NATURAL GAS DEHYDRATION USING SILICA GEL:
FABRICATION OF DEHYDRATION UNIT

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JUDUL: **NATURAL GAS DEHYDRATION USING SILICA GEL: FABRICATION OF DEHYDRATION UNIT**

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NATURAL GAS DEHYDRATION USING SILICA GEL: FABRICATION OF DEHYDRATION UNIT

SITI SUHAILA BT MOHD ROHANI

A thesis submitted in fulfillment
of the requirements for the award of the degree of
Bachelor of Chemical Engineering (Gas Technology)

Faculty of Chemical and Natural Resources Engineering
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APRIL 2009

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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I would like to dedicated this thesis to all those who believe in the richness of learning. Especially my beloved

Mother, Katisah Bt Husin

Father, Mohd Rohani Bin Johari

Siblings, and

Iskandar Izany Bin A Rahman

who have been great sources of motivation and inspiration.

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ABSTRACT

The purpose of this study is to remove water content in untreated natural gas using solid desiccant dehydration unit. Dehydration of natural gas is needed to remove the water that is associated with natural gases in vapor form. The natural gas industry has recognized that dehydration is necessary to ensure smooth operation of gas transmission lines. Dehydration prevents the formation of gas hydrates and reduces corrosion. Unless gases are dehydrated, liquid water may condense in pipelines and accumulate at low points along the line and reducing its flow capacity. Several methods have been developed to dehydrate gases on an industrial scale. The three major methods of dehydration are direct cooling, adsorption, and absorption. In this experiment, the adsorption process was choosing. Silica gel was the desiccants used in adsorption processes. The desiccant dehydration is a very simple process, ideal for remote locations with limited utilities, environment benefit, easy to install and operate and it also suitable in laboratory scale. In this study, it focuses on designing, fabrication, hydrostatic test and experimental part. On the experimental part, the quality of the desiccant and the temperature is constant because it only focuses on operating pressure. At a constant temperature the water content of the gas decreases with increasing pressure, thus less water must be removed if the gas is dehydrated at a high pressure.

ABSTRAK

Kajian ini dilakukan bertujuan untuk menyingkirkan kandungan air didalam gas asli mentah. Penyahhidratan pada gas asli adalah perlu untuk menyingkirkan air yang berada pada fasa wap. Industri gas asli telah mengakui bahawa penyahhidratan adalah perlu untuk melancarkan operasi pada aliran penghantaran. Pengecualian pada gas asli yang telah terhidrat, air mungkin termeluap pada aliran paip dan terkumpul pada takat terendah sepanjang aliran dan mengurangkan kapasiti aliran gas. Beberapa kaedah telah dihasilkan untuk menghidratkan gas pada skala industi. Tiga kaedah major untuk menghidratkan gas ialah penyejukan secara terus, penyerapan dan resapan. Di dalam eksperimen ini, proses resapan telah dipilih. Silika gel adalah bahan pengering yang digunakan dalam proses resapan. Unit penghidrat ini disebut unit penghidrat bahan pengering, proses ini merupakan proses yang mudah, sesuai untuk tempat terpencil yang mempunyai kurang kemudahan , pemasangan dan operasi yang mudah dan juga terdapat pada skala makmal. Di dalam kajian ini ia menfokuskan pada merekabentuk, membina, ujian cecair dan bahagian eksperimentasi. Pada bahagian eksperimentasi, kualiti bahan kering dan suhu adalah tetap kerana eksperimen ini hanya memfokuskan pada tekanan operasi. Pada suhu yang tetap, wap air berkurangan pada tekanan yang tinggi. Oleh itu, kandungan wap air adalah kurang terhidrat pada tekanan operasi yang tinggi.

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D	Diameter
L	Length
m	mass
M	Water content adsorbed
wt %	Weight Percentage
cm	centimetre
min	minutes
g	gram
m	meter

LIST OF ABBREVIATION

NG	Natural Gas
CH_4	Methane
C_2H_6	Ethane
C_3H_8	Propane
C_4H_{10}	Butane
CO_2	Carbon Dioxide
N_2	Nitrogen
He	Helium
H_2S	Hydrogen Sulfide

CHAPTER 1

INTRODUCTION

1.1 General

Natural gas is generally considered a nonrenewable gaseous fossil fuel. Most scientists believe that natural gas was formed from the remains of tiny sea animals and plants that died 200-400 million years ago. When these tiny sea animals and plants died, they sank to the bottom of the oceans where they were buried by layers of sediment that turned into rock. Over the years, the layers of sedimentary rock became thousands of feet thick, subjecting the energy-rich plant and animal remains to enormous pressure. Most scientists believe that the pressure, combined with the heat of the earth, changed this organic mixture into petroleum and natural gas. Eventually, concentrations of natural gas became trapped in the rock layers like wet sponge traps water. [1]

About 2,500 years ago, the Chinese recognized that natural gas could be put to work. The Chinese piped the gas from shallow wells and burned it under large pans to evaporate seawater for the salt. Natural gas was first used in America in 1816 to illuminate the streets of Baltimore with gas lamps. Lamplighters walked the streets at dusk to light the lamps. By 1900, natural gas had been discovered in 17 states. In the past 40 years, the use of natural gas has grown. Today, natural gas accounts for 21.6 percent of the energy we use. [1]

Raw natural gas comes primarily from any one of three types of wells that are crude oil wells, gas wells, and condensate wells. Natural gas that comes from crude oil wells is typically termed associated gas. This gas can exist separate from the crude oil in the underground formation, or dissolved in the crude oil. Natural gas from gas wells and from condensate wells, in which there is little or no crude oil, is termed non-associated gas. Gas wells typically produce only raw natural gas, while condensate wells produce raw natural gas along with a very low density liquid hydrocarbon called natural gas condensate (natural gasoline). [2]

The former Soviet Union holds the world's largest natural gas reserves, 38% of the world's total. Together with the Middle East, which holds 35% of total reserves, they account for 73% of world natural gas reserves. World's ratio of proven natural gas reserves to production at current levels is between 60 and 70 years. This represents the time that remaining reserves would last if the present levels of production were maintained. [3]

Total world production in 2000 was 2422.3 billion cubic meters. Production growth in 2000 was 4.3%, a significantly higher growth that the 1990-2000 annual average. World natural gas production is expected to grow in the future as a result of new exploration and expansion projects, in anticipation of growing future demand. [3]

Natural gas prices, as with other commodity prices, are driven by supply and demand fundamentals. Prices paid by consumers were increased from 1930 through 2205 by processing and distribution costs. U.S. natural gas prices were relatively stable at around (2006 US) $30/Mcm in both the 1930s and the 1960s. Prices reached a low of around (2006 US) $17/Mcm in the late 1940s, when more than 20 percent of the natural gas being withdrawn from U.S. reserves was vented or flared. [4]

Natural gas contains many contaminants, of which the most common undesirable impurity is water. It is necessary to eliminate water to avoid some problem to happen and to meet a water dew point requirement. Several methods can be used to dry natural gas and in this study, a solid desiccant dehydrator using silica gel is considered due to its ability to provide extremely low dew points. Solid desiccant dehydrator unit is very simple process and use adsorption process.

The rational of this research is to remove water vapor from natural gas that can reduce the potential for corrosion, hydrate formation, and freezing in the pipeline. It also stops sluggish flow conditions that may be caused by condensation of water vapor in natural gas.[5] Besides that, it produces what is known as 'pipeline quality' dry natural gas. Otherwise, there are no volatile organic compounds or aromatic hydrocarbon emissions by using solid desiccant dehydrator unit as a method to remove water vapor. [6]

1.2 Problem Statement

All natural gas well streams commonly exists in mixtures with other hydrocarbons, principally ethane, propane, butane, and pentanes. In addition, raw natural gas contains water vapor, hydrogen sulfide (H_2S), carbon dioxide, helium, nitrogen, and other compounds. As the gas travels up the well bore to the surface, it cools due to pressure reduction and heat conduction to cooler formations. The ability of gas to hold water vapor decreases as the gas temperature decreases, so natural gas is nearly always saturated with water vapor when it reaches the surface.

