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Simulation of Dehydration Process by Using Ethylene Glycol Butyl Ether (Egbe)

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Abstract

The raw natural gas extracted from production wells contains many impurities such as oil, sulphur, carbon dioxide, nitrogen, and other impurities. Among these impurities that must be removed in order to achieve the specifications of the liquid natural gas (LNG) is a water vapor. Because free water causes hydrate formation in transport pipelines and in addition to corrosion when combine with acid gases, resulting in heavy losses in maintenance costs of transport pipelines. For these reasons, natural gas must be dehydrated. The most common methods is Glycol dehydration process, and this process has a good results. In this paper, we have suggested a solvent and simulated it and proof its effectiveness in dissolving the water and dehydration the gas instead of using Tri-ethylene Glycol (TEG). This solvent is Ethylene Glycol Butyl Ether (EGBE), It is used widely as a solvent in surface coatings, and used in metal and household cleaners. It isn't use in previously natural gas processing. The comparison between glycol types done by Aspen Hysys (glycol package model approach) and according to the dry gas specifications, the simulation results show that: the appropriate flow rate for EG, DEG, TEG, TREG and EGBE are 500 Kgmol/h, 429.5 Kgmol/h, 337.1 Kgmol/h, 80 Kgmol/h and 25.3 Kgmol/h, respectively. Ethylene Glycol Butyl Ether prove a high the efficiency it in dissolving the water with a little flow rate, as well as decrease the energy required for the operation. This paper looks to the use of EGBE as an alternative to TEG for its high efficacy in dissolving water, also significant decrease in the cost of dehydration gas about 98.7 x 10^9 \$/Year**]**.

Keywords: Glycol, Dehydration, Natural Gas, Software, Butyl Glycol, EGBE.

INTRODUCTION

It is believed that natural gas was initially used for commercial purposes by the Chinese approximately 2,400 years ago. Shallow wells provided the gas, which was carried in bamboo pipes and utilized in gas-fired evaporators to create salt from brine. In the late 17th and early 18th centuries, the gas was also used in the United States for home lighting and streetlights. The second known usage of natural gas for commercial purposes was in 1821. In Fredonia, New York, William Hart dug a shallow 30-foot (9-meter) well, and he used wooden pipes to deliver the gas to nearby homes.

A few small-scale, local programs involving natural gas were implemented in the ensuing years, but large-scale activity didn't start until the early 1900s. The United States was the world's top consumer of natural gas (22.9 TCF) and the second-largest production (19.2 TCF) in 2004.

Natural gas is mostly used as fuel, but it is also a significant supply of elemental sulfur, a crucial industrial ingredient, and hydrocarbons for petrochemical manufacturing. One of the safest, most convenient, and cleanest sources of energy for daily use is natural gas (NG). As indicated in Table 1, its primary constituent is methane (CH4), although it also contains ethane, propane, butane, and other chemicals. You can find natural gas on its own or in combination with oil. When the gas is extracted from the earth, it may be contaminated with water, oil, sulphur, carbon dioxide, nitrogen, and other substances. The water vapor in the gas created issues since it caused the water to condense on cold surfaces such as pipeline walls or storage tanks if the temperature drops below the water vapor's dew point temperature (Tdew) (Arthur et al 2006).

Condensed water in the pipeline creates slug flow and erosion, water vapor increases the volume and lowers the heating value of the gas, and the dissolved water in NG is corrosive, particularly when it contains CO2 and/or H2S (Francis et al 1991). Finally, NG in combination with liquid water can form methane hydrate. Gas hydrates are formed at high pressures and low temperatures when water lattice with cavities trap gas molecules such as methane (Kelly et al 2019). By employing a physical absorption technique in which the gas is in contact with a liquid that selectively absorbs the water vapor, the amount of water in NG can be lowered to the 10 ppmv level.

