These mixtures in natural gas can cause the problems for the production operation, transportation, storage and use of the gas. One of those contaminants is water content. This water can result in corrosion of pipeline and fittings in gas transmission systems and the formation of ice or hydrates that causing flow restriction, with resulting consequences in terms of plant operating efficiency.

1.3 Objective

To remove water content in natural gas by using triethylene glycol (TEG).

1.4 Scope of Study

1. Fabrication of dehydration unit.
2. Investigate the effect of operating pressure and volumetric flowrate of natural gas toward dehydration.
3. Analyze the water content is removed in natural gas.

CHAPTER 2

LITERATURE REVIEW

2.1 Types of Dehydration of Natural Gas

Dehydration of natural gas is the process removal of the water that is associated with natural gases. The natural gas industry has recognized that dehydration is necessary to ensure smooth operation of gas transmission lines. Several methods have been developed to dehydrate gases on an industrial scale. The four major methods of dehydration are absorption, adsorption, gas permeation and refrigeration. Absorption dehydration involves the use of a liquid desiccant to remove water content from the gas. Although many liquids possess the ability to absorb water content from gas, the liquid that is most desirable to use for commercial.

Adsorption (or solid bed) dehydration is the process where a solid desiccant is used for the removal of water content from a gas stream. The solid desiccants commonly used for gas dehydration are those that can be regenerated and, consequently, used over several adsorption-desorption cycles. The mechanisms of adsorption on a surface are of two types; physical and chemical. The latter process, involving a chemical reaction, is termed "chemisorption". Chemical adsorbents find very limited application in gas processing. Adsorbents that allow physical adsorption hold the adsorbate on their surface by surface forces. For physical adsorbents used in gas dehydration, the following properties are desirable:

i. large surface area for high capacity. Commercial adsorbents have a surface area of 500-800 m /g.
ii. good "activity" for the components to be removed and good activity retention with time/use.
iii. high mass transfer rate or high rate of removal.
iv. easy, economic regeneration.
v. small resistance to gas flow, so that the pressure drop through the dehydration system is small.
vi. high mechanical strength to resist crushing and dust formation. The adsorbent also must retain enough strength when "wet".
vii. cheap, non-corrosive, non-toxic, chemically inert, high bulk density, and small volume changes upon adsorption and desorption of water.

The most widely used adsorbents today are activated alumina, silica gel, molecular sieves (zeolites). A hydrated form of aluminum oxide ($Al_2 O_3$), alumina is the least expensive adsorbent. It is activated by driving off some of the water associated with it in its hydrated form (($Al_2 O_3.3H_2 O$) by heating. It produces an excellent dew point depression values as low as -100 ^{0}F, but requires much more heat for regeneration.

Gels are granular, amorphous solids manufactured by chemical reaction. Gels manufactured from sulfuric acid and sodium silicate reaction are called silica gels, and consist almost solely of silicon dioxide (SiO_2). In chemistry, silica gel is used in chromatography as a stationary phase. In column chromatography the stationary phase is most often composed of silica gel particles of 40-63 µm. In this application, due to silica gel's polarity, non-polar components tend to elute before more polar ones, hence the name normal phase chromatography. The advantages of silica gel as a desiccant is too much. So, this is more important about silica gel. Silica gel has many other properties that recommend it as a desiccant.

It will adsorb up to one third of its own weight of water content in natural. This adsorption efficiency is approximately 35% greater that typical desiccant clays, making silica gel the preferred choice where weight or efficiency are important factors. It also has an almost indefinite shelf life if stored in airtight conditions. It can be regenerated and reused if required. Gently heating silica gel will drive off the adsorbed water content and leave it ready for reuse. It is a very inert material, it will not normally attack or corrode other materials and with the exception of strong alkalis and hydrofluoric acid is itself resistant to attack. It is non-toxic and non-flammable. It is most frequently and conveniently used packed in a breathable sachet or bag. These are available in a wide range of sizes suitable for use with a wide range of applications. Standard white silica gel is referred to as being non-indicating. As it adsorbs water content it remains physically unchanged. Non-indicating silica gel is cheap and effective, available loose in bulk packs or packed in sachets. Silica gel also as a self-indicating silica gels are coloured.

Molecular sieves are a crystalline form of alkali metal (calcium or sodium) alumina-silicates, very similar to natural clays. Molecular sieves are used to obtain very low water levels in the processed gas (down to 0.03 ppm vol).They are highly porous, with a very narrow range of pore sizes, and very high surface area. Manufactured by ion-exchange, molecular sieves are the most expensive adsorbents and must be replaced every three years. Thus for structure A sieves, depending on the compensation cation, the size of the access cavities maybe about 3A (3A sieves), 4A (4A sieves) or 5A (5A sieves).They possess highly localized polar charges on their surface that act as extremely effective adsorption sites for polar compounds such as water and hydrogen sulfide. Solid desiccants or absorbents are commonly used for dehydrating gases in cryogenic processes. The use of solid adsorbent has been extended to the dehydration of liquid. Solid adsorbents remove water from the hydrocarbon stream and release it to another stream at higher temperatures in a regeneration step.

2.2 Dehydration by Using Triethylene Glycol (TEG)

There are numbers of liquids that can be used to absorb water from natural gases such as calcium chloride, lithium chloride and glycols. Glycol dehydration is a liquid desiccant system for the removal of water from natural gas. It is the most common and economic means of water removal from these streams [6]. Glycol, the principal agent in this process, has a chemical affinity for water. The liquid glycol will absorbs the water content in the natural gas. This means that, when in contact with a stream of natural gas that contains water, glycol will serve to 'steal' the water out of the gas stream. This operation is called absorption.

There are a few types of glycol usually used in industry with their advantages and disadvantages like ethylene glycol (EG), diethylene glycol (DEG), triethylene glycol (TEG), and tetraethylene glycol (TREG). One of the best glycol frequently used in industry is TEG. Essentially, glycol dehydration involves using a glycol solution, usually either DEG or TEG, which is brought into contact with the wet gas stream in what is called the 'contactor' or dehydration unit. The process function of glycol is absorbing the water from the wet gas. Once absorbed, the glycol particles become heavier and sink to the bottom of the contactor where they are removed. The natural gas, having been stripped of most of its water content, is then transported out of the dehydrator. Glycols typically seen in industry include monoethylene glycol (MEG) [2].Table 2.1 shows the properties of the glycols.

Usually, TEG is used because it is the most commonly used glycol in industry. TEG is used as absorber of water content in natural gas.TEG, or triglycol is a colourless, odourless viscous liquid with molecular formula $C_6H_{14}O_4$ and molecular structure as shown in Figure 2.1 [7].Although many liquids possess the ability to absorb water from gas, the liquid that is most desirable to use for commercial dehydration purposes should possess the following properties [8]:

i. Strong affinity for water
ii. High boiling points
iii. Low cost.
iv. Noncorrosive
v. Low affinity for hydrocarbons and acid gases.
vi. Thermal stability.
vii. Easy regeneration
viii. Low viscosity.
ix. Low vapor pressure at the contact temperature
x. Low solubility in hydrocarbon.
xi. Low tendency to foam and emulsify.

The rational of using TEG or advantages of TEG is ease of regeneration and operation, minimal losses of drying agent during operation, high affinity for water, chemical stability, high hygroscopicity and low vapor pressure at the contact temperature.