It is necessary to remove most of the water vapor for gas processing and transportation. Free water in a natural gas stream can result in line plugging due to hydrate formation, reduction of line capacity due to collection of free water in the line, and increased risk of damage to the pipeline due to the corrosive effects of water. Reducing the water vapor content of natural gas reduces its saturation temperature (or dew point), thereby reducing the chance that free water will form in the pipeline. [7]

The removal of the water vapor that exists in solution in natural gas requires a complex treatment. This treatment consists of dehydrating the natural gas, 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. In this research, the focus is on solid-desiccant dehydrator unit using silica gel.

1.3 Objective

The objectives of this research is

1) To remove water vapor from untreated natural gas by using solid (silica gel) desiccant dehydrator unit.

1.4 Scope of Study

1) Fabrication of a dehydration unit
   - The main component of the dehydration unit is clear PVC pipe with diameter 4 inches.
2) Experimental
   - The experiment will be carried out using four different pressures. The pressure range is from 0.1 to 0.4 bar. The relationship between the pressure and the water collected is considered in this present study.
3) Analyzing

   - The estimation of water collection will be done by differentiate the mass before and after of the silica gel. (Quantitative Analyzing)

CHAPTER 2

LITERATURE REVIEW

2.1 Natural Gas

2.1.1 Component of Natural Gas

Natural gas (NG) is a gaseous fossil fuel composed mainly by 70–90 mol% methane (CH_4), the remainder being higher molecular weight hydrocarbons, such as ethane (C_2H_6), propane (C_3H_8), and butane (C_4H_{10}). Water vapor, carbon dioxide (CO_2), nitrogen (N_2), helium (He), hydrogen sulfide (H_2S) can also be present. The exact composition of natural gas varies between gas fields. Natural gas that contains hydrocarbons other than methane is called wet natural gas. Natural gas consisting only of methane is called dry natural gas.

Table 2.1: Component of natural gas

Component	wt. %
Methane (CH_4)	70-90
Ethane (C_2H_6)	5-15
Propane (C_3H_8) and Butane (C_4H_{10})	< 5
Water vapor,CO_2, N_2, H_2S, etc.	balance

(http://www.naturalgasbank.com)

2.1.2 Natural Gas Use

Natural gas is a bridge to a sustainable energy system in the future and there is a need to put research on the alternatives such as hydrogen and biofuel. [8] As a clean alternative, it produces relatively few pollutants, so the air inside and outside stays clean. Natural gas ranks number three in energy consumption, after petroleum which provides almost 39 % of energy demand and coal which provide 22.6%. Natural Gas also has fewer emissions than coal or oil and has virtually no ash particles left after combustion. [1]

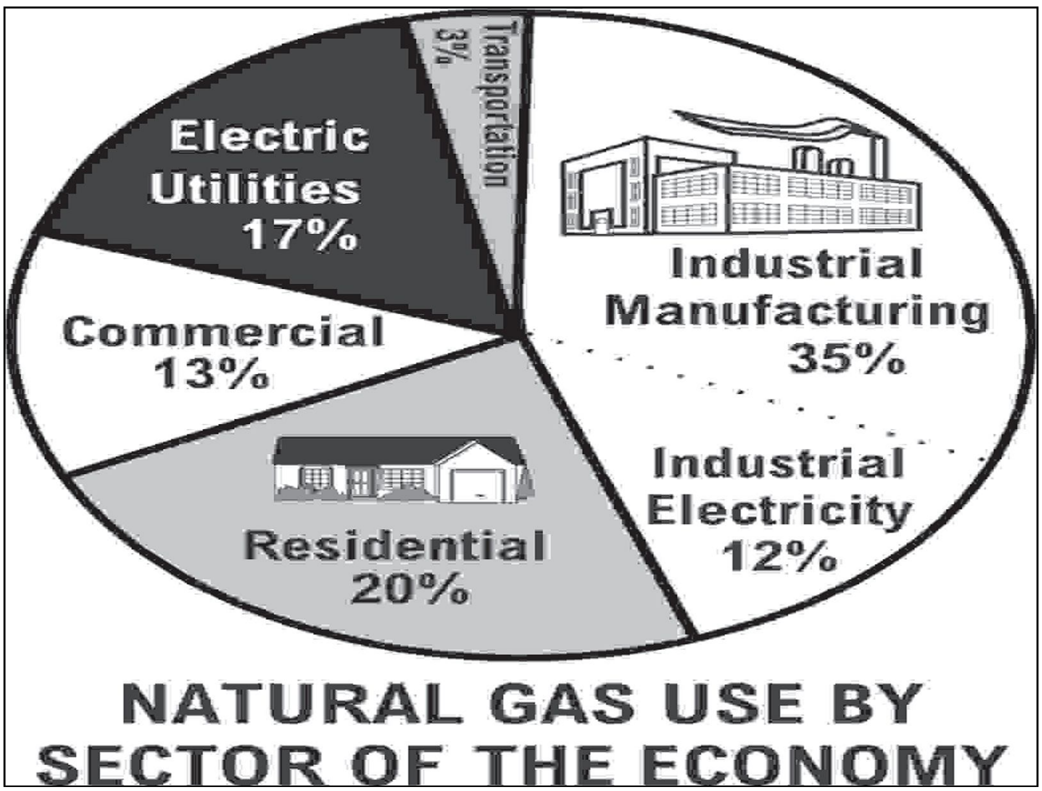

Figure 2.1: Natural gas use by sector of the economy

Industrial manufacturing is the biggest consumer of natural gas, 35 %, using it mainly as a heat to manufacture goods. Industry also uses natural gas as an ingredient in fertilizer, photographic film, ink, glue, paint, plastic, laundry detergent and insect repellents. Synthetic rubber and man-made fiber like nylon also could not be made without the chemicals derived from natural gas.

The residential and commercial sectors are the second biggest uses of natural gas, 20%. Natural gas is supplied to homes, where it is used for such purposes as cooking in natural gas-powered ranges and ovens, natural gas-heated clothes dryers, heating/cooling and central heating. Commercial use of natural gas is mostly for indoors heating of stores, office buildings, schools and hospitals. Natural gas is a major source of electricity generation through the use of gas turbines and steam turbines. Compressed natural gas (methane) is a cleaner alternative to other automobile fuels such as gasoline and diesel. Natural gas is a major feedstock for the production of ammonia, via the Haber process, for use in fertilizer production. Natural gas can be used to produce hydrogen, with one common method being the hydrogen reformer. [9]

2.1.3 Natural Gas processing

Natural gas processing begins at the wellhead (Figure 2.2). The composition of the raw natural gas extracted from producing wells depends on the type, depth, and location of the underground deposit and the geology of the area. The processing of wellhead natural gas into pipeline-quality dry natural gas can be quite complex and usually involves several processes. Various types of processing plants have been utilized since the mid-1850 s to extract liquids, such as natural gasoline, from produced crude oil. However, for many years, natural gas was not a sought after fuel. Prior to the early 20thcentury, most of it was flared or simply vented into the atmosphere, primarily because the available pipeline technology permitted only very short-distance transmission.

Figure 2.2 shows a schematic block flow diagram of a typical natural gas processing plant. It shows the various unit processes used to convert raw natural gas into sales gas pipelined to the end user markets. The block flow diagrams also shows how processing of the raw natural gas yields byproduct sulfur, byproduct ethane, natural gas liquids (NGL) propane, butanes and natural gasoline.