Table:(1). The main constituents of natural gas

Class	Compnent	Formuls
Hydrocarbon	Methane	CH_4
	Ethane	C_2H_6
	Propane	C_3H_8
	i-Butane	i-C_4H_{10}
	n-Butane	n-C_4H_{10}
	i-Pentane	i-C_5H_{12}
	n-Pentane	n-C_5H_{12}
	Cyclopentane	C_5H_{10}
	Hexane and ggheavier	C_{6+}
Inert Gases	Nitrogen	N_2
	Helium	He
	Argon	Ar
	Hydrogen	H_2
	Oxygen	O_2
Aicd Gases	Hydrogen-Solifide	H_2S
	Carbon Dioxide	CO_2
Sulfur Compounds	Mercaptans	R-SH
	Sulfides	R-S- $R^{'}$
	Disulfides	R-S-S-$R^{'}$
Water Vapor		H_2O
Liquid sluges	Free water or Brine	
	Corrosion inhibitores	CH_3OH
	Methanol	
Solids	Millescale and rust	
	Iron sulfide	FeS
	Reservior fines	

The most widely used absorbents are ethylene glycol (EG), diethylene glycol (DEG), tri-ethylene glycol (TEG), tetra-ethylene glycol (TREG), and propylene glycol; tri-ethylene glycol is the glycol of choice in most cases. The process of removing water is called the glycol dehydration process. (Arthur et al 2006).

This paper presents a novel approach in which we demonstrate the efficacy of butyl glycol as a solvent for absorbing water vapor. Additionally, we will compare ethylene glycol (EG), diethylene glycol (DEG), tri-ethylene glycol (TEG), tetra-ethylene glycol (TREG), and ethylene glycol butyl ether (EGBE).

DESCRIPTION OF TRADITIONAL PROCESS

In order to exclude any liquid hydrocarbons from the gas stream, wet natural gas normally first passes through an input separator, as illustrated in figure 1. The gas then travels to a contractor, or absorber, where the lean glycol comes into contact with it and dries it. The dry gas exiting the absorber passes through a gas/glycol heat exchanger and then into the sales line.

Rich glycol exiting the absorber flows through a valve to decrease the pressure, and then rich glycol is flashed to remove dissolved hydrocarbons and can be used for fuel and/or stripping gas. Heat exchange between the cool rich glycol and the hot lean glycol is improved by using two or more shell and tube heat exchangers in series.

The stripper's top is where the desorbed natural gas and water vapor are released. After exiting the reboiler, the hot, regenerated lean glycol is cooled by cross-exchange with returning rich glycol. It is then pushed to a glycol/gas heat exchanger and returns to the absorber's top. Must add a TEG solution makeup before feeding it to the contactor column. (Fabrizio et al 2016/2017).

