GAS DEHYDRATION USING GLYCOL SOLUTION IN ABSORPTION AND ADSORPTION UNIT

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ABSTRACT

Gas dehydration is widely used in natural gas treatment plant as a common process, because water and hydrocarbons can form hydrates, which may block valve and pipelines. Water also can cause corrosion in the gas contain acid components. Until today, among the most popular dehydration technology is either absorption or adsorption process. In this research, a novel study on gas dehydration a combination of absorption and adsorption process, where tri-ethylene glycol (TEG) and silica gel are absorbent and adsorbent respectively. A laboratory absorption-adsorption unit is studied in terms of natural gas (methane) flow rate and operating temperature to the percentage of water removal. The experimental work started at room temperature by controlling the valve of methane flow rate at 2.5 m^3/hr initially and then allows the gas through the absorption-adsorption unit. Meanwhile, tri-ethylene glycol (TEG) flows at 120 L/hr from a circulation pump. Experiment was repeated with different methane flow rates and different operating temperature in the range of 30^{o}C until 50^{o}C. Experimental results showed that, increasing of methane flow rate causes increasing of water removal while increasing of operating temperature give a result of decreasing of water removal. Thus, in analyzing the gas dehydration efficiency, in an absorption-adsorption unit, parameters such as gas (methane) flow rate and operating temperature are among to be considered for a reliability and economic benefit.

ABSTRAK

Penyahhidratan gas adalah digunakan secara meluas dalam loji rawatan gas asli seperti satu proses biasa, kerana air dan hidrokarbon akan membentuk hidrat, yang mana akan menghalang injap dan talian paip. Air juga boleh menyebabkan karatan di dalam gas yang mana mengandungi komponen gas asid. Sehingga hari ini, antara teknologi penyahhidratan paling popular ialah penyerapan dan penjerapan dengan cecair tri etilena glikol (TEG). Dalam satu kajian, penyahhidratan gas menggunakan gabungan antara process penyerapan dan penjerapan, di mana tri etilena glikol (TEG) dan gel silica masing-masing adalah pengisap. Dalam kajian ini, makmal unit penyerapan dan penjerapan yang dipelajari lebih tertumpu pada peratusan bagi penyingkiran air mengikut kadar aliran gas metana dan suhu kendalian. Kerja experimen itu bermula pada suhu bilik di mana dengan mengawal injap kadar aliran metana pada 2.5 m^3 / hr pada mulanya dan kemudian membenarkan gas itu melalui unit penyerapan dan penjerapan. Manakala, tri etilena glikol sedang mengalir pada 120 L / hr dengan menggunakan pam edaran. Eksperimen ini telah diulang dengan kadar aliran metana yang berbeza dan suhu kendalian berbeza dalam julat 30^oC hingga 50^oC. Di dalam keputusan experiment, didapati bahawa kenaikan kadar aliran gas metana menyebabkan pertambahan peratus air yang disingkirkan sementara itu kenaikan suhu kendalian menyebabkan penurunan peratusan air yang disingkirkan. Oleh itu, dalam menganalisa kecekapan penyahhidratan gas, dalam unit penyerapan dan penjerapan, parameter seperti kadar aliran gas asli (metana) dan suhu pengendalian adalah antara yang perlu dipertimbangkan untuk keblehpercayaan dan manfaat ekonomi.

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CH_4	-	Methane
C_2H_6	-	Ethane
C_3H_8	-	Propane
C_4H_{10}	-	Butane
C_5H_{12}	-	Pentane
CO_2	-	Carbon Dioxide
N	-	Nitrogen
He	-	Helium
H_2S	-	Hydrogen Sulfide
CV	-	Calorific Value
P_C	-	Critical Pressure
T_4EG	-	Tetra-ethylene Glycol
TEG	-	Tri-ethylene Glycol
DEG	-	Di-ethylene Glycol
EG	-	Ethylene glycol
M-SG	-	Metals Silica Gel
C_{18}	-	Hydrophobic group
LNG	-	Liquid Natural Gas
HCHO	-	Formaldehyde
HCO	-	Formyl Radical
CO	-	Carbon Monoxide
H_2O	-	Water
H_2	-	Hydrogen

F	-	Fluorine
Cl	-	Chlorine
Br	-	Bromine
I	-	Iodine
HCl	-	Hydrochloric acid
CH_3Cl	-	Methyl chloride
QLD	-	Quantum Lead Dehydrator
HAP	-	Hazardous Air Pollution
SDTC	-	Sustainable Development Technology Canada
PTFE	-	Polytetrafluoroethylene
Pdl	-	Differential Pressure Transmitter
PFA	-	Perfluoroalkoxy or plastic or polymer resin
DN	-	Diameter Normal
BTEX	-	Benzene-Toluene-Ethylbenzene-Xylene
KF	-	Karl-Fisher

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CHAPTER 1

INTRODUCTION

1.1 Natural Gas

Millions of years ago, the remains of plants and animals decayed and built up in thick layers. This decayed matter from plants and animals is called organic material - which was once alive. Over time, the mud and soil changed to rock, covered the organic material and trapped it beneath the rock. Pressure and heat changed some of this organic material into coal, some into oil (petroleum), and some into natural gas - tiny bubbles of odorless gas. The main ingredient in natural gas is methane, a gas (or compound) composed of one carbon atom and four hydrogen atoms.