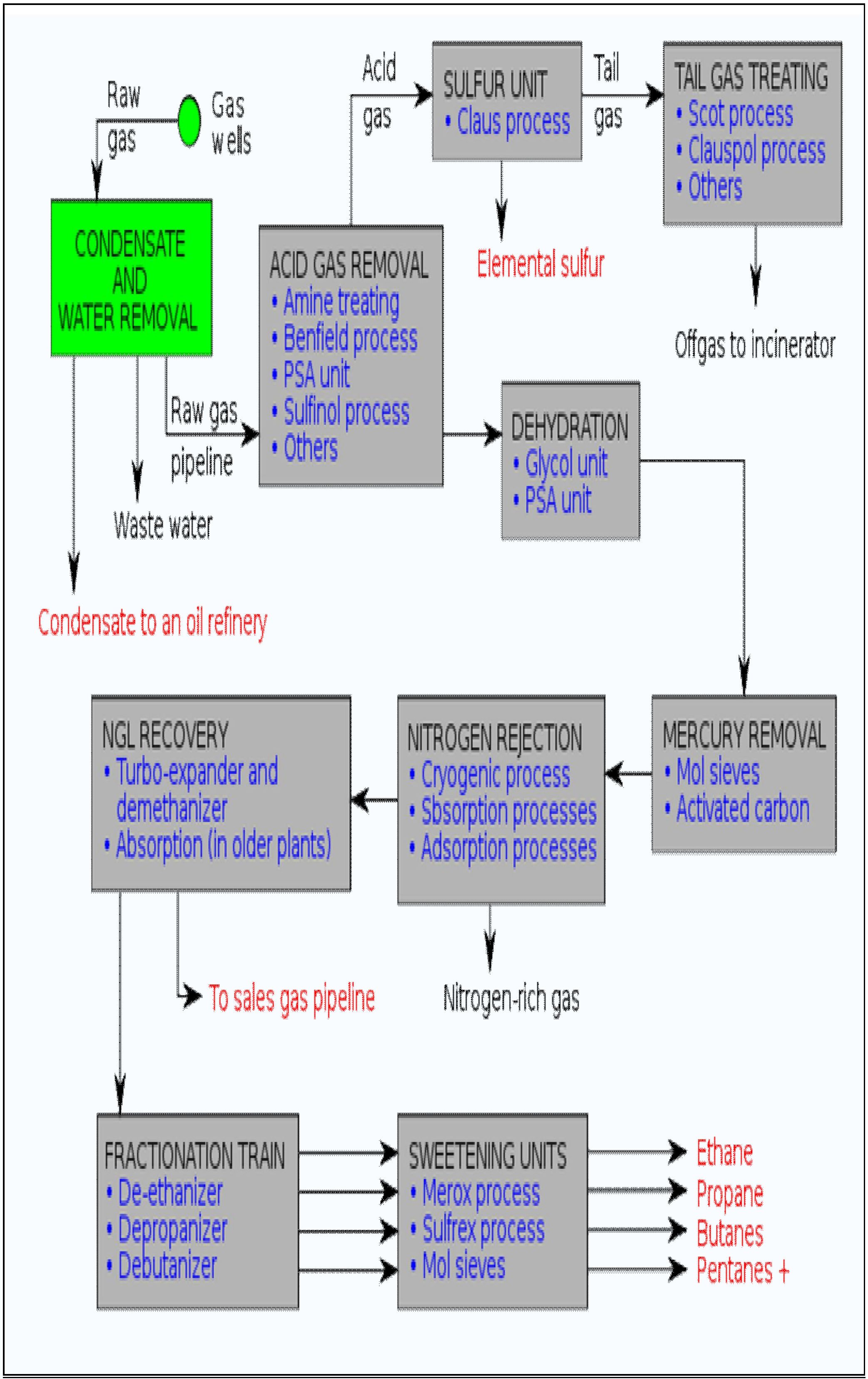

Figure 2.2: Natural gas processing
(http://en.wikipedia.org/wiki/Natural_gas_processing)

Natural gas, as it is used by consumers, is much different from the natural gas that is brought from underground up to the wellhead. Although the processing of natural gas is in many respects less complicated than the processing and refining of crude oil, but it is necessary before its use by end users. All natural gas well streams contain many contaminants, of which the most common undesirable impurity is water. So that, free water associated with extracted natural gas is removed by simple separation methods at or near the wellhead. Removal of water from the gas stream reduces the potential for corrosion, hydrate formation, and freezing in the pipeline. It is necessary to remove water vapor from natural gas and in this study the method use is using solid desiccant dehydrator unit using silica gel.

2.2 Gas Dehydration

Natural gases either from natural production or storage reservoirs contain water, which condense and form solid gas hydrates to block pipeline flow and especially control systems. Natural gas in transit to market should be dehydrated to a controlled water content to avoid hydrate as well as to minimize the corrosion problems.

Natural gas processing consists of separating all of the various hydrocarbons and fluids from the pure natural gas. Major transportation pipelines usually impose restrictions on the make-up of the natural gas that is allowed into the pipeline. That means that before the natural gas can be transported it must be purified. While the ethane, propane, butane, and pentanes must be removed from natural gas, this does not mean that they are all 'waste products'.

The natural gas received and transported by the major intrastate and interstate mainline transmission systems must meet the quality standards specified by pipeline companies in the “General Terms and Conditions (GTC)” section of their tariffs. These quality standards vary from pipeline to pipeline and are usually a function of a pipeline system’s design, its downstream interconnecting pipelines, and its customer base. In general, these standards specify that the natural gas: [9]

i. be within a specific Btu content range (1,035 Btu per cubic feet, +/- 50 Btu)

ii. be delivered at a specified hydrocarbon dew point temperature level (below which any vaporized gas liquid in the mix will tend to condense at pipeline pressure)

iii. contain no more than trace amounts of elements such as hydrogen sulfide, carbon dioxide, nitrogen, water vapor, and oxygen

iv. be free of particulate solids and liquid water that could be detrimental to the pipeline or its ancillary operating equipment.

Dehydration of natural gas is the removal of the water that is associated with natural gases in vapor form. The natural gas industry has recognized that dehydration is necessary to ensure smooth operation of gas transmission lines. Dehydration prevents the formation of gas hydrates and reduces corrosion. Unless gases are dehydrated, liquid water may condense in pipelines and accumulate at low points along the line, reducing its flow capacity. Several methods have been developed to dehydrate gases on an industrial scale.

The three major methods of dehydration are direct cooling, adsorption, and absorption. Molecular sieves (zeolites), silica gel, and bauxite are the desiccants used in adsorption processes. In absorption processes, the most frequently used desiccants are diethylene and triethylene glycols. Usually, the absorption/stripping cycle is used for removing large amounts of water, and adsorption is used for cryogenic systems to reach low moisture contents. [10]

2.2.1 Direct Cooling

The saturated vapor content of natural gas decreases with increased pressure or decreased temperature. Thus, hot gases saturated with water may be partially dehydrated by direct cooling. Gases subjected to compression are normally after cooled, and this cooling may well remove water from the gas. The cooling process must reduce the temperature to the lowest value that the gas will encounter at the prevailing pressure to prevent further condensation of water. [10]

2.2.2 Absorption of Water in Glycols

Absorption dehydration involves the use of a liquid desiccant to remove water vapor from the gas. 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:

i. high absorption efficiency.
ii. easy and economic regeneration.
iii. non-corrosive and non-toxic.
iv. no operational problems when used in high concentrations.
v. no interaction with the hydrocarbon portion of the gas, and no contamination by acid gases. [10]

The glycols, particularly ethylene glycol (EG), diethylene glycol (DEG), triethylene glycol (TEG), and tetraethylene glycol (T4EG) come to closest to satisfying these criteria to varying degrees. Water and the glycols show complete mutual solubility in the liquid phase due to hydrogen-oxygen bonds, and their water vapor pressures are very low. One frequently used glycol for dehydration is triethylene glycol, or TEG. This is mainly an absorption/stripping type process, similar to the oil absorption process. The wet gas is dehydrated in the absorber, and the stripping column regenerates the water-free TEG. The glycol stream should be recharged constantly because some TEG may react and form heavy molecules, which should be removed by the filter.