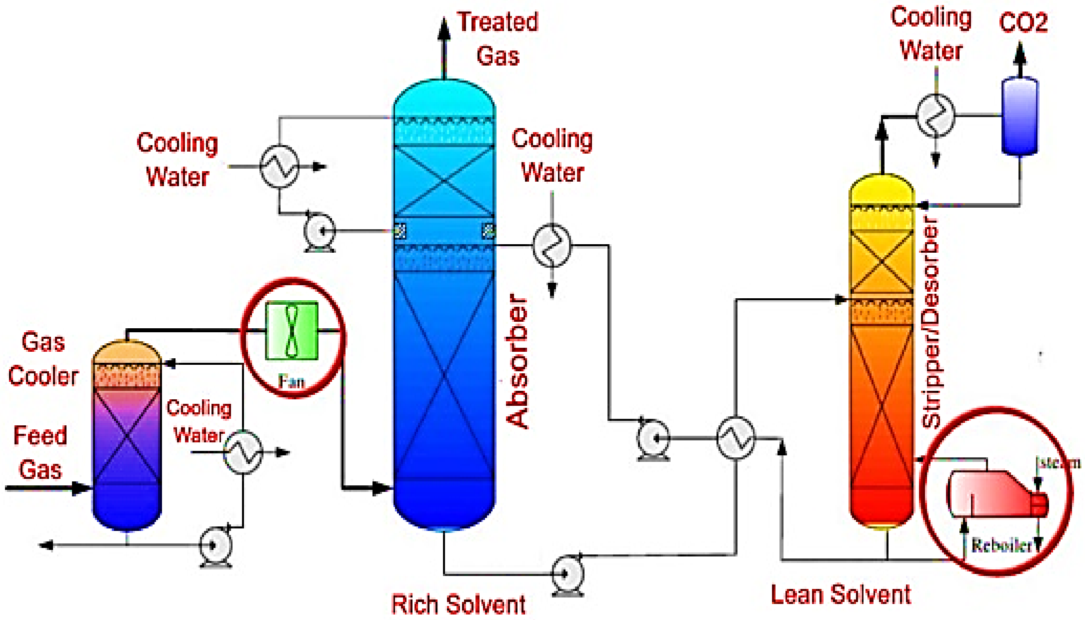

Figure: (1). Typical glycol dehydration unit

In simulation of the process, there are two different streams exist in the Plant. The inlet streams for the process were: Wet Gas and the other is lean glycol. The basis for the simulation was 50 MMSCFD of wet gas, where the data of NG from Arabian Gulf Oil Company (AGOCO). The specification of these streams is existent in Table 2 and as shown in figure 2 after the simulation.

Table :(2). Characteristics of streams' physical attributes

Name	Wet Gas (Feed 1)	Lean Glycol (Feed 2)
Temperature	35	41
Pressure	24.82	24.82
Mole Flow	50 MMSCFD	208 Kmol/h
	Composition	
CH_4	0.715700	0
C_2H_6	0.102160	0
C_3H_8	0.069694	0
n-C_4H_{10}	0.029119	0
i-C_4H_{10}	0.014414	0
n-C_5H_{12}	0.008293	0
i-C_5H_{12}	0.006934	0
n-C_6H_{14}	0.005462	0
n-C_7H_{16}	0.002684	0
n-C_8H_{18}	0.000556	0
n-C_9H_{20}	0.000015	0
H_2O	0.002500	0.005
CO_2	0.016907	0
H_2S	0.001300	0
N_2	0.028060	0
Glycol (TEG)	0	0.995

