Sensitivity Analysis and Simulation of TEG Dehydration Unit in Central Rumaila Compression Station in Basrah-Iraq

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***Abstract*- In the operating of TEG- dehydration unit in Central Rumaila Compression Station. Two operating parameters determine the efficient operating of the unit, the desired dew point depression and the losses of TEG. This work presents an attempt to study the effect of all the operating variables on the efficiency of the dehydration unit such as: the effect of pressure and temperature of the natural gas has to be treated on the water content. Contactor pressure, TEG circulating rate and stripping gas flow rate are also considered in this study. The results showed that decreasing the temperature of the absorber from 130 F to 120 F will reduce the mass fraction of water in the dry gas stream from 0.000076 to 0.00002. Increasing the absorber pressure from 549.7 psia (design pressure) to 600 psia will also reduce the water content in the outlet dry gas from 0.000076 to 0.000022 as mass fraction. The simulation result shows linear relation between the wet gas flow rate from the regeneration column and the lean glycol flow rate.**

Keywords: Dehydration, Simulation, Rumaila, Triethylenglycol

I. Introduction

The dehydration unit is very important process in gas industry due to its ability to remove all water and some obnoxious impurities from the natural gas in gas stream. The main reason for hydrate formation in the dehydration unit is the existence of free water in the gas stream, which can block the pipes and fittings, and accelerate the corrosion inside pipes and equipment. The presence of water in natural gas at source or as a result of sweetening with an aqueous solution presents no danger as long as the water is in the vapor phase. However, several processing and transmission problems arise as soon as liquid water is formed [1,2]. Operation experience has proved that it is necessary to reduce and control the water content of gas to ensure safe processing and transmission. Dehydration is the process used to remove water from natural gas, and it is necessary due to the following reasons:

- Natural gas in the right conditions can combine with liquid water to form ice like material called hydrates that can plug valve fittings, pipelines as well as other equipment.
- Liquid water can accelerate the corrosion of transmission lines by combining with CO2 and/or H2S present in natural gas.
- Liquid water in a natural gas pipeline potentially causes slugging flow conditions resulting in lower flow efficiency of the pipeline.
- Water vapor increases the volume and decreases the heating value of the gas.
- A minimum water content of 112 mg/m^3 of gas or less has to be met [3,4].

Glycol dehydration is the most common dehydration process used to attain pipeline sales specifications and field requirements. Glycols are the most commonly used liquid desiccants in the absorption process, such as; mono-ethylene glycol (MEG), di-ethylene glycol (DEG), tri-ethylene glycol (TEG) and tetra-ethylene glycol (TREG). TEG is the most commonly used glycol for natural gas dehydration; this is because it can be regenerated to high concentration without degradation. [5,6]

In the present study, a natural gas dehydration unit in the central Rumailah, Iraq along with its absorbent regeneration cycle is simulated by using Aspen HYSYS software. The main objective of this study is to conduct a sensitivity analysis in order to obtain the main parameters that can affect the performance of the dehydration unit and eventually study the possibility of optimizing the whole process. Simulation results were compared with real plant data to ensure accuracy of the simulation package.

II. Process Description

In typical dehydrators, dry lean glycol and wet gas are contacted counter-currently in the contactor tower where mass transfer taken place in a 8 bubble cap tray column. The wet gas enters the tower from the bottom and exits from the top. The lean glycol enters from the top and exits from the bottom with absorbed water (water rich glycol). The lean glycol is cooled from 93 ^oC to 66 ^oC by passing through the glycol coil of the air cooler.

On the top tray, the cool lean glycol is maintained at the proper depth by a weir which acts as a dam in holding back the glycol before it spills over the down comer onto the tray below. Rising gas comes into intimate contact with the glycol as it flows across the bubble caps. As the gas flows from tray to tray through the column, it comes in contact with progressively drier glycol and the driest gas at the column contacts the driest glycol. This permits attainment of the desired dew point and makes the most efficient use of the water carrying ability of the glycol. At the top of the contactor, the dry gas passes through the mist eliminator to separate any droplets of glycol carried over with the gas. The dry gas then flows through the outlet valve.

The process of removing water from natural gas consists of two main parts. the first part, the absorption tower to absorb the water from the gas by using TEG solution and the second part is the stripping tower to recover the solvent and return it back to the absorption column, while the water flows with hydrocarbon gases outside from the top tower. In addition to these two parts, the process also includes heat exchangers, valve to reduce pressure, and a flash tank as it shown in Figure 1.