2.2.3 Adsorption of Water by a Solid

Adsorption (or solid bed) dehydration is the process where a solid desiccant is used for the removal of water vapor from a gas stream.

In adsorption processes one or more component of a gas or liquid stream are adsorbed on the surface of a solid adsorbent and a separation is accomplished. In commercial processes, the adsorbent is usually in the form of small particle in a fixed bed. The fluid is passed through the bed and the solid particle adsorb component from the fluid. When the bed is almost saturated, the flow in this bed is stopped and the bed is regenerated thermally or by other methods so that desorption occur. The adsorbed material is thereby recovered and the solid adsorbent is ready for another cycle of adsorption. [13]

Applications of liquid-phase adsorption include removal of organic compounds from water or organic solutions, colored impurities from organics, and various fermentation products from fermentor effluents. Separators include paraffin from aromatics and fructose from glucose using zeolites. Applications of gas-phase adsorption include removal of water from hydrocarbon gases, sulfur compounds from natural gas, solvents from air and other gases and odors from air.[13]

Solid desiccant dehydration is an adsorption process, which is any process wherein molecules from the gas are held on the surface of a solid by surface forces. The adsorption process, as opposed to the absorption process, does not involve any chemical reaction. Adsorption is purely a surface phenomenon. [5]

The adsorption capacity is determined by the particular gas being adsorbed, the nature of solid desiccant, its effective surface area and internal porosity, the temperature and the partial pressure of the adsorbate gas. The strength of the adsorption bond depends primarily on the natures of the gas and solid surfaces. [14]

2.3 Solid Desiccant Dehydrator Unit.

2.3.1 Description of Solid Desiccant Dehydrator Unit Process

The solid desiccant dehydrator is a very simple process. It has no moving parts and needs no external power so that it can be used in offshore or remote sites. Wet natural gas enters the dehydrator vessel below the perforated. Desiccant tablets are placed on the perforated tray. The perforated tray is in the middle of the vertical vessel. Perforated are located several feet up from the vessel bottom. The wet gas flows upward through the perforated where it interacts with the desiccant tablets. The moisture from the gas is adsorbed by the tablets and accumulates on the surface of the tablet. [11] Water removed from the gas combines with desiccant tablets. Gas exiting at the vessel top has been dried to a point consistent with the equilibrium point of each desiccant and collect using gas bag through gas outlet pipe. The collected gas will analyze using gas chromatography or gas analyzer to know the component present in it. The moisture remove are the different of weigh before and after of the silica gel. There are no other byproducts or emissions.

The amount of water removed by the desiccant tablets depends on the quality of the desiccant and the temperature and the pressure of the inlet gas. Desiccant tablets work best for a natural gas processing at high pressure and low temperature. As the desiccant tablets adsorb moisture from the gas, the level of the desiccant tablets in the drying bed slowly decrease to the minimum desiccant tablet level. Figure 2.3 shows the typical flow diagram for solid desiccant dehydrator unit. Adsorption dehydration utilizing dry-bed dehydrators towers, which contain desiccants such as silica gel and activated alumina, to perform the extraction.

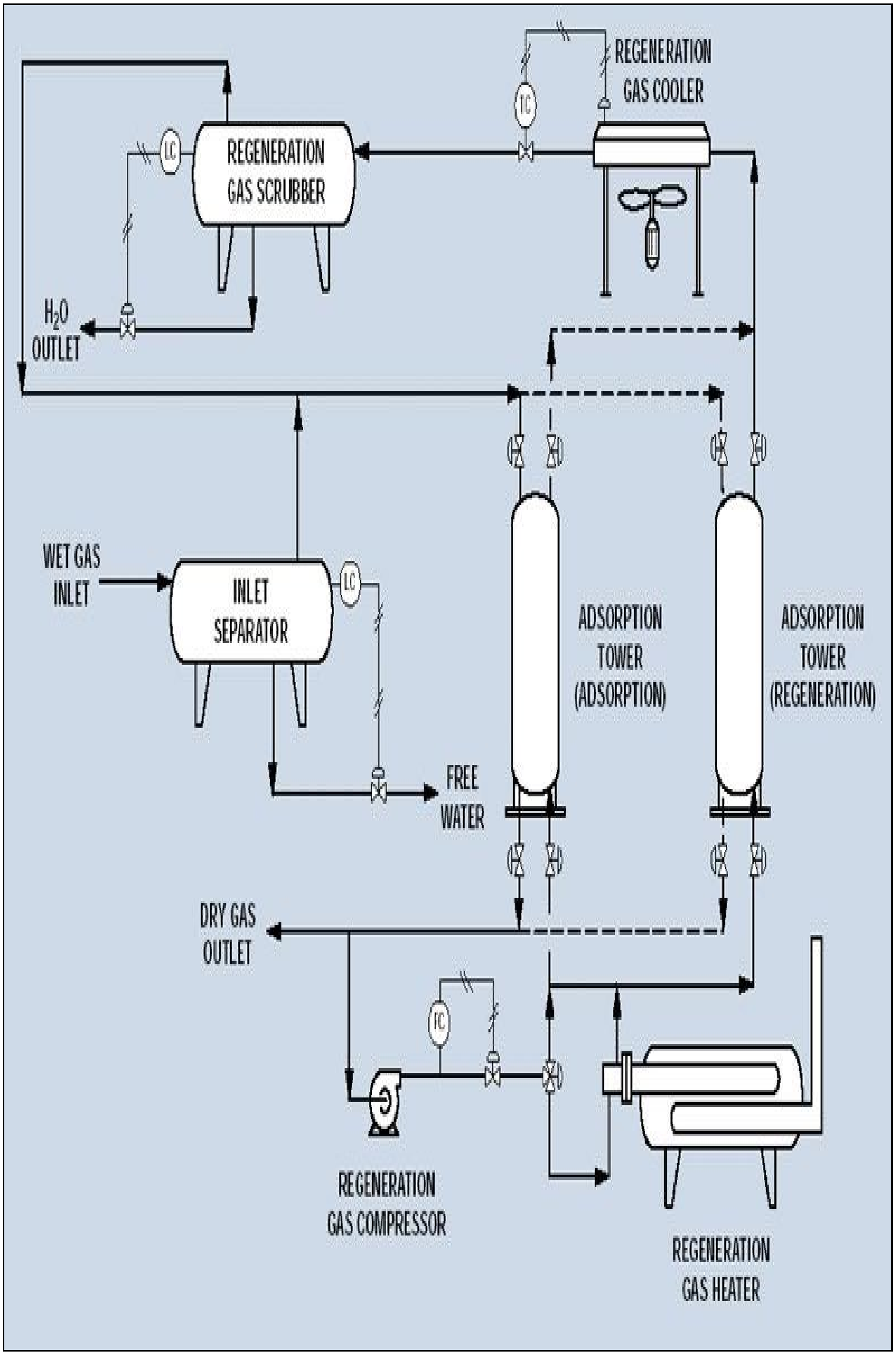

Figure 2.3: Flow Diagram of Solid Desiccant Dehydrator Unit

(http://www.natcogroup.com/Content.asp?t=ProductPage&ProductID=20)

2.3.2 Application of Desiccant Dehydration

i) Hydrate Control

Hydrate control was the first, and is now the most widely used application for deliquescing desiccant drying. Gas is typically dried with a single vessel using the lowest grade desiccant. Therefore both equipment and operating costs are very low. Gas must only be dried to a dew point below the minimum expected pipeline temperature to prevent free water and hence hydrate formation. For surface lines, the minimum gas temperature is the coldest ambient air temperature, but for lines buried below frost level the lowest gas temperature is typically 35 °F.