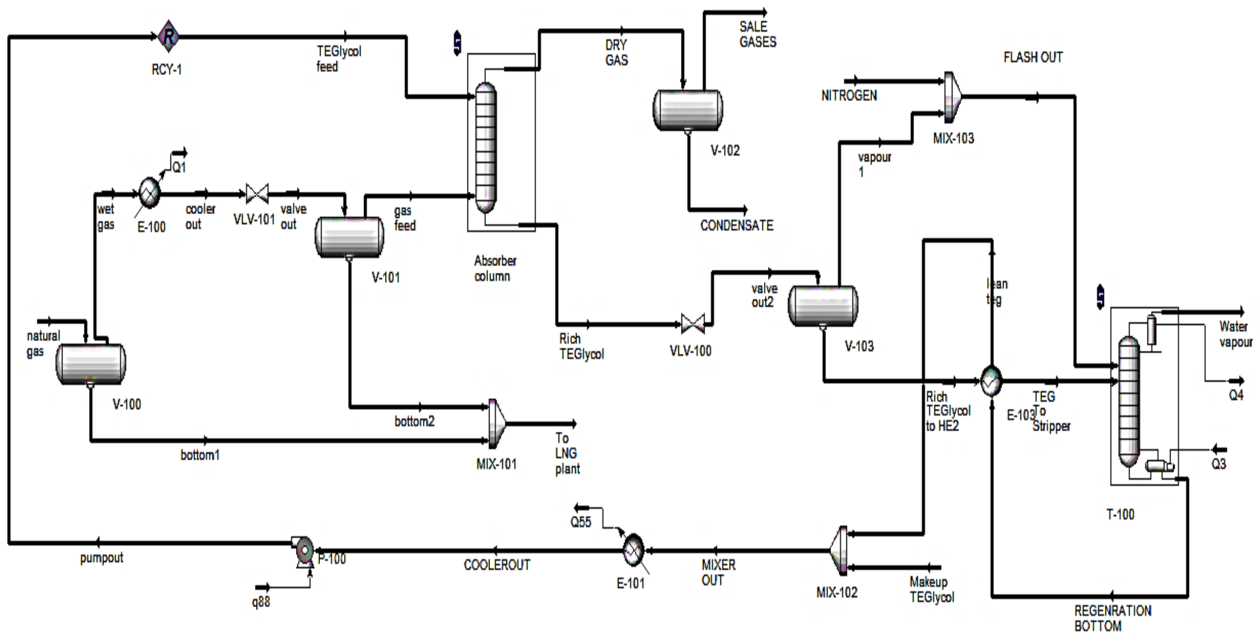

Figure: (2). Simulation of dehydration unit

COMARISON OF ABSORPTION PROCESSES BY DIFFERENT TYPES OF GLYCOL

Some types of glycol ethers have been widely utilized for about half a century, having first been developed in the 1930s. Typically, they dissolve in both water and oil, and they include a diverse family of over thirty solvents. Due to their miscibility in a wide range of organic solvents including water.

Absorption Process by Mono-ethylene Glycol (MEG):
The most basic glycol is ethylene glycol, which is the adduct of ethylene oxide (EO) and water. Because MEG has a high viscosity at low temperatures, it is employed more as an inhibitor (to stop the formation of hydrates) than as a solvent.

Absorption Process by Diethylene Glycol (DEG):
Although diethylene glycol is low efficiency to absorb the water only to is uses for gas dehydration in colder climates (e.g., the North Sea) because of its lower viscosity (Arthur et al 2006).

Absorption Process by Tri-ethylene Glycol:
Tri-ethylene glycol (TEG) is the most common absorbent for gas dehydration, and it is traditional process for dehydration of the gas. It is easy to regenerate it and we can get about 98-99 percent purity of the TEG after regeneration.

Tetra-ethylene Glycol (TREG):
Tetra-ethylene glycol is the high efficiency absorbent for dehydration, but due to more expensive than TEG, therefore it is not a lot used for this purpose.

Absorption Process by Butyl Glycol:
Trade names for Butyl Cellosolve, O-Butyl Ethylene Glycol, Butyl Glysolv, Butyl Oxital EB, and Glycol Ether EB are examples of Ethylene Glycol Butyl Ether (EGBE).

EGBE is colorless organic liquid with a mild, non-residual odor, a sweetish odor, or a mild ether odor (Michael 1993). Solubility of EGBE in water can be considered as highly miscible in water up to about 100 g/l. It is extensively utilized as a solvent in surface coatings, including quick-dry and spray lacquers, enamels, varnishes, varnish removers, and latex paint. It is also used in metal and household cleaners (Ms J.Wess et al 1998).

Most glycol ethers have minimal acute toxicity (Brussels 2005). During 2003, the production of EGBE in the European Union was approximately 161,000 tonnes. Ethylene oxide and n-butyl alcohol are added to create EGBE. The properties of TEG, BG and the water are present in Table 3.
As shown in Figure 3, the butyl glycol has lowest boiling point, that's mean the energy needed for the dehydration process of NG will be low.