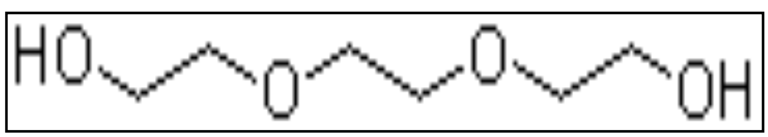

Figure 2.1: Molecular structure of triethylene glycol (TEG)

(Source: http://www.chemblink.com/products/112-27-6.htm,Accessed at 28 August 2008)

Table 2.1: The composition of natural gas

Components	Symbol	Percentage (%)
Methane	CH_4	70-90
Ethane	C_2H_6	0-20
Propane	C_3H_8	
Butane	C_4H_8	
Carbon Dioxide	CO_2	0-8
Oxygen	O_2	0-0.2
Nitrogen	N_2	0-05
Hydrogen Sulphide	H_2S	0-5
Rare Gases	A,He,Ne,Xe	trace

(Source: http://www.naturalgas.org/overview/background.asp,Accessed at 25 August)

Table 2.2: Properties of glycol

Physical Properties	Monoethylene Glycol (MEG)	Diethylene Glycol (DEG)	Triethylene Glycol (TEG)	Tetraethylene Glycol (TREG)
Formula	$C_2H_6O_2$	$C_4H_{10}O_4$	$C_6H_{14}O_4$	$C_8H_{18}O_5$
CAS Number	107-21-1	111-46-6	112-27-6	112-60-7
Molecular Weight, g/mol	62	106.12	150	194.2
Boiling Point @ 760 mm Hg, °C (°F)	197 (387)	245 (473)	288 (550)	329 (625) Decomposes
Vapor Pressure at 20°C (68°F) mm Hg	0.06	0.002	<0.01	<0.01
Density, (g/cc) @ 20°C (68°F)	1.115	1.118	1.125	1.124
Density, (g/cc) @ 60°C (140°F) 1.096	1.085	1.087	1.093	1.096
Pounds Per Gallon @ 25°C (77°F)	9.26	9.27	9.35	9.37
Freezing Point, °C (°F)	-13.4 (7.9)	-9.0 (16)	-4.3 (24)	-4 (25)
Pour Point, °C (°F)	<-59 (<-75)	-54 (-65)	-58 (-73)	-41 (-42)
Viscosity, cP @ 25°C (68°F)	16.9	35.7	49.0	58.3
Viscosity, cP @ 60°C (140°F)	5.2	7.3	10.3	11.4
Surface Tension, dynes/cm @ 25°C (77°F)	48	44.8	45.5	44.0
Refractive Index @ 20°C (68°F)	1.430	1.447	1.455	1.459
Specific Heat @ 25°C (77°F) Btu/lb/°F	0.58	0.55	0.52	0.52
Flash Point, °C (°F)	116 (241) [(2)]	154 (310) [(2)]	177 (350) [(2)]	202 (395) [(2)]
Dipole Moment in Debyes	2.28	2.69	2.99	3.25
Coefficient of Expansion x 104 (0-60°C)	6.5	6.6	7.2	7.3
Thermal Conductivity, Btu hr-1 ft-1 °F-1 25°C (77°F)	0.1490	0.1175	0.1133	0.1106
Thermal Conductivity, Btu hr-1 ft-1 °F-1 25°C (77°F)	0.1490	0.1175	0.1133	0.1106
Heat of Formation, Btu/lb@ 25°C (77°F)	-93	-131	-171	-212
Heat of Vaporization, Btu/lb@ 25°C (77°F)	369	234.4	179	139
Electrical Conductivity, mhos/cm,@20°C	1.07 [(3)]	0.0042 [(3)]	0.002 [(3)]	0.0016 [(3)]

(Source: http://www.dow.com/ Physical Properties l/index.htm,Accessed at 20 July 2008)

2.3 Dehydration Unit

Generally, in the glycol dehydration process as shown in Figure 2.2, TEG is pumped to the top of a dehydration unit or contactor tower where it is flow countercurrent with wet gas flowing up the tower. The TEG adsorbs water from the wet gas and is passed to the glycol regeneration unit where, very simply, adsorbed gases are flashed off and the water is removed from the reboiler by heating the wet glycol to around 400ºF at atmospheric conditions gas. The processes are continuous, that is glycol flow continuously through dehydration unit where they come in contact and the glycol absorbs the water. The regenerated TEG is then pumped back to the dehydration unit inlet [9].

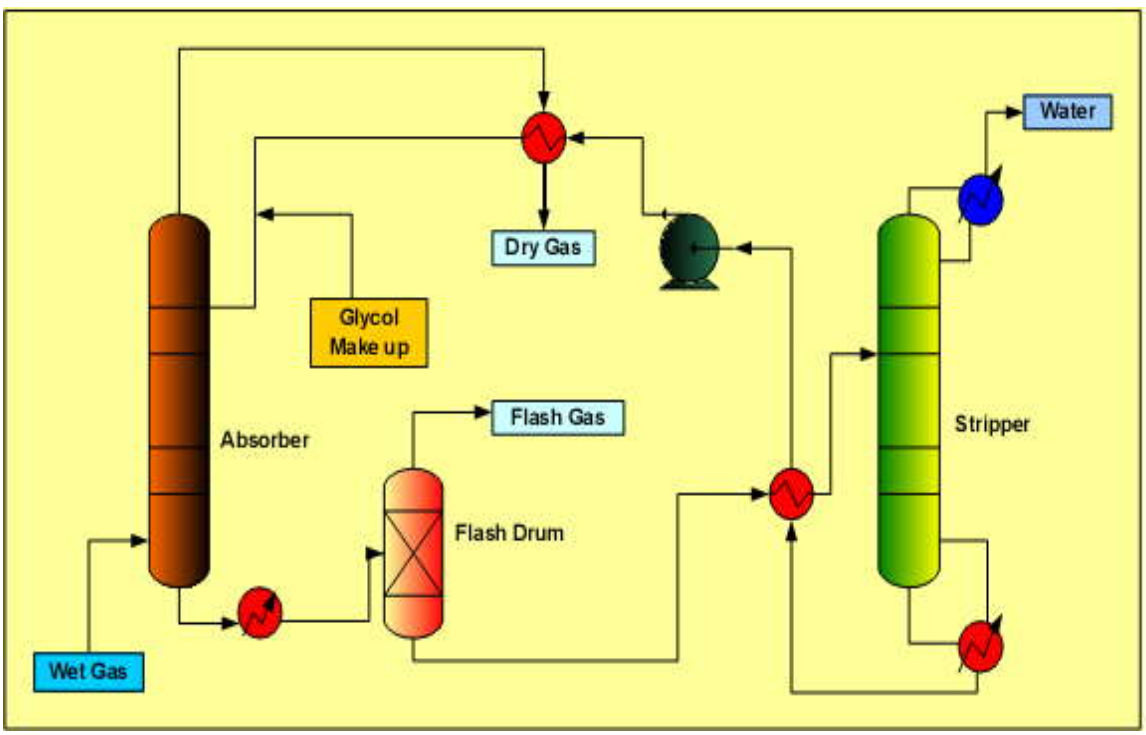

Figure 2.2: Flow sheme of glycol unit

(Source: Kh. Mohamadbeigy, Studying Of the Effectiveness Parameters on Gas Dehydration,Research Institute of Petroleum Industry Tehran, Iran)

The details process in the dehydration unit or contactor tower as shown in Figure 2.3, natural gas enters near the bottom of the dehydration unit and flows upwards through the internal trays/packing. Lean glycol enters the dehydration unit near the top and cascades down through the dehydration unit internals, making contact with the up-flowing gas stream. The counter-current flow path of the glycol and the high contact surface area adsorbs water into the glycol from the gas stream. Dehydrated natural gas flows out of the top of the dehydration unit, while the rich glycol flows out of the bottom of the dehydration unit [10].