Natural gas is a gaseous fossil fuel consisting primarily of methane but including significant quantities of ethane, propane, butane, and pentane – which need to be removed before the gas is considered clean fuel to be used —as well as water, carbon dioxide, nitrogen, helium and hydrogen sulfide.

1.1.1 Properties of Natural Gas

Natural gas is non-toxic and odorless. Natural gas companies inject a sulpher based, nontoxic odorant, that smells like rotten eggs, into the gas so it is easily detectable at very low concentrations. Natural gas also has a very narrow combustion range. This means that it will only ignite or burn when the natural gas/air concentration is between 4 and 15 percent natural gas in air. Concentrations outside this range will not burn. Natural gas is also lighter than air, so if natural gas escapes from a pipeline, it rises harmlessly into the atmosphere [1].

Treated natural gas consists mainly of methane: the properties of both gases (natural gas & methane) are nearly similar. However, natural gas is not pure methane. Natural gas has a peculiar characteristic of igniting only when there is an air-and-gas mixture and the percent of natural gas is between 5 and 15 percent. A mixture containing less than 5 percent or greater than 15 percent of natural gas would not ignite. Natural gas contains small quantities of nitrogen, oxygen, carbon dioxide, sulfur components and water. Liquefaction is a process involving cooling and condensing of natural gas that removes the non-methane components such as carbon dioxide and sulfur. It leads to the formation of an extremely pure, clean-burning product that is efficient to transport and store.

Table 1 showed the properties of natural gas. The density of the natural gas is 432.54 kg/m^3, lower the air. The boiling point of natural gas is -158^oC, close to the methane temperature. So, most of the engineer assumes that natural gas is the methane gas. The calorific value, CV is 49,313.32 KJ/kg. The critical temperature, T_C, is -82.3^oC. Besides that, the critical pressure, P_C, is -4638.9 kPa

Table 1.1: Properties of Natural Gas

Properties of Natural Gas	Value
Density, kg/m^3	432.54
Boiling point, ^oC	-158
Calorific value, KJ/kg	49313.32
Specific volume, m^3/kg	0.0023
Critical temperature, ^oC *	-82.3
Critical pressure, kPa*	-4638.9

** Critical temperature and pressure for pure liquid methane.*

1.2 Water Vapour

Water vapour also known as *aqueous vapor*, is the gas phase of water. Water vapour is one state of the water cycle within the hydrosphere [7]. Water vapour can be produced from the evaporation of liquid water or from the sublimation of ice. Under normal atmospheric conditions, water vapour is continuously generated by evaporation and removed by condensation [8].

1.2.1 Properties of Water Vapor

Table 2 shows the properties of water vapour. The properties of water vapour same as the pure water; have a boiling point at 100°C while the melting point is 0°C at the room temperature and atmospheric pressure. The molecular weight of water vapour is 18.02 g/mol and it has two atom of hydrogen and one atom of oxygen. The boiling point of water is higher because of the hydrogen bond. Much heat required to broke the hydrogen bonding. Water vapor is lighter or less dense than dry air. At equivalent temperatures it is buoyant with respect to dry air [10].

Table 1.2: Properties of Water Vapor

Water Vapor	
Systematic name	Water vapor
Liquid state	Water
Solid state	Ice
Properties	
Melting point	0 °C
Boiling point	100 °C
Individual gas constant	461.5 J/ (kg.K)
Latent heat of evaporation	2.27 MJ/ kg
Molecular weight	18.02 g /mol
Specific heat capacity	1.84 kJ/ (kg.K)

1.2.2 The Effects of Water Vapour in Natural Gas Flow

1.2.2.1 Hydrate Formation

Hydrates are solids formed by the physical combination of water and other small molecules of hydrocarbons [6]. They are icy hydrocarbon compounds of about 10% hydrocarbons and 90% water. Hydrates grow as crystals and can build up in orifice plates, valves and other area not subjected to full flow. Thus, hydrates can plug lines and retard the flow of gaseous hydrocarbon streams. The primary conditions promoting hydration formation are the following the certain characteristic. The characteristic of hydration formation are gas must be at or below its water (dew) point with “free” water present and it also occur in low temperature and high pressure.