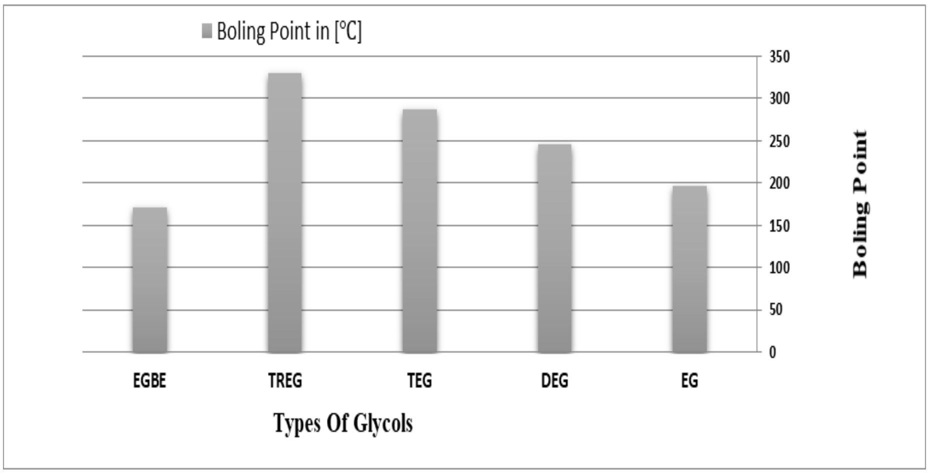

Figure: (3). Boiling of Glycols

Table :(3). Properties of TEG, BG and the water

Properties	MEG	DEG	TEG	TREG	Butyl Glycol	Water
Formula	$C_2H_6O_2$	$C_4H_{10}O_3$	$C_6H_{14}O_4$	$C_8H_{18}O_5$	$C_4H_9OCH_2CH_2OH$	H_2O
Molar Mass [Kg/Kmol]	62.07	106.12	150.17	194.23	118.2	18.015
Normal Boiling Point [℃]	197.1	245.3	288.0	329.7	171	100.0
Vapor Pressure@ 20 ℃ $[Pa]$	8.3	0.34	0.05	0.007	0.117	3170
Density @ 20 ℃ $[kg / m^3$	1113	1120	1126	1126	902	55.56
Viscosity @ 20 ℃ $[mPa.s]$	16	38	48	52	3.3	0.894
Maximum recommended regeneration temperature [°C]	163	177	204	224	140	-

The butyl glycol star brightened in 2010 as it contributes for solved the Gulf of Mexico disaster, as a result of the leakage of approximately 4.9 million barrels in its water at a depth of 1500 m below sea level.

MATERIALS AND METHODS

In this paper we will use a substitute for Tri-ethylene glycol for dehydration of natural gas. The study done on jest absorber column as shown in figure 4, with same specification that existent in Table 2.