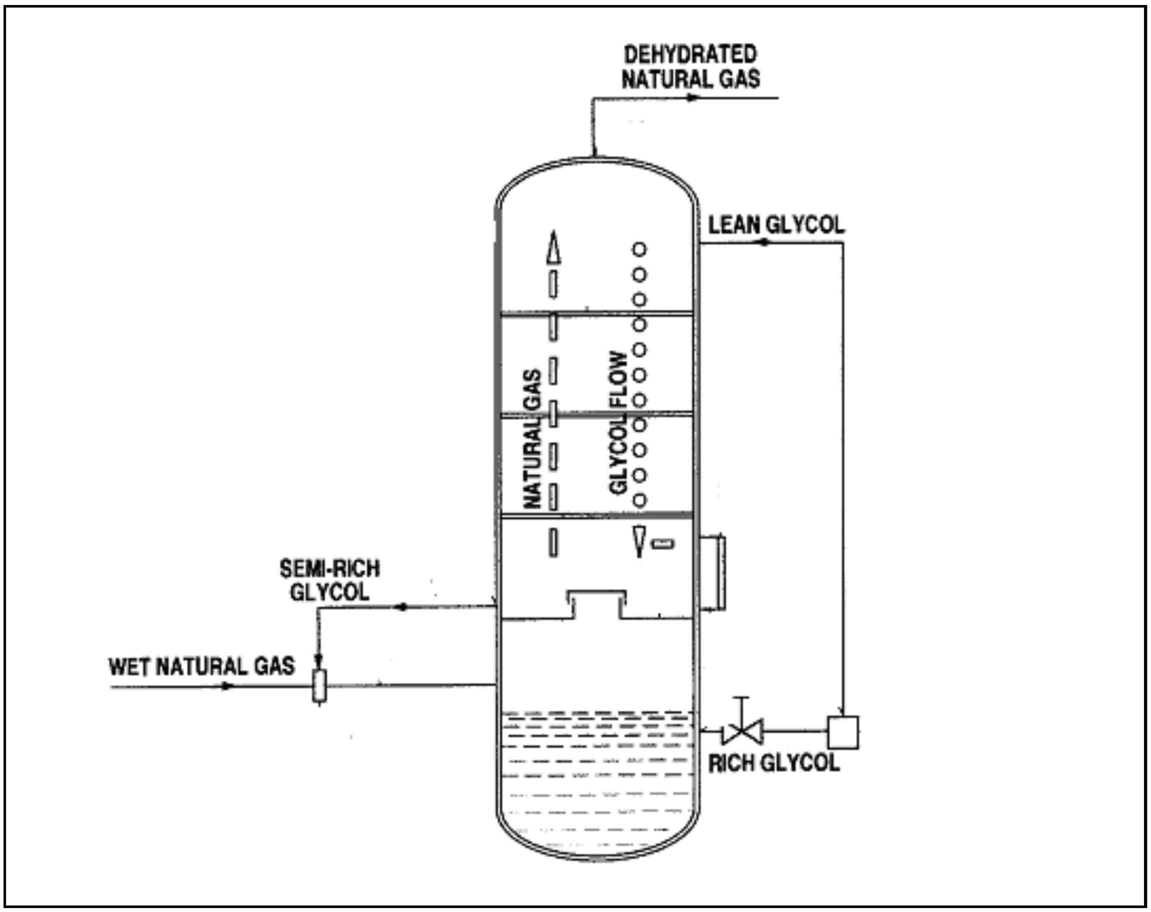

Figure 2.3: Dehydrator unit

(Source: Co-current and counter- current gas dehydration system, Paul Carmody,United Stated Patent)

The suitable type of unit used in dehydration is plug flow reactor (PFR) because it's continuously flow and provide turbulent profile for gas phase reaction which increases the efficiency of whole process. Moreover, PFR has high volumetric unit conversion, run for long periods of time without maintenance [11].

Plug flow reactors are used for some of the following applications:

i. large-scale reactions
ii. fast reactions
iii. homogeneous or heterogeneous reactions
iv. continuous production
v. high-temperature reactions

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the research work focuses the overall procedures. The methods that were used in this research are designing, fabrication, testing, experimental and analyzing. The detail procedures of the research are discussed through out this chapter.

3.2 Flow Chart of Methodology

The overall flows process of methodology in this study is summarized in Figure 3.1. The process flow was started with the preparation of material and component and ended with analyzing.

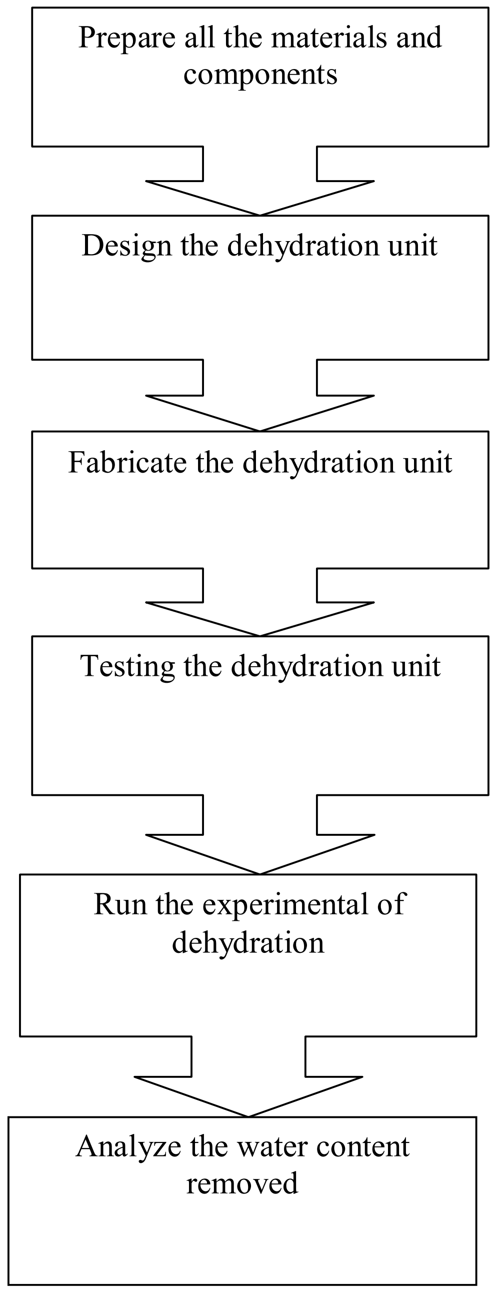

Figure 3.1: Overall methodology flow process

3.3 List of Material and Component

The material and component selection are important part in order to make a strongly built of dehydration unit. The selection of material and component also are depending on condition of experimental that wanted to test like pressure and temperature. The listed of material and component and also machine that was used in this research are as shown below:

3.3.1 Material

1. Triethylene glycol (TEG)
2. Untreated natural gas

3.3.2 Component

1. 4 inch PVC pipe clear(Schedule 40)-1 unit
2. Transparent plate-2 units
3. Steel relief valve-3 units
4. T-junction valve-1 unit
5. Teflone tube-1 unit
6. Gas bag
7. Plastic tube-1 unit
8. Gas hose-1 units
9. Glycol container-4 units
10. Disposable pipette
11. Natural gas regulator
12. Manual pump
13. Hydrostatic test pump

3.3.3 Machine

1. Bench drill
2. Cut off machine
3. Tap and die set
4. Hand drill
5. Jigsaw

3.4 Designing of Dehydration Unit

Designing is one of important method before the dehydration unit is fabricated. It is first process to know characteristic and dimension of unit wanted.