1.2.2.1 Corrosion Problems

Corrosion often occurs when liquid water is present along with acidic gases, which tend to dissolve and disassociate in the water phase, forming acidic solutions. The acidic solutions can be extremely corrosive, especially for carbon steel, which is typically used in the construction of most hydrocarbon processing facilities.

1.3 Method / Technique in Gas Dehydration

1.3.1 Absorption Technique

Figure 1.1 illustrates the dehydration unit by absorption technique. Absorption dehydration generally has two sections – absorption column (contactor) and stripping column (regenerator). The absorption step is carried out in a plate or packed column. For small diameters, packing is generally used, while the larger columns are equipped with bubble-cap or valve trays. After the absorption step, the glycol leaving at the bottom is regenerated by distillation and recycled. Intensive dehydration of natural gas demands high purity of the recycled solvent. This purity is improved by lowering the pressure and raising the temperature during the regeneration step.

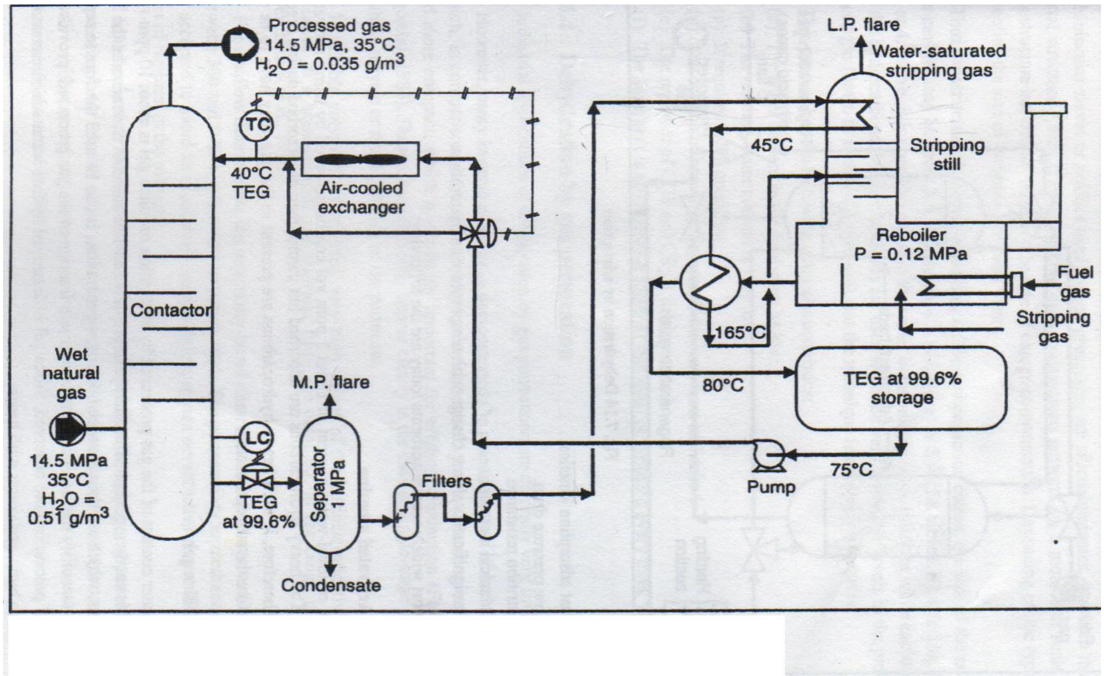

Figure 1.1: Dehydration by Absorption using TEG

1.3.2 Adsorption Technique

The flow scheme of a dehydration operation by adsorption in a fixed bed is shown in figure 1.2. The process is conducted alternately and periodically, with each bed going through successive steps of adsorption and desorption. During the adsorption step, the gas to be processed is sent on the adsorbent bed which selectively retains the water. When the bed is saturated, hot gas is sent to regenerate the adsorbent. After regeneration and before the adsorption step, the bed must be cooled. This is achieved by passing through cold gas. After heating, the same gas can be used for regeneration. In these conditions, four beds are needed to practice, two beds operating simultaneously in adsorption, one bed in cooling and one bed in regeneration.