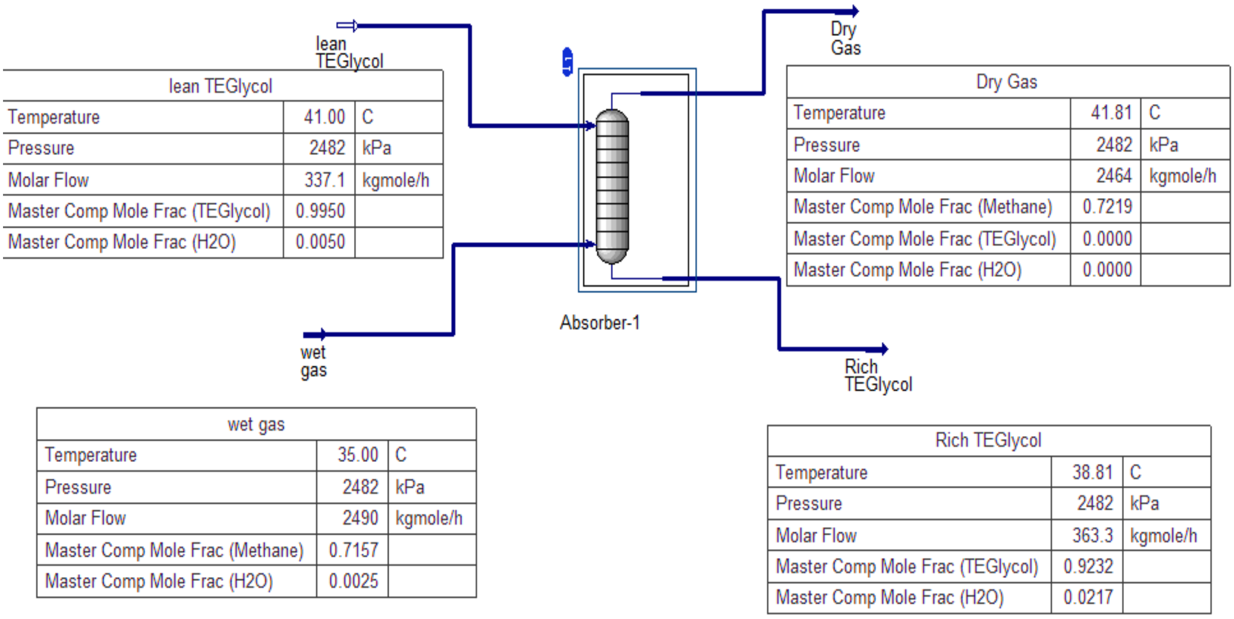

Figure: (4). Absorber column

DISCUSSION AND RESULT

From figure 5, it can be deduced the appropriate flow rate for each type of glycols, also we note that, when we use the butyl glycol (EGBE) as a replacement for tri-ethylene glycol (TEG), it has much lower flow rate about [4 – 7 lb/MMSCF]) with retaining the natural gas specifications as a dry gas.

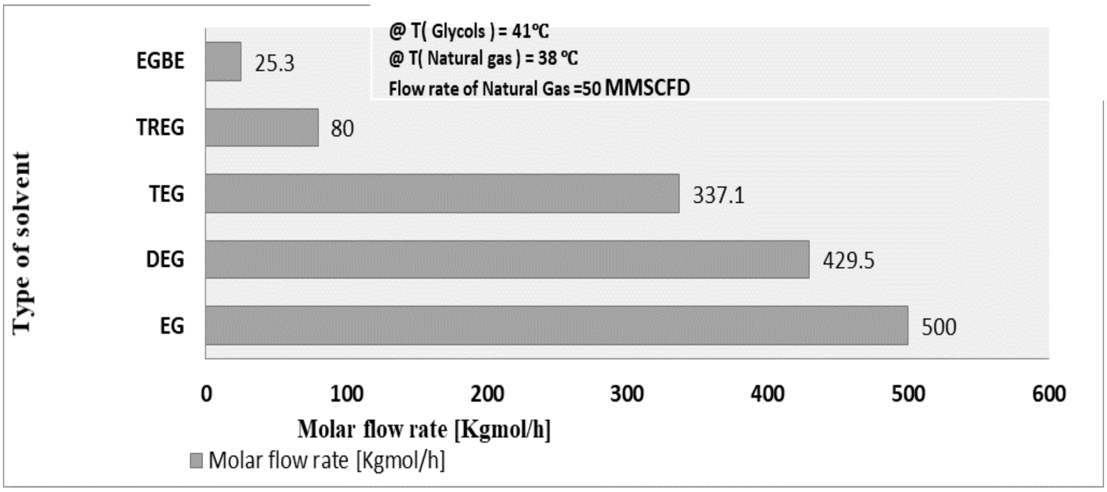

Figure: (5). The Quantity suitable for all Glycol types

Through figure 6, evidently, the effect of the EGBE in dissolving the water and dehydrate the natural gas.