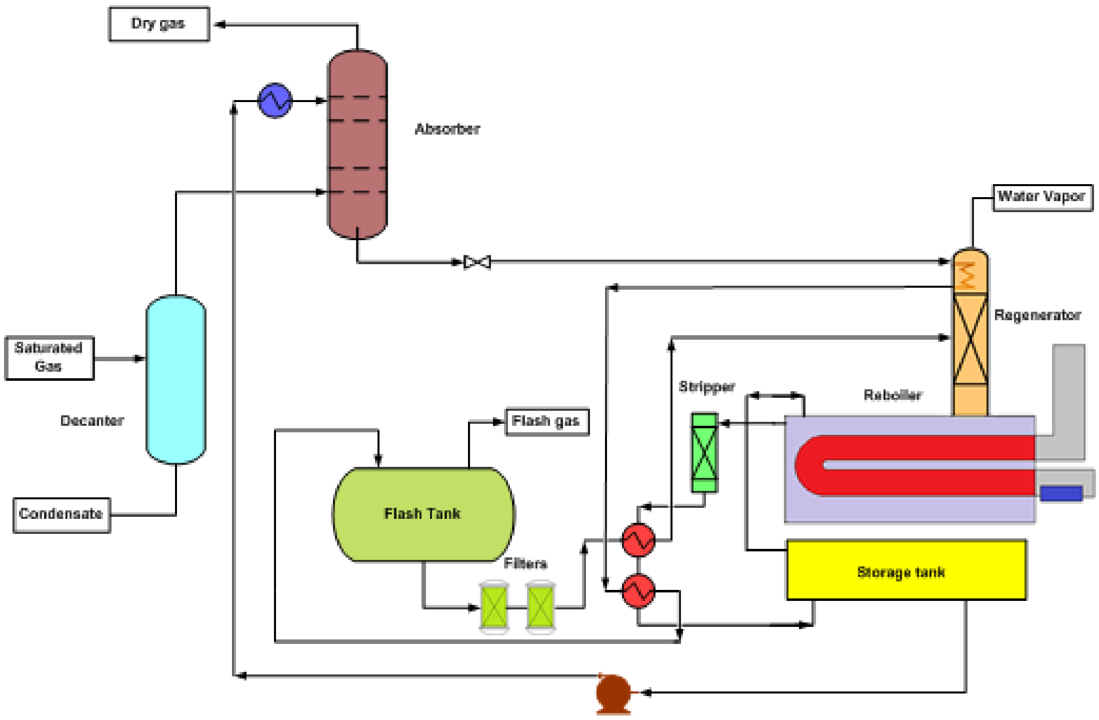

Figure 1: Central Rumailah dehydration unit.

The dehydrated gas exists from top of the contactor as dry gas while the rich TEG flows downward the absorption column. From the bottom of the contactor the rich TEG flows to the gas- glycol separator, where it subjected to sudden decrease in pressure. The absorbed gaseous mixture will liberate in the separator due to the flashing process. The liberated gases may be used as fuel in the reboiler. The rich glycol stream flows to the stripper where all the liquid is boiled of the rich glycol. The regenerated glycol then cooled and returned to the contactor by Glycol pump.

At the end of the regeneration process, the regenerated TEG is cooled by using of heat exchanger and is sent back to the dehydration column for reuse. There are two factors affect the efficiency of the dehydration process: The dew point depression of the process gas and the losses of the glycol in the dehydration cycle. The desired dew point depression can be achieved if the following parameters are precisely controlled.

1. Lean TEG concentration.
2. The flow of lean TEG to the contactor.
3. The temperature of the incoming natural gas.
4. The pressure of the absorber.

The losses of the glycol usually occur in the dehydration process and exceed the design losses limit due to the following

1. Leakages of the glycol from contactor, flash tank, reboiler, storage or glycol pump.
2. Foaming.
3. Inadequate mist extraction.
4. Losses of glycol from pinholes in a gas-glycol coil in the top of the regenerator.
5. Surging the process natural gas flow in the contactor.
6. Degradation because of the temperature of the reboiler higher than the operating temperature.

This paper presents an attempt to examine the effect of all the operational parameters using simulation software on the efficiency of the dehydration process. The results provide an analysis of the dehydration operation variables for Central Rumailah dehydration facility.