The characteristic in designing is defined the maximize pressure and temperature of components can stand. The operating pressure and temperature will be not exceeding 2 bar and $40^{o}C$. For that characteristics the best component was used like PVC pipe clear (Schedule 40) that can stand the maximum pressure of 7.58 bar and temperature higher than $40^{o}C$.

For the sizing ,the suitable ratio *Diameter: Length* of dehydration unit found are 1:2, 1:3, and 1:4.The most suitable ratio and was used is 1:4.In calculating, the diameter was estimated 10cm and length 42cm.For the precaution safety ,2cm of length was added.

The dimension in designing is defined the suitable dimension or position of inlet natural gas, outlet natural gas, inlet TEG and outlet TEG and the details dimension of unit is shows in Figure 3.2 . For example, the minimum level position of inlet natural gas was calculated by considering the maximum amount of glycol was used to avoid the flooding by referring Appendix B.

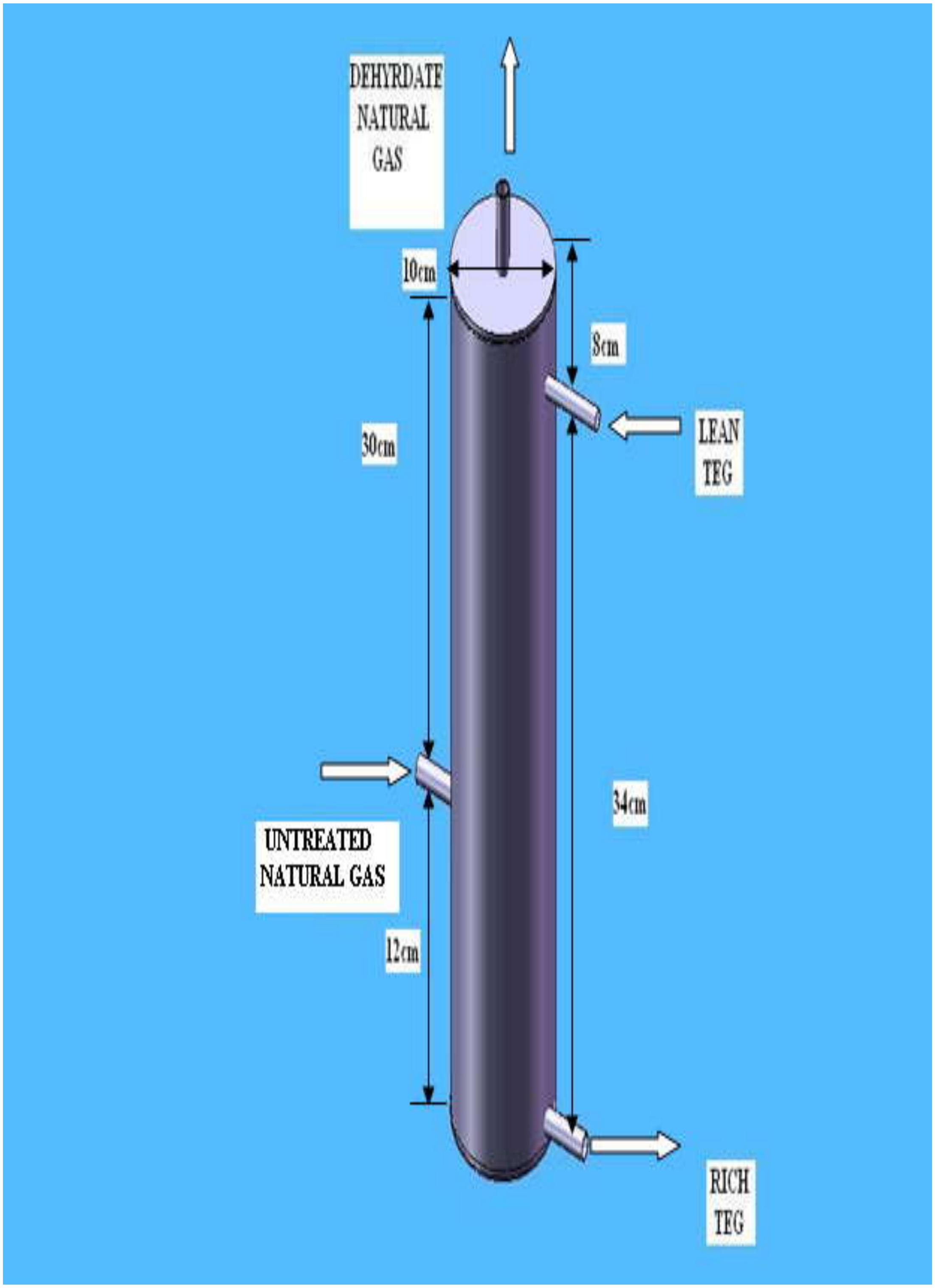

Figure 3.2: Overall dimension of dehydration unit

3.5 Fabrication of Dehydration Unit

Fabrication is process of making something from raw material. In this research, the dehydration unit was fabricated from components and by using machines that was listed before. Below are the methods how the dehydration unit was fabricated.

Step 1

The length of 4 inch PVC pipe (Schedule 40) was measured 42cm and cut by using cut off machine.

Step 2

Three holes were drilled about ½inch on surface of 4 inch PVC pipe for inlet flow untreated natural gas, inlet flow lean TEG and outlet flow for rich TEG by using bench drill. The holes that were drilled then threaded by using tap and die set.

Step 3

Then, steel relief valve was fixed in drilled holes for inlet flow untreated natural gas and outlet flow rich TEG .For the inlet flow lean TEG, the t-junction valve was fixed in that hole.

Step 4

Few small holes were drilled on the surface of teflone tube by using hand drill in order TEG can be spray out or out in drop less. Then, it was attached in hole of inlet flow lean TEG.

Step 5

A hole was drilled in the middle one of two transparent plates and fixed with steel relief valve for the outlet of dehydrate natural gas. The transparent plates were sticked for the caps at the top and the bottom of the 4 inch PVC pipe to make a pipe like a closed vessel by using strong gum.

Step 6

Finally, the manual pump was connected to t-junction valve of the inlet flow lean TEG via plastic tube.

3.6 Hydrostatic Test

Hydrostatic test is common procedure used to performance verify a fluid pressure vessel such as cylinder, boiler or tubes. Hydrostatic test also a command testing procedure to verify pressure vessel do not leak or have manufacturing flaws. In this research, hydrostatic testing was tested to dehydration unit because it is important for pressure unit in the interest of device safety and durability under operating pressure. Testing also is very important because the unit can explode if it fails when containing natural gas. Below are the methods how the dehydration unit was tested by using hydrostatic test pump as shown in Figure 3.3.

Step 1

All the valves of dehydration unit were closed and the dehydration unit was filled with a nearly incompressible liquid (water).

Step 2

In the first stage of pressurization, the water was pumped in using hydrostatic test pump until reach 50% of maximum test pressure. The pressure was maintained for a few minutes. All the potential leakage point was checked.

Step 3

In the second stage, pressurization will be continued until the pressure achieves the desire pressure.

Step 4

The pressure was let stabilize before it processed with the maintaining the pressure for 15 minutes. The pressure was recorded for every 3 minutes.

Step 5

After the hydrostatic pressure time has been satisfied, all the potential leakage point shall be examined visually for leaks. The leakage that was detected shall be repaired.