As an example, assume saturated wellhead gas (100 % methane) being dried at 600 psig and 60 °F, and the gathering pipeline operates at 450 psig and 35 °F in the winter. Inlet gas contains approximately 24/MMCF water vapor. To dry to a dew point of 30 °F at 450 psig, resultant moisture content must be 11.7/MMCF. Drying this gas with a single vessel filled with the lowest grade desiccant yields 7/MMCF gas at an operating cost of approximately one cent per mcf. Gas can be flowed to a central plant for further processing and dehydration, without hydrates in the gathering system. [6]

ii) Sour gas Dehydration

Regardless of the application, desiccant dehydration offers substantial benefits for drying sour gas. Desiccant tablets react only with water and their performance is unaffected by gas composition. Tablets do not react with hydrogen sulfide, carbon dioxide, oxygen or other gases. Service interval can be extended by simply over-sizing the vessel, or by using several vessels in parallel. Unlike TEG systems, there is no continuous odor, and the operator does not have to dispose of contaminated TEG. The only emission is gas used to blow brine to storage, which is typically treated with a small sweetening pot located on the water tank vent. Most systems include a sweet gas purge system using either city gas or bottled nitrogen. After vessels are depressurized sweet gas is purged through the vessels, normally several times, before the vessels are opened. Naturally the operator should still wear proper safety equipment as if he were working in a hydrogen sulfide environment. Reducing employee exposure to hydrogen sulfide can be a valuable benefit of desiccant dehydration. [6]

iii) Fuel Gas

Desiccant dehydration is well suited for drying fuel gas for heaters and treaters. This equipment is often remote and frequently experiences fuel line freezing in the winter months. Drying fuel through a single desiccant vessel typically prevents fuel line problems at very low net costs. Because fuel flow is normally low, most fuel gas systems can economically provide very long service intervals, reducing labor expenses. [6]

2.3.3 Advantages of Solid Desiccant Dehydrator Unit

Using desiccant dehydrators as alternatives to glycol dehydrators can yield significant economic and environmental benefits.

i) Reduce Capital Cost

The capital costs of desiccant dehydrators are low compared to the capital costs of TEG dehydrators. Unlike TEG dehydrators, desiccant dehydrators do not use pumps, contactors, and fired reboiler/regenerator. The only capital cost is for the vessel. [11]

ii) Reduced operation and maintenance cost

Since most of the well heads and processing units are located in remote areas, it is important for the dehydrator units to be reliable and continuously accessible and with minimum oversight from operation and maintenance personal. [11]

iii) Methane or high hydrocarbons are not emitted

The desiccant tablets only adsorb water, therefore, methane and other hydrocarbons will not be vented to the atmosphere. [11]

iv) Remote or unmanned locations

In an effort to reduce labor costs, companies are designing, installing and operating more and more unmanned facilities. These require expensive automation controls and remote monitoring. Desiccant dehydration is ideal for remote or unmanned locations since it is very simple and requires very little maintenance. [6]

2.4 Solid Desiccant

2.4.1 Properties of Solid Desiccant

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 chemisorptions. 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. [10]

i. Large surface area for high capacity. Commercial adsorbents have a surface area of 500-800 m^2/g.

ii. Good activity for the components to be removed and good activity retention with time/use.

iii. High mass transfer rate, such as 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.

2.4.2 Types of Solid Desiccant

The absorbents most commonly used for gas dehydration are:

i. bauxite ore
   - consisting primarily of alumina (($Al_2O_3 . x H_2O$).
   - not used much because it contains iron and is thus unsuitable for sour gases. [6]

ii. alumina
   - the least expensive adsorbent.
   - it is activated by driving off some of the water associated with it in its hydrated form (($Al_2O_3 . 3H_2O$) by heating. [6]

iii. silica gels and silica-alumina gels
   - granular.
   - greatest ease of regeneration of all desiccants. [6]

iv. molecular sieves
   - a crystalline form of alkali metal (calcium or sodium) alumina-silicates. very similar to natural clays.
   - they are highly porous, with a very narrow range of pore sizes.

- very high surface area. [6]

2.4.3 Silica Gel

Silica gel was patented in 1919 for use in the adsorption of vapors and gases in gas mask canisters during World War I. During World War II, it was commonly used as a dehydrating agent to protect military and pharmaceutical supplies, among a number of other applications. Its use as a buffering agent to control RH within the mid-range rather than as a desiccant is a unique to museum applications. Silica gel are: [12]

i. rugged material with good attrition resistance characteristics.
ii. available commercially as powdered.
iii. granular.
iv. spherical beads of various sizes.
v. excellent thermal and mechanical stability.
vi. unique large surface area.
vii. well-defined pore sizes as well as well-modified surface properties.

2.4.3.1 Features of Silica Gel

i. Easy to regenerate
   - Silica gel is easier to regenerate due to the lower adsorption forces. [12]

ii. Adsorption Capacity
   - Silica gels maintain their structure when activated.
   - Activation frees the large internal surface area and pore volume, enabling physical adsorption and capillary condensation.
   - Shows higher capacity than activated alumina. [12]

iii. Purity:

- By industrial standard, Silica gel can be found to be extremely pure by industrial standards. This is due to the non-presence of any remarkable concentrations of metallic compounds like iron, aluminium, or heavy metals. This makes pure silica gel much less active as a catalyst than adsorbents in the same category like zeolites or aluminas. This prevents unwanted reactions like cracking reactions in hydrocarbon streams. As a result coke formation can be minimized. [12]

iv. High Porosity

- Silica gel offers a very high porosity, something around, 800 m^2/g, that allows it to adsorb water readily, thus making it very useful as a desiccant (drying agent). [12]

v. Low pressure drop

- It offers right particle size distribution, that is typically in the range of 2-5 mm range. [12]

vi. Long Life

- That is charecterized by less maintenance cost, lesser cost for replacement.
- Minimal loss of production. [12]

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Introduction

The flow chart of the method applied in this study is briefly shown in Figure 3.1. The dehydration unit was design using solid works software. It is followed by fabrication phase that use PVC 4 inch as a main component. After fabrication phase, the rig was under go for hydro test to qualify newly manufactured and to help maintain safety standards and durability of a vessel over time. At constant temperature and volume, the pressure was regulated at set pressure and the experiment was run. The experiment was repeated for four different pressures. Finally, the result then was analyzed and the relation between the pressure and water vapor content was considering in this study.