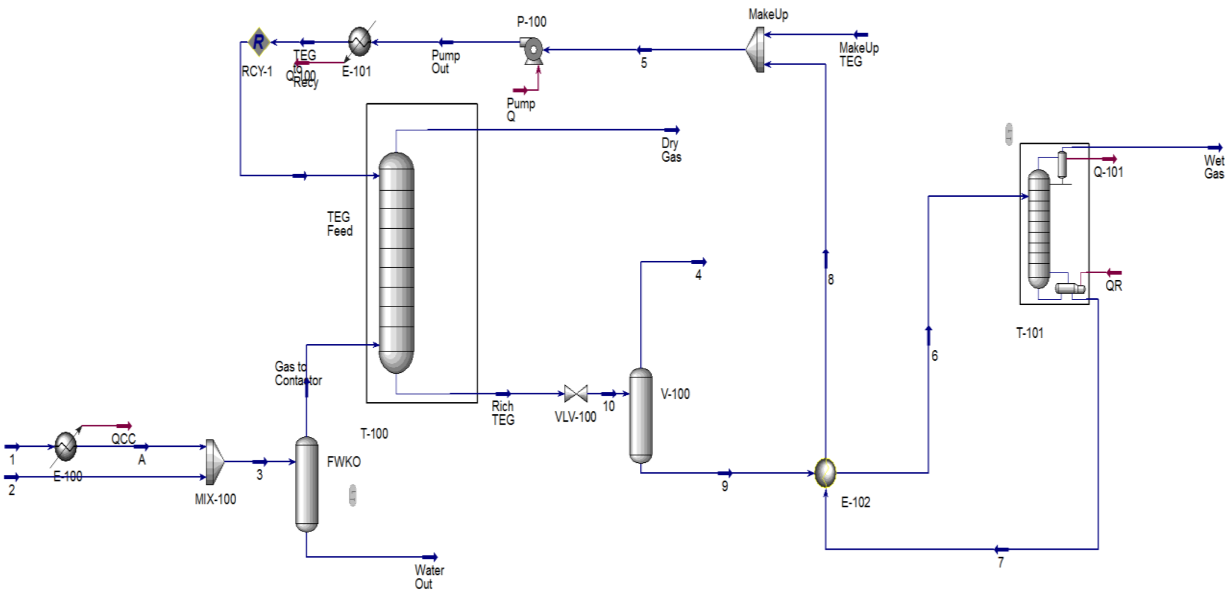

Fig. 2: Process flow diagram of Central Rumailah dehydration unit.

Table (1) Rumaila natural gas compositions and operation condition

Components	Mole fraction %
N_2	0.0046
CO_2	0.0381
C_1	0.3783
C_2	0.2189
C_3	0.1769
i-C_4	0.03606
n-C_4	0.07133
i-C_5	0.01995
n-C_5	0.02218
C_{6+}	0.03015
H_20	0.0032
Operating Condition	
Inlet gas Flow: $4.289x10^5$ lb/hr Inlet gas temperature: 130°F Inlet gas pressure: 497 psi TEG Flow rate : 35275.06 lb/hr	

III. Process Simulation

In order to carry out this study and to provide the result needed, a case study was made to predict the plant behavior under different operation variables, the operation variables presented in the operating manual of TEG- dehydration unit in Central Rumaila compression station are selected for the simulation process. Aspen Plus (V9) was used to perform the simulation for this work. The studied natural gas dehydration plant includes an absorption column (497 psi), a flash unit (58 psi), two heat exchangers and atmospheric regenerator and stripper columns with TEG as solvent constituting recycle loop. The plant operating conditions were employed to validate simulation results. The composition of natural gas and operation conditions are shown in Table 1 and the Glycol package is used to evaluate the thermodynamic properties for natural gas components and TEG solution. The dehydration unit is simulated entirely because the software includes a library of standard unit operation by using the built-in units in the Aspen HYSYS, (e.g. pump, absorber, separator, heat exchanger), which represent processes taking place in the actual dehydration process as it is shown figure 2. The type of fluid package selected is glycol package, because it is suitable for many hydrocarbon compounds in a wide range of temperature and pressure conditions and the state of one, two and three-phase and polar compounds usable and suitable.