Figure 3.3: The hydrostatic test

3.7 Experimental of Dehydration

The experimental of dehydration is the process to remove the water content in natural gas at different operating pressure. The methods of experimental are as shown below.

Step 1

All the valves of dehydration unit were closed and the pressure regulator of natural gas tank was set at 0.2 bar.

Step 2

The natural gas was released from the tank into the dehydration unit by open valve of inlet flow natural gas in 5 second and then closed it.

Step 3

300mL of TEG was sprayed out via inlet flow lean TEG into the dehydration using manual pump.

Step 4

Then, all the valves were closed and the process was left about 1 hour for a complete contact between natural gas and TEG.

Step 5

The dehydrated natural gas was released in a gas bag by open the outlet flow of dehydrates natural gas valve as safety precaution avoid any ignition from surrounding. The gas in bag then released to a safer environment.

Step 6

The TEG that was sprayed out into the dehydration unit then was collected by open outlet flow rich TEG valve to analyze.

Step 7

Steps 1 to 6 were repeated for the operating pressure of 0.4 bar, 0.6 bar and 0.8 bar.

Figure 3.4: Experimental of dehydration process

3.8 Analyze the Water Content

Analyze the water content are measure the amount of water content that was removed in natural gas. The method that was used is quantitative analyzing not qualitative analyzing, where the amount of water trapped in TEG was calculated by using the equation as below:

Water Content =Volume of TEG after experiment - Volume of TEG before experiment

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discussed on the data collection from the experiments that have been carried out via dehydration unit. This chapter also covered on results in design, fabrication and testing of the unit.

The data collection which obtained from the experiment were analyzed in order to describe the effectiveness of absorption by using liquid desiccant such as TEG at different operating pressure and volumetric flowrate as well as to know the best condition of absorption process in natural gas.

4.2 Designing, Fabrication and Testing of Dehydration

In this result, the best selection of the dimension and the making of dehydration unit have been made. Then, the outcome of the unit was tested to know the maximum resistance of pressure and temperature allowable.

4.2.1 Designing of Dehydration Unit

Based on several journals, the best ratio Diameter: Length of dehydration unit is 1:4.This ratio is adapted into small scale in the solid work design before fabricated. Figure 4.1 shows the actual scale of diameter and length of dehydration unit. The diameter of unit is 10 cm and the length of unit is 42 cm. For the safety precaution 2 cm of length was added.

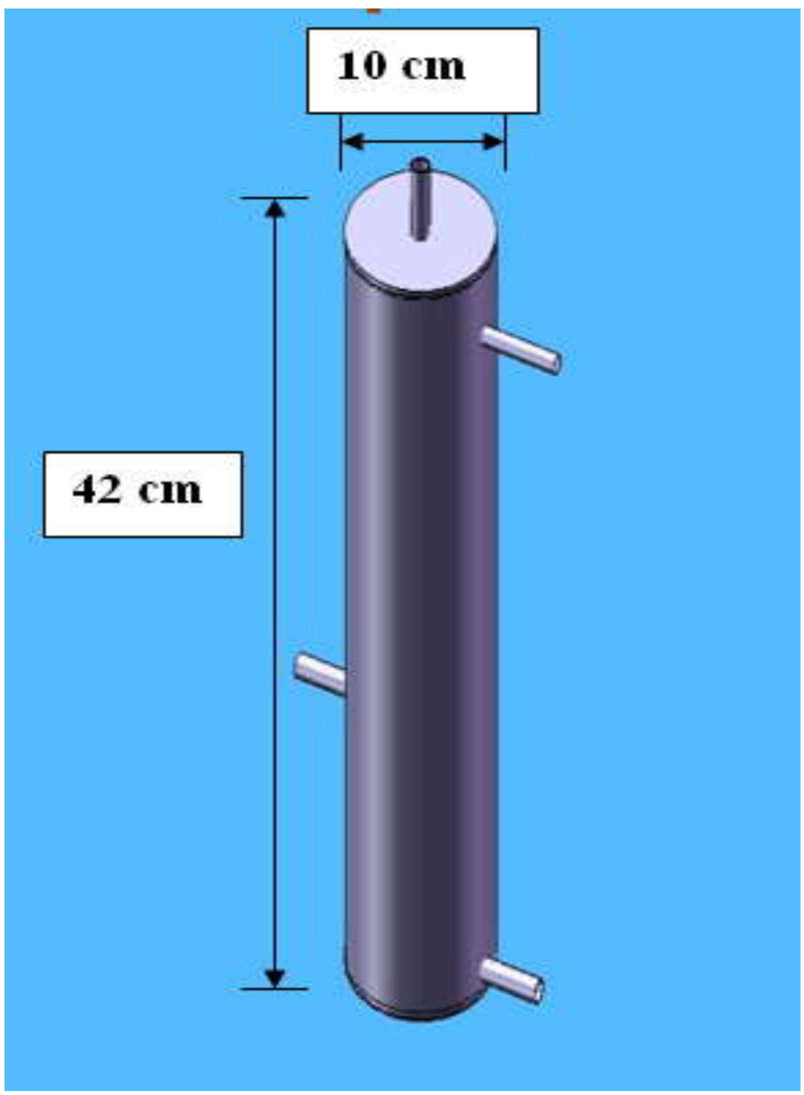

Figure 4.1: Dimension of dehydration unit

4.2.2 Fabrication of Dehydration Unit

In the fabrication stage, the suitable materials were selected to make a resistible unit as well as to avoid any leakage. The PVC pipe schedule 40 was used due to capability to resist the high pressure (7.58 bar maximum) and temperature. The best materials are important to build a firm dehydration unit. Figure 4.2 shows the main components in fabrication of dehydration unit.

Figure 4.2: The components in fabrication of dehydration unit

4.2.3 Testing of Dehydration Unit

The last stage in engineering work was testing the unit by hydrostatic test. The result shows that the maximum pressure allowable is 1.0 bar respectively as shown in Table 4.1. Beyond that pressure, the unit was unstable.

Table 4.1: The various pressure test on dehydration unit

Pressure (bar)	**Yes**	**No**
0.2	✓	
0.4	✓	
0.6	✓	
0.8	✓	
1.0	✓	
1.2		X
1.4		X

4.3 Effect of Operating Pressure on Dehydration

Table 4.2 shows the effect of the operating pressure on the dehydration of natural gas by using liquid desiccant TEG. The range of operating pressure was used in this experiment are 0.2 bar to 0.8 bar respectively.

Figure 4.3 shows that the operating pressure is inversely proportional with the amount of water content. At constant temperature the water content in natural gas increased when the pressure decreases. From the observation, pressure at 2.0 bar,17.70 mL of water content in natural gas was removed, however when the pressure increased to 0.8 bar, only 7.5 mL water was removed.

It is revealed that the increasing of pressure, a smaller diameter contact between natural gas and liquid desiccant TEG, which result less molecules of natural gas migrate across the gas- liquid interface and dissolved in liquid desiccant TEG. Hence, lower amount of water content is absorbed and removed by TEG. However when the pressure decreased, a large diameter contact between natural gas and liquid desiccant TEG, which result more molecules of natural gas migrate across the gas–liquid interface and dissolved in liquid desiccant TEG .Hence, higher amount of water content trapped and removed by TEG.