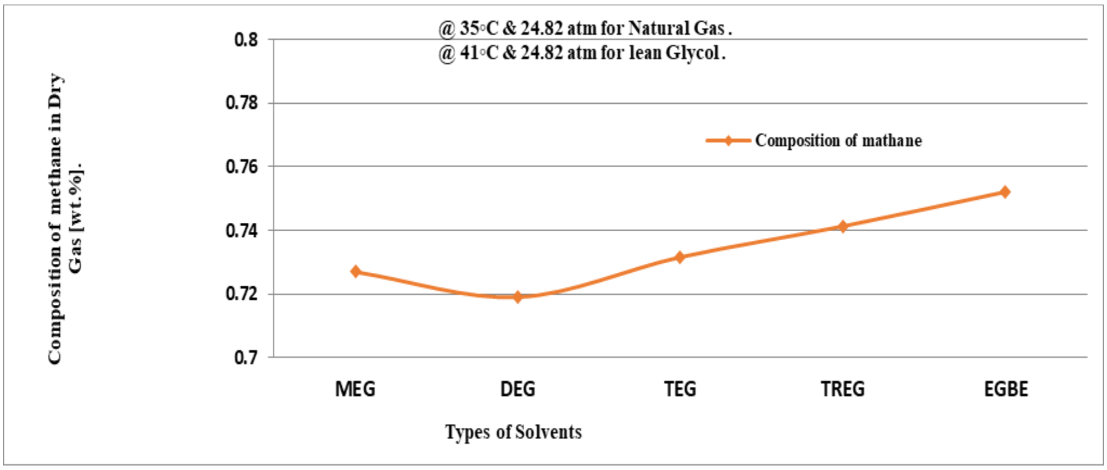

Figure: (6). Composition of Methane in Dry Gas. Vs Types of Solvents

SOLVENTS COST

Additionally, based on each solvent's flow rate during the process, as shown in Table 4 cost of the solvents at current prices (2021) was compared.

Table :(4). Price of Glycol and the cost of glycols

Type of Solvent:	The price in [$/ 1 Kg]	The Cost	
		In [$ /h]	In [$/Year]
MEG	0.86[9]	0.86 * 3.092 x 10^4 =26608.4	233 x 10^6
DEG	40.5[10]	40.5 * 6.421 x 10^4 =26 x 10^5	228 x 10^8
TEG	200[11]	200*5.638 x10^4 = 11.2 x 10^5	988 x 10^8
TREG	142[12]	142*1.547x10^4 = 22 x 10^6	192x 10^9
EGBE	4[13]	4 * 2977 = 11908	104 x 10^6

Figure 7 compares the costs of the solvents and shows that the EGBE is more economically viable.

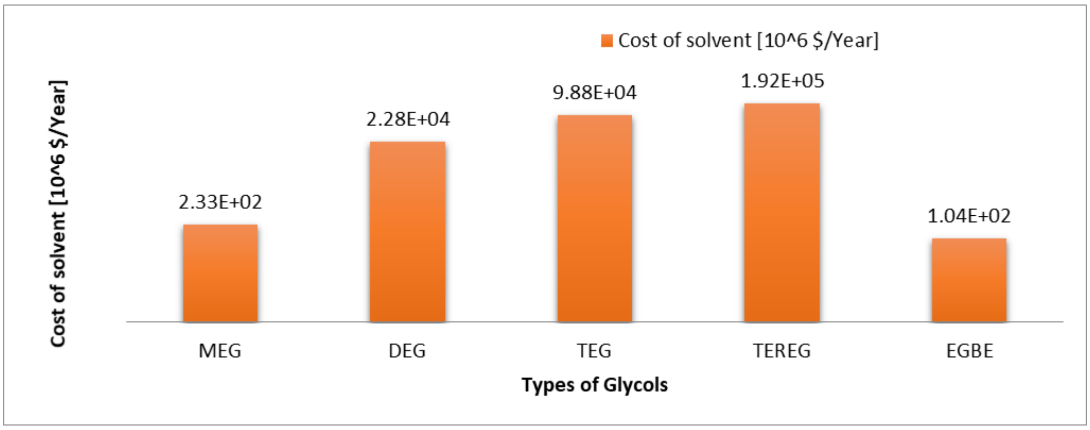

Figure: (7). Comparison between the Costs of Solvents

CONCULSION

The dehydration process is important part in treatment of the natural gas, because the water dissolved in the NG made many of problems such as dehydrate formation, corrosion specially when combine with CO_2 and/or H_2S. In view of this, it concludes with the following:

- TEG has a good efficiency for dehydration the gas.
- TREG has a high efficiency, but also needs to high cost for this reason, therefore it is not a lot used for this purpose.
- Since the molecule contains both functional groups, glycol mono-ethers (EGBE) are a liquid that combine the solubility properties of ethers and alcohols. They are therefore widely used in solvent application, including formulations such a paints, inks and cleaning fluids.
- EGBE prove a high the efficiency it in dissolving the water, and in the same time reduce the cost of dehydration of natural gas.

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