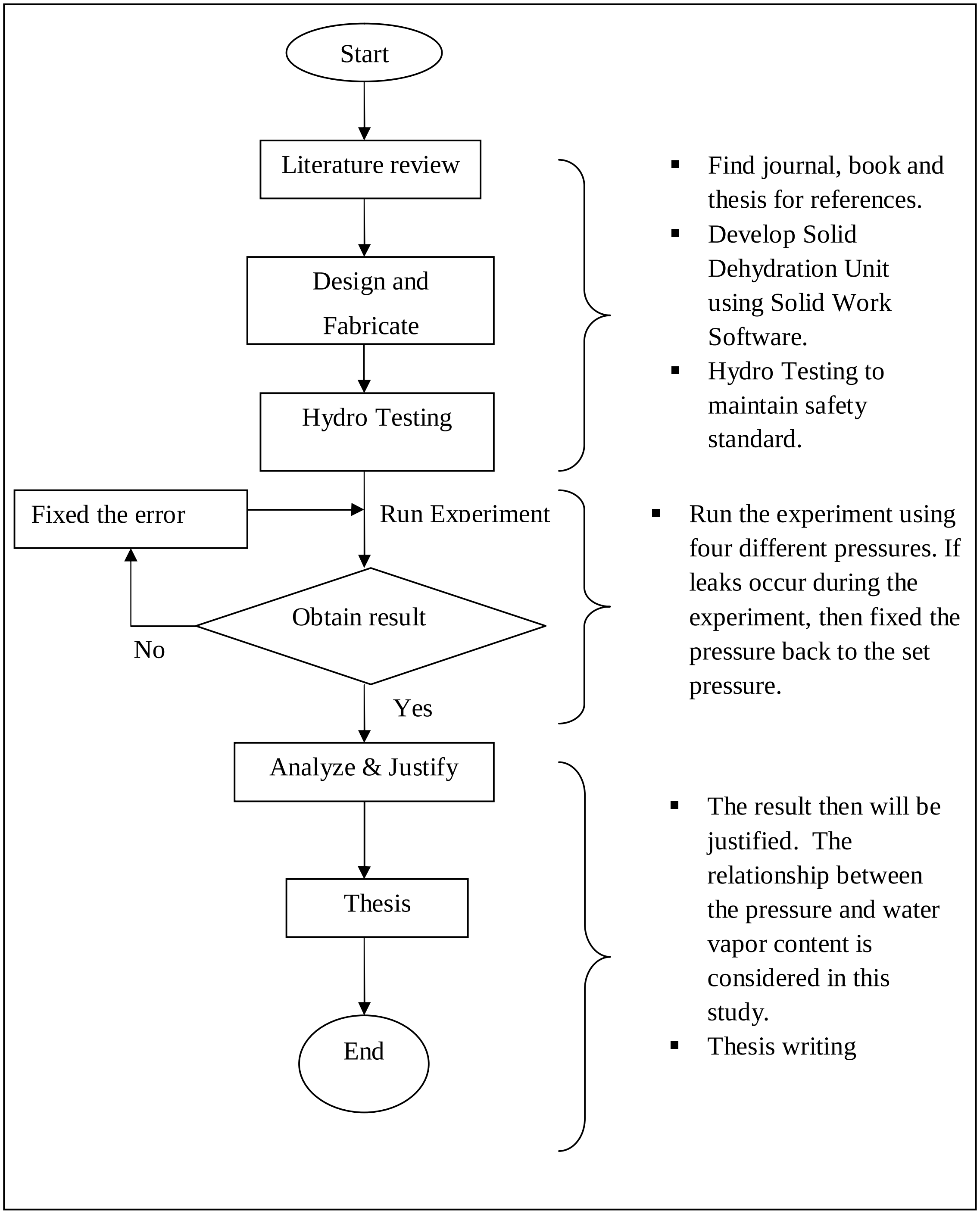

Figure 3.1: Flow chart of the project

3.2 Design

The material and chemical, component, and equipment of the dehydration unit were stated below. All the materials, chemical and component were order in the early of semester to make sure our project was not delayed. The equipment that use was borrowed from the workshop.

3.2.1 Material and Chemical

i. Untreated methane
ii. Silica gel
iii. Acetic Silicon Sealant
iv. Parafilm
v. Vacuum Grease

3.2.2 Equipment

i. Pipe Cutter RIDGID 590L
ii. HITACHI B135 13 mm BENCH DRILL
iii. TAP and DIE SET
iv. Spanner
v. Weighing Machine

3.2.3 Component

i. Clear PVC pipe 4 inches
ii. PVC Cap
iii. Transparent Plate
iv. Flange (PVC) size 4 inches
v. Perforated tray
vi. Valve

vii. Vertical steel

viii. Screw

ix. Gas bag

x. Gasket

xi. Beaker

3.2.4 Estimation of length to diameter

Length to diameter ratio is a numerical value describing the length of a cylindrical tool or work piece compared to its diameter. Higher length-to-diameter ratios offer less rigidity. The Length-to-Diameter Ratio should not exceed 4:1. Ratios of between 1:1 and 2:1 are preferred for most circuits. For this model, the ratio of 4:1 was preferred because it is the most suitable for the design. [14]

L/D Ratio = 4: 1

The diameter of the cylinder is fixed = 4inches = 10.16cm

So,

Length = 40.64cm ±5% = 42.67cm

±5% = Safety Aspect

3.2.5 Develop Model Using Solid Work Software

The model of Solid Desiccant Dehydration Unit was developing using Solid Work Software. The analysis of the conceptual idea of Solid Works indicates that it represents mechanical design automation software for a 3D computer simulation of bodies. This model gives better understanding on the design due to 3D model. It will help in the next process which is fabrication process. The advantages of using Solid Work Software are: [15]

i. easy and fast creation and modifying of a 3D geometrically drawing of bodies, influencing their performances (sizes).

ii. possibilities of creation from separate pieces of an assembled unit, defining the relations and the location of their contacting surfaces.

iii. realizing of a 2D geometrically drawing of the separate pieces as well as of the assembled unit.

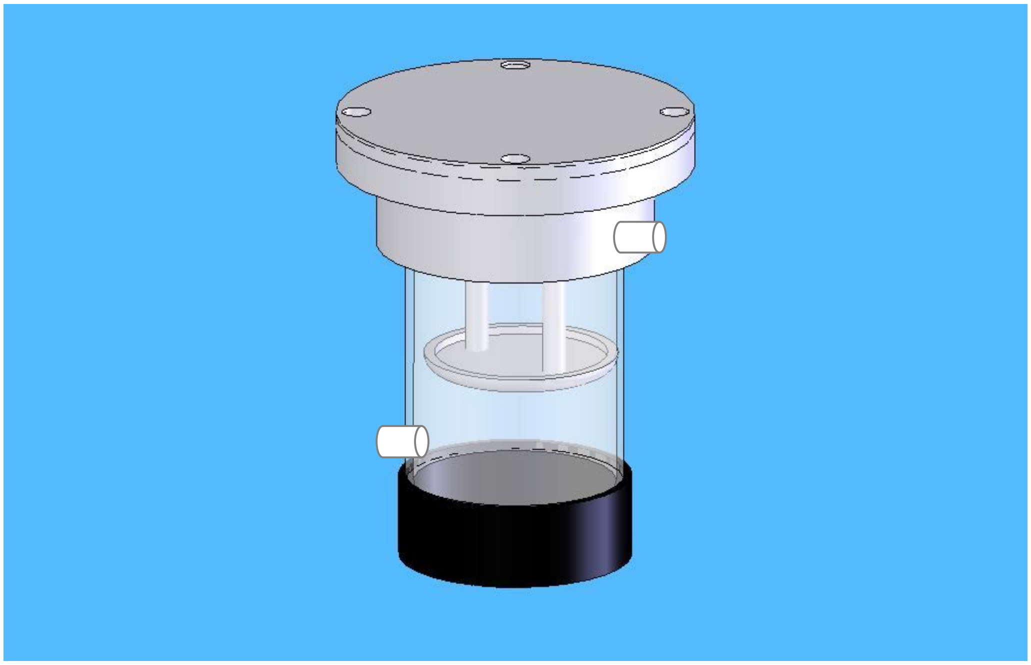

Figure 3.2: Solid Dessicant Dehydration Unit Design

Figure 3.3 : Transparent plate with perforated tray

3.3 Fabrication (Procedure)

1. The 4 inches PVC pipe was cut into the specified length that is 43cm.

2. The transparent plate was cut into the specified diameter. The transparent plate and the perforated tray were joining using vertical steel.

3. The flange was located at the top of the pipe together with the gasket. The transparent plate that unites with the perforated tray was located as an upper cover. Screw it tightly.

4. The PVC black bottom cover was install using glue.

5. The valve was installed in the drilled hole and the rig is ready for hydro testing.

3.4 Hydrostatic Testing

3.4.1 Introduction

Figure 3.4: Hydrostatic Test Set

A hydrostatic test is the common way in which leaks can be found in pressure vessels such as pipelines and plumbing. Hydrostatic testing is also a way in which a gas pressure vessel such as a gas cylinder or a boiler is checked for leaks or flaws. The hydrostatic testing procedure is used to determine if a pressure vessel is safe for continued use, or has suffered from degradation in its structural integrity and must be condemned. Using this test helps maintain safety standards and durability of a vessel over time. Testing is very important because such containers can explode if they fail when containing compressed gas.