Table 4.2: The water content at different operating pressure

Pressure (bar)	Water Content (mL)
0.2	1.770
0.4	1.370
0.6	0.750
0.8	0.160

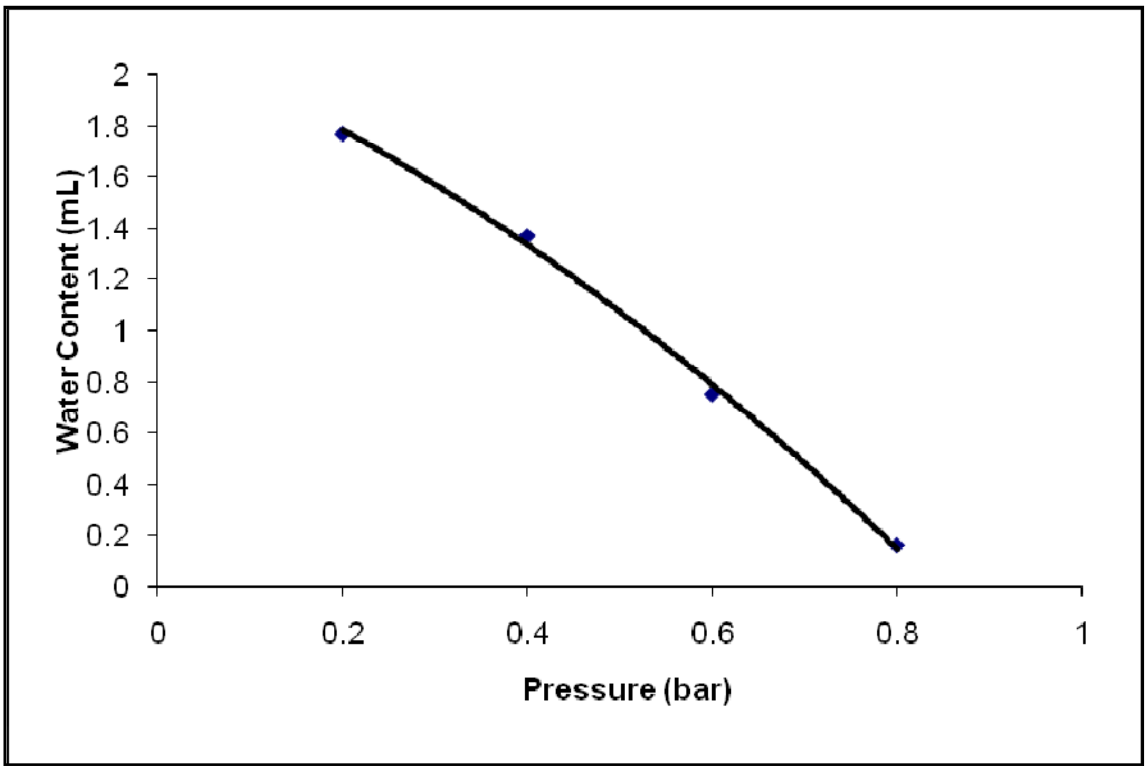

Figure 4.3: Effect of operating pressure toward dehydration

4.4 Effect of Volumetric Flowrate on Dehydration

Table 4.3 shows the effect of the volumetric flowrate toward the dehydration of natural gas by using liquid desiccant TEG. The water content increases when the volumetric flowrate was increased from 0.0081 m^3/s to 0.0325 m^3/s respectively.

Figure 4.4 reveals that the volumetric flowrate is directly proportional with the amount of water content. At constant temperature the water content in natural gas increased when the volumetric flowrate increases. From the observation when the volumetric flowrate at 0.0081 m^3/s,0.160 mL of water content in natural gas was removed, however when the volumetric flowrate increased to 0.0325 m^3/s , water content was removed to 1.770 mL.

Thus more water will be removed if the natural gas is dehydrated at a higher volumetric flowrate because of a larger diameter contact between natural gas and liquid desiccant TEG. It is proved that the evidence in idea gas equation (PV=nRT), pressure inversely proportional with volumetric flowrate. The ideal gas law of Boyle state that the volumetric flowrate of the gas is directly proportional to the absolute temperature and inversely proportional to the absolute pressure.

Table 4.3: The water content at different volumetric flowrate

Volumetric Flowrate (m^3/s)	**Water Content (mL)**
5.85	0.160
7.80	0.750
23.38	1.770

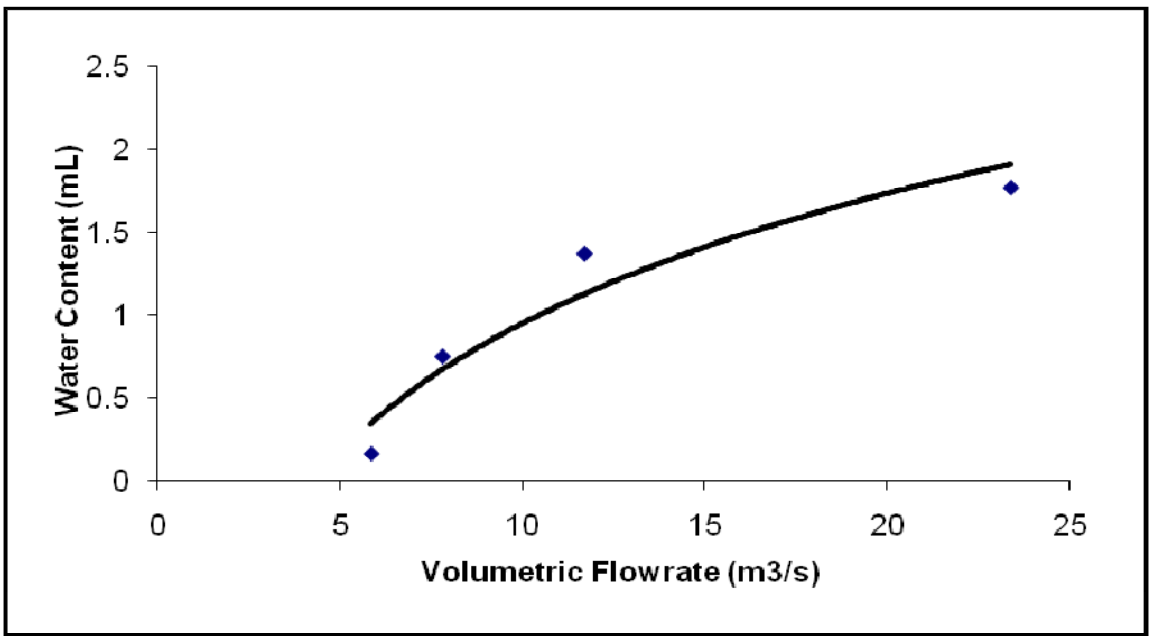

Figure 4.4: Effect of volumetric flowrate toward dehydration

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

In this chapter the overall scope of the study in the research is concluded and proposed. The main objective of this present study is to remove the water content in natural gas by using TEG. An analysis the performance of absorption by emphasizing important parameter of operating pressure and volumetric flowrate was conducted to obtain the comprehensive conclusion towards achieving the objective of the study.

5.2 Conclusions

Based on the result that has been revealed in this research, it shows that the objective of this research is achieved. At the beginning, a lot of challenge had to be faced in order to achieve the objectives of this study .Some of the problem that was faced in this research especially in the designing and fabrication of the dehydration unit. In the designing, the right ratio of diameter: length needs to obtain and the best ratio that was used is 1:4 after consider all the aspect. In the fabrication of unit, the selection of the best material and component are a challenge to make a strong unit which needs the high resistance towards pressure. Finally, these entire problems had be managed intelligently and easily handled and the research was being done successfully.

The experimental results indicated that the increasing of operating pressure in dehydration, the lower water content in natural gas that was removed. It is shown that when the operating pressure at 2.0 bar, 1.770 mL of water content in natural was removed, however when the pressure increased to 0.8 bar, only 0.75 mL water was removed.