IV. Process Simulation Results

After setting the simulation and the investigation of the effective operational parameter have been carried out, the following design variables are studied

1- Effect of Gas Temperature:

A case study was made to simulate the plant behavior under different feed gas temperatures. Designed feed gas temperature to absorber is 130F. Figure (3) illustrates the effect of temperature of the gas on the water content. The water content of the gas increases by increasing the temperature of the gas, because the ability of the gas to absorb the free water increases by increasing the temperature. Higher amount of water is loaded to the absorber instead of condensing inside the decanter if the temperature of the gas is raised higher than the operating temperature. The temperature effect of the gas illustrates in figure (3) is consistence the standard graph presented in GPSA (Gas Processes Suppliers Association), which illustrate the water content in saturated gas. The impact of pressure and temperature on the water content of the natural gas is presented in Figure 4. It can be seen form Figure 4 that high temperature to contactor leads to more glycol losses by the heat vaporization and thermal degradation of glycol [7]. The temperature of the natural gas entering the absorber is 130 F (54.44 °C), and the temperature of the TEG entering is 150 F (65.55 °C). To obtain largest effect of dew-point depression, the temperature of TEG should be low. As the temperature of TEG decreases, the flow rate of TEG through absorber is also reduced. However, the inlet temperature of TEG to the absorber has to higher than the inlet gas temperature in order to avoid the hydrocarbons condensation [8].

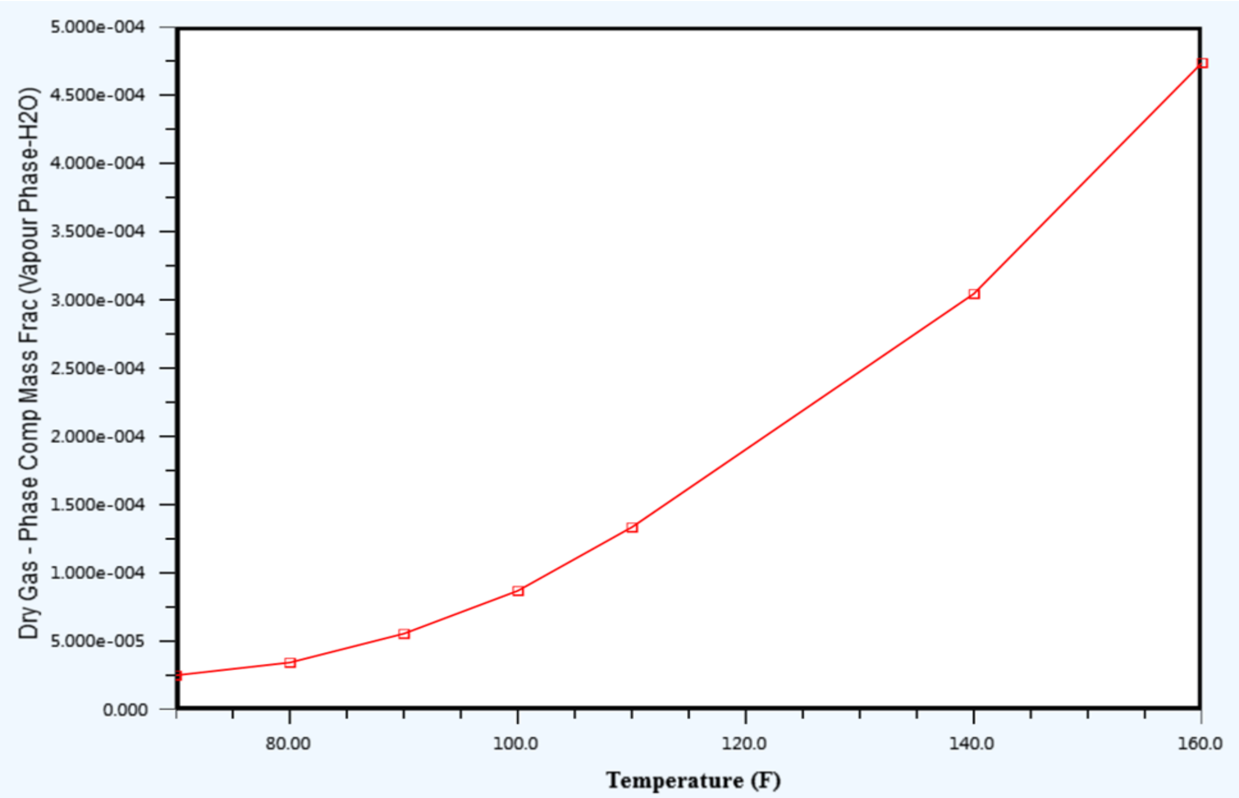

Fig. 3. Effect of feed gas temperature on the water mass fraction in dry gas.