3.4.2 Procedure

1. The hydrostatic tubing was assembling to the rig inlet.

⇩

2. The outlet valve of the rig was closed to complete the closed system.

⇩

3. In the first stage of pressurization, the water was pump using hand pump until reach 50% of maximum test pressure.

⇩

4. The pressure was maintained for a few minutes. Check all the potential leakage point such as flange connection, and others.

⇩

5. In the second stage, pressurization will continue until the pressure achieves the desire pressure.

⇩

6. Let the pressure stabilize before proceed with the maintaining the pressure for 15 minutes. The pressure was recorded for every 3 minutes.

⇩

7. After the hydrostatic pressure time has been satisfied, all joints were examined visually for leaks.

⇩

8. Mechanical joint leakage at permanent joints shall be repaired and it was examined in accordance with original requirements, and re-tested to the original test pressure.

3.5 Experimentation (Procedure)

1. Set up the equipment
   - The beaker and silica gel was weighed.
   - The silica gel was located at the perforated tray.
   - The transparent plate was screwed tightly. Link it using parafilm and apply vacuum grease at every connection.
   - The gas tubing was jointed to the inlet valve of the dehydration unit.
   - Make sure the inlet and outlet valve is shut off during the pressure regulation.
   - The gas pressure is regulating to the specified pressure.

2. The experiment was carried out with constant temperature (27^{o}C), volume (34.86m^3), and silica gel mass (5g) respectively.

3. As the pressure of the natural gas is in the specified pressure, conduct untreated natural gas to the dehydration unit for 10 minutes and let the gas

4. The gas bag was collected and the silica gel that already associated with moisture was weight.

5. The experiment will be carried out using four different pressures. Regulate the pressure into specified reading and repeat procedure 2 to 4.

3.6 Quantitative Analyzing

The silica gels that already adsorb water are collected and weigh and then differentiate it between weight before and after.

M = Ma (g) – Mb (g)

The reading get is the amount of water remove from the natural gas.

M = Water vapor adsorbed

Ma = Mass silica gel after the experiment

Mb = Mass silica gel before the experiment

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, there are four element covered which are design, fabrication, hydrostatic and experimental result. The design was made up using solid work software and the dimensions were getting from the length to diameter ratio. The main equipment use in fabrication part were RIDGID 590L machine, BENCH DRILL machine and BOSH GST 54 Professionals machine. On the hydrostatic result, the rig was test with various pressures in order to determine the maximum pressure it can stand.

In this chapter, the mass of the desiccant, the operating temperature and the volume of the rig were constant. The experimental result discusses the effect of operating pressure on water vapor removal. At a constant temperature the water content of the gas decreases with increasing pressure, thus less water must be removed if the gas is dehydrated at a high pressure.

4.2 Design Result

The natural gas dehydrator is design to trap the water vapor in natural gas using silica gel. The silica gel act as a moisture indicator by changing color. The rig was made of transparent 4 inches PVC pipe with two nozzles with inlet and outlet stream. The rig was provided with transparent plate that can open to put and take the silica gel. The silica gels were put on the perforated tray that unites with the transparent plate. The bottom of the rig was covered by black PVC cap. The length of the rig is design based on length to diameter ratio which is four to one. The diameter of the rig was fixed that is 10.16cm. From the calculation, the height was 40.64cm. By considering safety aspect (±5%), the height became 42.67cm. Table 4.1 shows the dimensions of dehydration unit.

Table 4.1: The dimensions of dehydration unit

Material	PVC Clear – Schedule 40
Height (cm)	10.16
Diameter (cm)	42.67

Figure 4.1: The material for the dehydrator unit

4.3 Fabrication Result

The fabrication starts with cutting the PVC pipe 4 inches using RIDGID 590L machine into its desired length. The hole for the inlet and outlet nozzles were made using BENCH DRILL machine. The transparent plate was cut into circular shape for the upper cover using BOSH GST 54 Professionals. The transparent plate was unites with the perforated tray using the provided screw. Black PVC cover was set into the position which at the bottom of the rig. The flange was installed and covered it using transparent plate. The silicon glue, vacuum grease and parafilm were used to prevent any leakage.

Figure 4.2: The Dehydrator Unit

4.4 Hydrostatic Result

Hydrostatic test is a method used to detect any leakage occurred in pipeline and vessels. In this study, pressure range, 0.1-0.5 bar was employed in order to satisfy the fabrication of the unit. Table 4.2 shows the result recorded in between 3 to 15 minutes. The results also reveal that the unit can withstand at only 0.5 bar. Beyond the pressure, the rig will rupture and cause leakage. The rig is a 42.67 cm length and 10.16 cm in diameter (4inc). The cylinder has a working pressure of 7.58 bar but the test pressure is only 0.5 Bar. The rig cannot maintain at a high pressure because glue at the black bottom PVC cover was not strong enough. So that, the experiment was carried out with pressure range from 0.1 to 0.4 bar only.

Table 4.2: Hydrostatic result

TEMPERATURE:CONSTANT (27^{o}C)	
Time, min	**Pressure, Bar**
3	0.1
6	0.2
9	0.3
12	0.4
15	0.5

4.5 Operating Pressure Result

The effect of operating pressure on the water vapor content is tabulated in table 4.1 and the graph is shown in figure 4.1. The experiment was carried out with four different pressures. The pressure range from 0.1 to 0.4 bar. Respectively, it is assumed that temperature and silica gel mass will be constant throughout the experiment. The amount of water vapor for various operating pressures was observed.

Table 4.3: Effect of operating pressures on the water vapor content

Operating Pressure, Bar	Water Vapor Content, g
0.1	0.0208
0.2	0.0165
0.3	0.0118
0.4	0.0073

Figure 4.3: The Equipment Setup

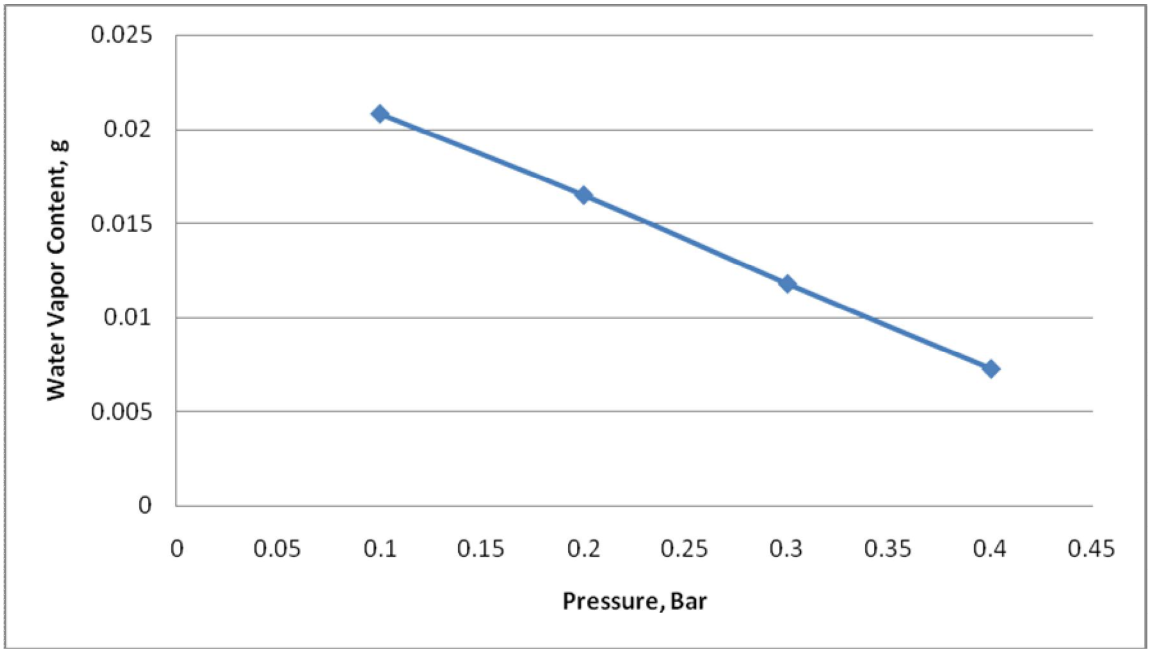

Figure 4.4: Effect of Operating Pressure on Water Vapor Content

The effects of operating pressure on water vapor content for natural gas dehydration are shown in figure 4.1. Water vapor is removed from natural gas as it flows through a silica gel in a pressure vessel. At a constant temperature the water content of the gas decreases with increasing pressure, thus less water must be removed if the gas is dehydrated at a high pressure. Result shows, gas pressure decrease, the amount of water vapor will increase as water vapor pressure becomes a large fraction of the total pressure. A large fraction of water vapor pressure leads to frequent collision between the water vapor particle and the cylinder wall which cause more water vapor to be adsorbed into the silica gel.