For the experimental of volumetric flowrate, the results indicated that the increasing of volumetric flowrate, the higher water content in natural gas that was removed. It is shown that when the volumetric flowrate at 0.0081 m^3/s, 0.160 mL of water content in natural gas was removed, however when the volumetric flowrate decreased to 0.0325 m^3/s, 0.75 mL water was removed.

Overall, the absorption of natural gas by using liquid desiccant TEG is an efficient method in order to removed water content. The effectiveness parameters such operating condition like pressure and volumetric flowrate should be investigated for a reliable, available and maintainable plant with economical consideration in the future.

5.3 Recommendations

From the results of this research, there are some recommendations that were suggested to improve or to enhance the maximum efficiency of the results. The following recommendations are proposed such fabricate the steel dehydration unit to provide more trail of experimental and obtain the accurate result because the PVC unit that has been used in the research could only provide the small range operating pressure capability (0.2 bar-1.0 bar) compared steel unit.

If don’t want to use steel dehydration unit, replace the transparent plate of the caps at the top and the bottom of unit with same material of PVC clear pipe schedule 40 the material. This is because the transparent plate is a potential leakage point of unit and could not resist the high pressure like PVC clear pipe schedule 40 that have maximum allowable pressure 7.58 bar.

Besides that, for further study use rotary pump to spray out the TEG constantly into dehydration unit compared manual pump. In addition, the experimental should be performed in vacuum room to prevent air humidity of surrounding toward liquid desiccant TEG that could be effected the experimental.

Lastly, in order to analyzing the amount of water content with correctly and exactly, purpose the moisture content analyzer as a suitable instrument that could analyze the water content directly in natural gas. All the recommendations could be improved for the further study respectively.

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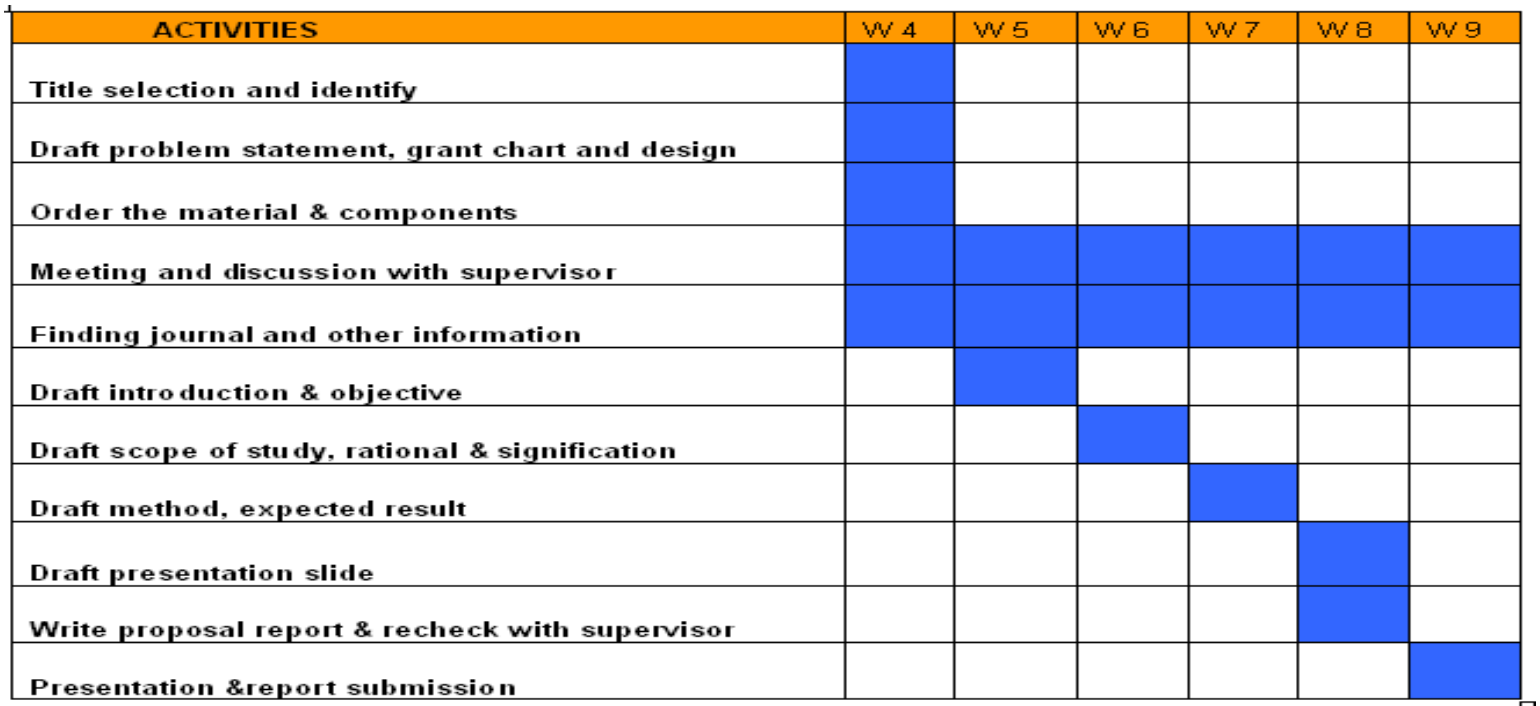
APPENDIX A

Gantt chart for undergraduate research project 1



APPENDIX B

Gantt chart for undergraduate research project 2

Week Activities	2	3	4	5	6	7	8	9	10	11	12	13
Run Experiment												
Discuss with supervisor												
Do the thesis report												
Presentation												
Submit thesis report												

APPENDIX C

Calculation of minimum level position of inlet natural gas, L

Maximum amount of TEG will be used, $V = 300mL = 300cm^3$

$D = 10cm$

$V = \pi D^2/4 \times L$

$L = V/(\pi D^2/4)$

$= 300/(\pi \times 10^2/4)$

$= 3.82$ cm

So, the level position of inlet natural gas must be higher than 3.82cm.

APPENDIX D

Calculation of water content

Volume of TEG before experiment = 300 mL

Time duration = 1 hour

Temperature = 300K

Calculation of water content in rich TEG

Pressure	Volume of TEG after experiment (mL)	Volume of water content (mL)
0.2	317.70	301.77 – 300 = 1.770
0.4	313.70	301.37 – 300 = 1.370
0.6	307.50	300.750 – 300 = 0.750
0.8	301.60	300.160 – 300 = 0.160

APPENDIX E

Calculation of volumetric flowrate

Based on the ideal gas equation PV = nRT and at constant:

Temperature = 300 K

R = 82.057x $10^{-3}m^3$.atm/kgmol.K

n = 0.95 kgmol

Time duration of gas released,t = 5s

P= Operating pressure

Example calculation for pressure 0.2 bar

V= nRT/P

= (0.95x82.057x 10^{-3}x300)/0.2

= 116.93 m^3

Volumetric Flowrate, = V/t

= 116.93/5s

= 23.38 m^3/

Pressure (bar)	**Volume of water content (mL)**	**Volumetric Flowrate (m^3/s)**
0.2	1.770	23.38
0.4	1.370	11.69
0.6	0.750	7.80
0.8	0.160	5.85