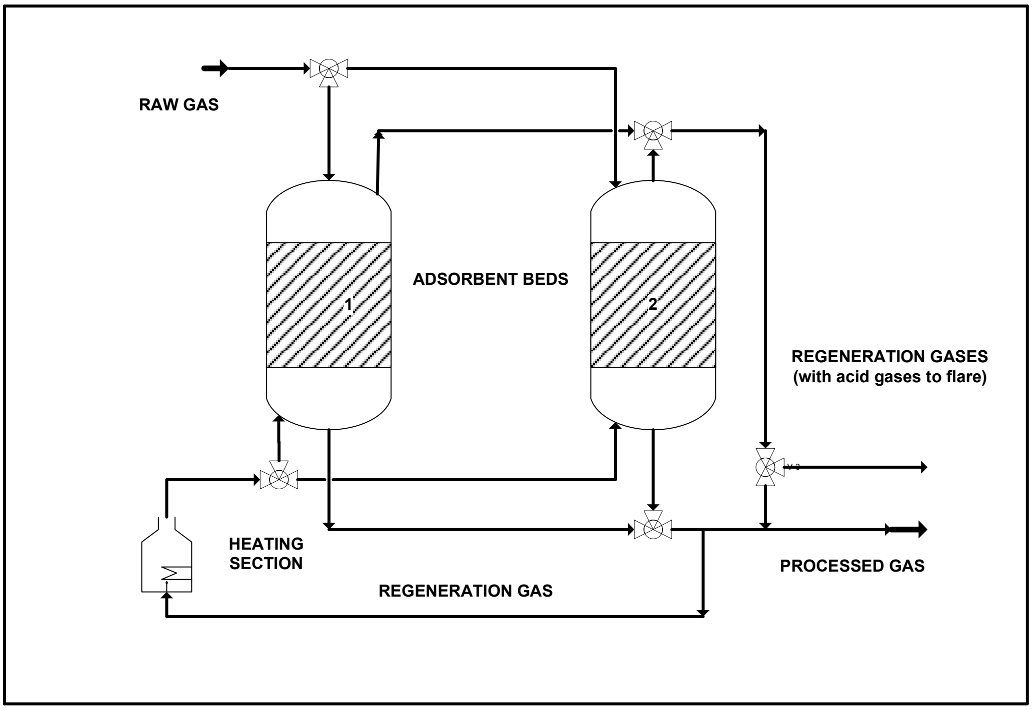

Figure 1.2: Dehydration by adsorption

The most widely used adsorbents today are the following;

Activated carbon

Activated carbon is high degree of microporosity, one gram of activated carbon has a surface area of approximately 500 m^2. It also higher density provides greater volume activity and normally indicates better quality activated carbon. Activated carbon as an adsorbent at low pressure and subsequent desorption by heating.

Activated alumina

Activated Alumina is achieving a low residual-water content of about 1 ppm vol. The heavy hydrocarbons are adsorbed but cannot desorbed during regeneration. Therefore, if such heavy hydrocarbons are present in the gas, they have to be removed before the adsorption step.

Silica gel

The water content of the gas processed by adsorption on silica gel is about 10 ppm vol. Silica gel is easily regenerated at a temperature between 120 and 200 ^{o}C. It adsorbs the hydrocarbons, where are then desorbed during regeneration. Therefore, it can be used to separate simultaneously the water and the condensate fraction of the gas processed, provided a number of precautions are observed.

Molecular sieves (Zeolites)

Molecular sieves is a silicoaluminates, in which the crystal sturcture forms cavities making up a microporous network on a molecular scale. Molecular sieves are used to obtain very low water levels in the processed gas (down to 0.03 ppm vol), but the technique is relatively expensive – the adsorbent is an expensive material that 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).

1.4 Problem Statement

The glycol dehydration unit is extensively used in the oil and gas industry to produce dehydrated gas. It also used in natural gas treatment plant as a common process, because water and hydrocarbon can form hydrates, which may block valves and pipelines.

Basically, without understanding and properly determining the parameters which affect analyze the removal of water vapours, it is unsufficient to the efficient gas dehydration process. Hence, this research is going to study among the important parameter which are natural gas or this case was referred to methane flow rate and operating temperature.The two parameters were manipulated to get the optimum value of removing water vapour.

1.5 Objectives

To analyze the performance of adsorption & absorption unit in removing water vapor by emphasizing important parameter such as Natural Gas (methane) flow rate and operating temperature.

1.6 Scope of Research Work

This research focuses on two main scopes which are:

1) The study for a combination of absorption and adsorption processes in an absorption-adsorption unit for a water removal in natural gas flow.

2) To analyze its two important parameter such as gas flow rate and operating temperature.

CHAPTER 2

LITERATURE REVIEW

2.1 Tri-ethylene Glycol

Tri-ethylene glycol (TEG), is a colourless, odourless, non-volatile, and hygroscopic liquid. It is characterized by two hydroxyl groups along with two ether linkages, which contribute to its high water solubility, hygroscopicity, solvent properties and reactivity with many organic compounds.

TEG is displacing diethylene glycol (DEG) in many of these applications on account of its lower toxicity. TEG finds use as a vinyl plasticizer, as an intermediate in the manufacture of polyester resins and polyols, and as a solvent in many miscellaneous applications. Tri-ethylene glycol (TEG) is derived as a co-product in the manufacture of ethylene glycol from ethylene oxide, and from "on-purpose" TEG production using diethylene glycol. Some capacities are based on total capacity for ethylene glycols.