Natural gas streams have the characteristics that as the pressure increases at a constant temperature, the saturated vapor decreased. At a constant temperature, increasing pressure will reduce the saturated vapor content until a minimum in water content is reach at about 600 psig. At further increase in pressure, water holding capacity increase substantially. For normal natural gas dehydration using silica gel, 6-7 % by weight of design loading or water absorbing capacities should be assume, these design loading are usually reduce somewhat for unusual situations such as cryogenic plants where a water dew point of -100 ^{o}F and lower its desired. In this experiment, that theory cannot be achieved because the effect of water vapors in the surrounding. [16]

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Dehydration of natural gas is a removal of the water that is associated with natural gases in vapor form. It is necessary to dehydrate the untreated natural gas because it prevents such problem such as plugging due to hydrate formation, reduction of line capacity due to collection of free water in the line, and increased risk of damage to the pipeline due to the corrosive effects of water. The technique employed for dehydrating natural gas is solid dehydrator unit using silica gel as a desiccant. Solid Desiccants Dehydrator Unit is a very simple adsorption process, ideal for remote locations with limited utilities, minimal maintenance costs, easy to install and operate.

The objective of this study was achieved, that is to remove water from untreated natural gas using Solid Desiccant Dehydration Unit. The water content remove is inversely proportional to the operating pressure. At a constant temperature the water content of the gas decreases with increasing pressure because the water vapor pressure becomes a larger fraction of the total pressure. This study was involved in the provision of engineering, procurement, construction, and commissioning (EPCC).

5.2 Recommendations

From all sections above that explains about gas dehydration, here are some recommendations that can be listed for the improvement of future research.

i. Qualitative analyzer such as Moisture Content Analyzer is required to analyze the gas output that contains water.
ii. Use the same material for the whole rig to prevent the different in working pressure.
iii. Study the other parameter such as temperature, the mass of silica gel, volume, gas flow rate, and desiccant volume.

References

[1] Secondary Energy Infobook

[2] Edward J Staples, Electronic Sensor Technology

[3] Prof.. Ing. Peter BALÁŽ, PhD. Head of the Department for International Business, University of Economics Bratislava, Faculty of Commerce, Dolnozemská str.

[4] UNCTAD based on data from BP Statistical Review of World Energy June 2005

[5] P. Gandhidasan, Abdulghani A. Al-Farayedhi and Ali A. Al-Mubarak, Dehydration Of Natural Gas Using Solid Desiccants, pp: 855-868; Vol: 26.

[6] David Mirdadian, NATCO and Bob Bowman, Benefit using Delisquesting Desiccants for Gas Dehydration.

[7] A. Rojey, C. Jaffret, B. Durand, M. Valais and S. Jullian (1997), Natural Gas Production Processing Transport

[8] George H B Verberg, President of International Gas Union, Daily Express, Thursday July 28 2005.

[9] James Tobin, Phil Shambaugh, Erin Mastrangelo, natural Gas Processing: The Crucial Link Between Natural Gas Production and its transportation to Market.

[10] Prof Jon Steiner Gudmundsson, Norwegian university of Science and Technology, Chapter 7, The Dehydration and Sweetening of Natural Gas.

[11] Lessons Learned Summaries developed by the EPA in cooperation with the natural gas industry on superior applications of Natural Gas STAR Program Best Management Practices (BMPs) and Partner Reported Opportunities (PROs).

[12] Steven Weintraub, Demystifying Silica Gel

[13] Chistie John Geankoplis, Transport Processes and Separation Process Principle, Fourth Edition.

[14] Martin E Meserve, Javascripe Electronic Notebook, Single Layer Air Core Inductor Design.

[15] Ass. Prof Dr Eng Pander G, University of Chemical Technology and Metallurgy_Sofia, Bulgaria, Possibilities of Graphic Software Solidworks.

[16] Arthur L. Kohl, Richard B. Nielsen, Gas Purification

APPENDIX A

GANTT CHART PSM 1

Task/Week	1	2	3	4	5	6	7	8	9	10	11	12
Discussion on assigned Research Titles												
Briefing on URP I by coordinator and technical unit (16/07/08)												
Research Methodology Seminar I (23/07/08)												
Start collecting material, study all the related topic												
Preparation of Report												
Submission of proposal to supervisor chapter 1(check)												
Submission of proposal to supervisor chapter 2 & 3(check)												
Seminar I Proposal Presentation (3/09/08)												
Submission of Report (16/09/08)												
Research Methodology Seminar II (17/09/08)												
Preparation for URP II and research work started												

GANTT CHART PSM 2

Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Briefing on URP II														
Research work continued														
Submission of report and presentation material Final draft														
Return back the report														
Final seminar presentation														
Correction and preparation of final draft and technical paper														

APPENDIX B

SCHEDULE 40

Nominal Pipe Size (in)	O.D.	Average I.D.	Min. Wall	Nominal Wt./Ft.	Max. W.P. PSI**
1/4"	0.540	0.344	0.088	0.086	390
3/8"	0.675	0.473	0.091	0.115	310
1/2"	0.840	0.602	0.109	0.170	300
3/4"	1.050	0.804	0.113	0.226	240
1"	1.315	1.029	0.133	0.333	220
1-1/4"	1.660	1.360	0.140	0.450	180
1-1/2"	1.900	1.590	0.145	0.537	170
2"	2.375	2.047	0.154	0.720	140
2-1/2"	2.875	2.445	0.203	1.136	150
3"	3.500	3.042	0.216	1.488	130
3-1/2"	4.000	3.521	0.226	1.789	120
4"	4.500	3.998	0.237	2.118	110
6"	6.625	6.031	0.280	3.733	90
6" X 1/8	6.625	6.335	0.125	1.647	45
8"	8.625	7.942	0.322	5.619	80
10"	10.750	9.976	0.365	7.532	70
12"	12.750	11.890	0.406	9.949	70

APPENDIX C

RESULT

Table C.1: Result for pressure 0.1

PRESSURE= 0.1	
Component	**Weight, g**
Beaker	100.1338
Silica Gel	5.0005
Beaker + Silica Gel	105.1343
Beaker + Silica Gel + Water Content	105.1551
Water Content	0.0208

Table C.2: Result for pressure 0.2

PRESSURE= 0.2	
Component	**Weight, g**
Beaker	97.4603
Silica Gel	5.0004
Beaker + Silica Gel	102.4607
Beaker + Silica Gel + Water Content	102.4772
Water Content	0.0165

Table C.3: Result for pressure 0.3

PRESSURE= 0.3	
Component	**Weight, g**
Beaker	94.8569
Silica Gel	5.0007
Beaker + Silica Gel	99.8576
Beaker + Silica Gel + Water Content	99.8694
Water Content	0.0118

Table C.4: Result for pressure 0.4

PRESSURE= 0.4	
Component	**Weight, g**
Beaker	96.5851
Silica Gel	5.0035
Beaker + Silica Gel	101.5886
Beaker + Silica Gel + Water Content	101.5959
Water Content	0.0073