APPENDIX F

Machines used in fabrication

Cut off machine

Bench drill

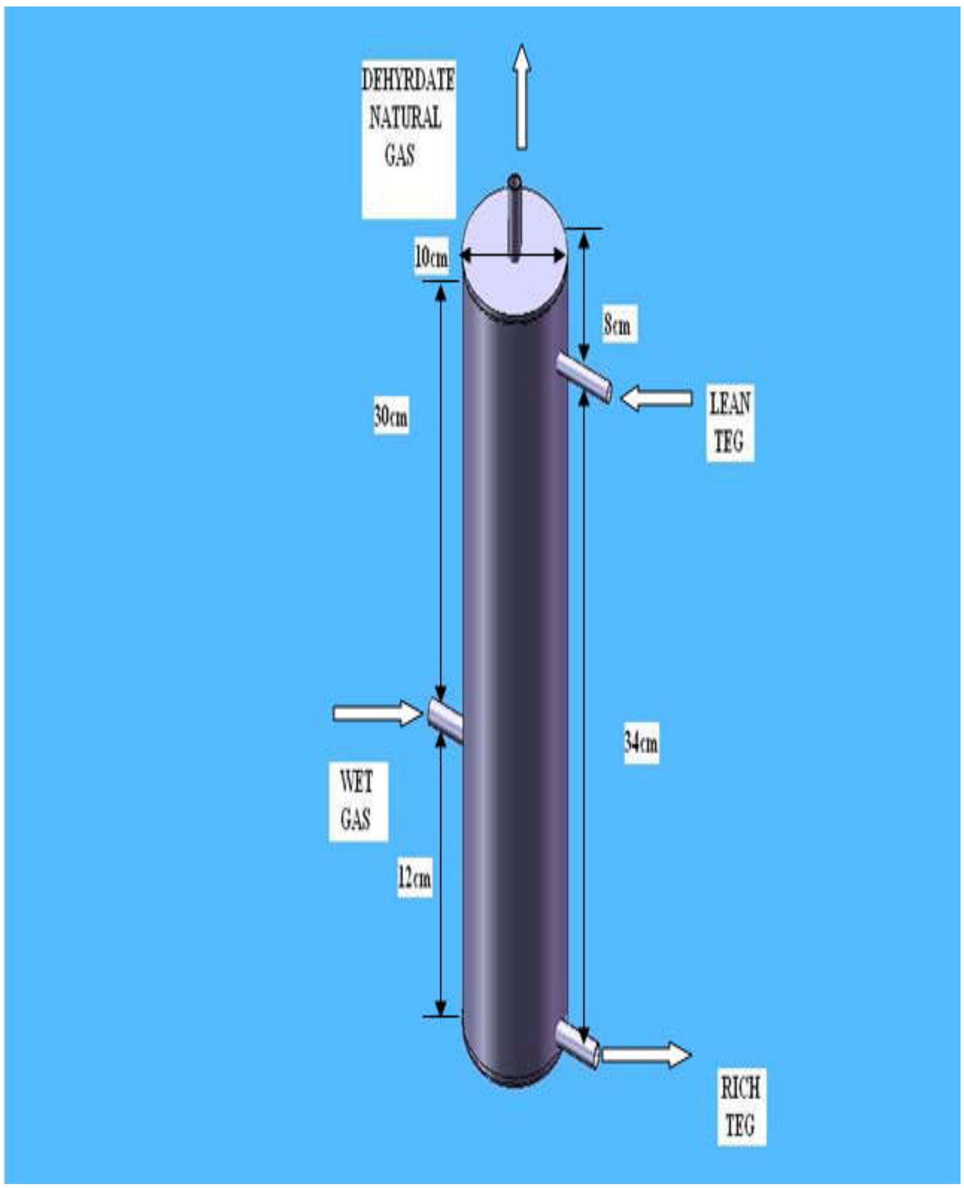
Tap and die set

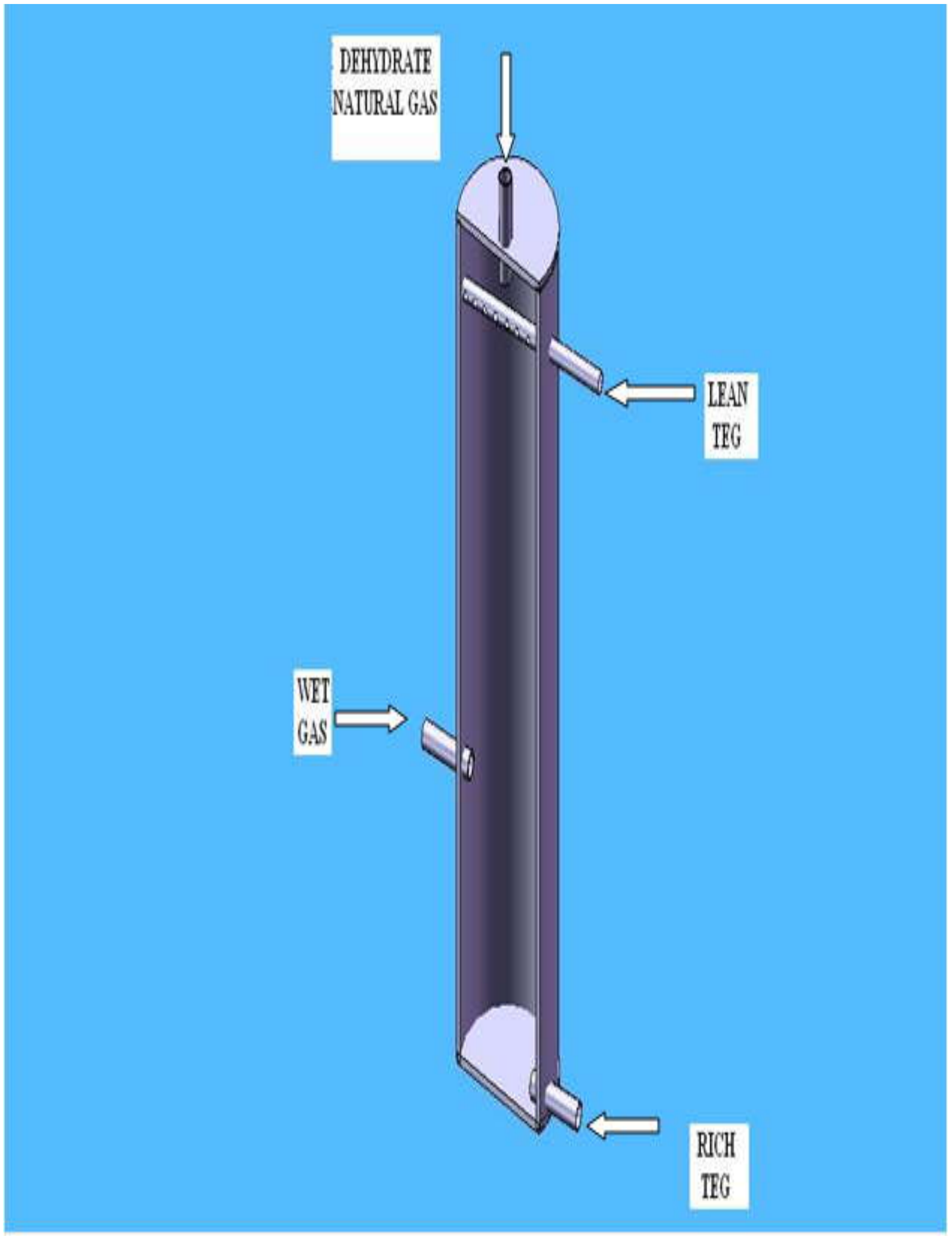
APPENDIX G

Engineering works

APPENDIX H

Dimension of dehydration unit in solid work




DEHYDRATE
NATURAL GAS
LEAN
TEG
WET
GAS
RICH
TEG

APPENDIX I

Fabricated of dehydration unit