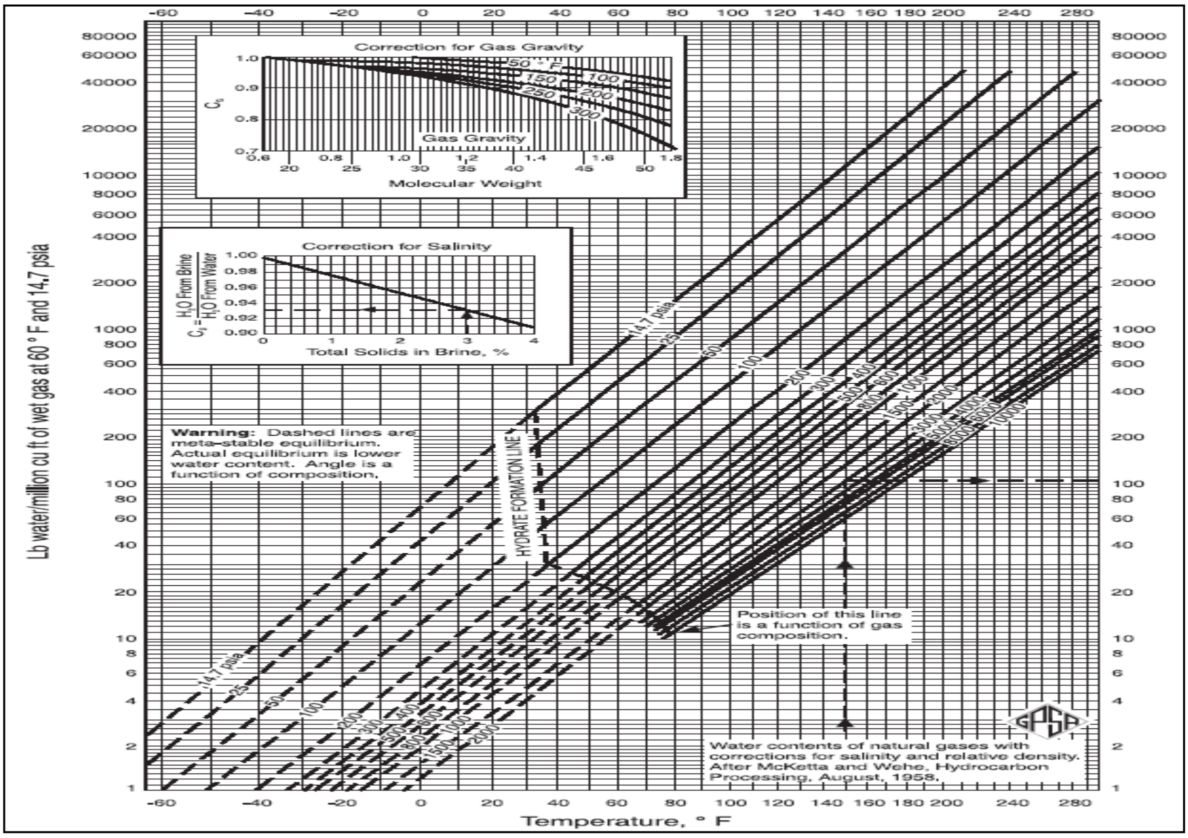

Fig. 4. Water content of sweet, lean natural gas [7].

2- Effect of Gas Pressure:

Figure (5) shows the effect of gas pressure on the water content at standard condition If the pressure increases higher than operating pressure, the water vapor will condense as free water inside the equipment. This will lead to higher separation rate inside the decanter instead of loading the contactor by extra amount of water. A high pressure reduces the water content in the inlet natural gas stream. At high pressures the gas velocity will be reduced, resulting in a smaller vessel needed. When the rich natural gas comes into contact with the TEG, the water vapor becomes dissolved in the TEG stream. The product stream, the dry natural gas, leaves the top of the absorber with water mass fraction of 0.0002 at operation pressure 497 psi.

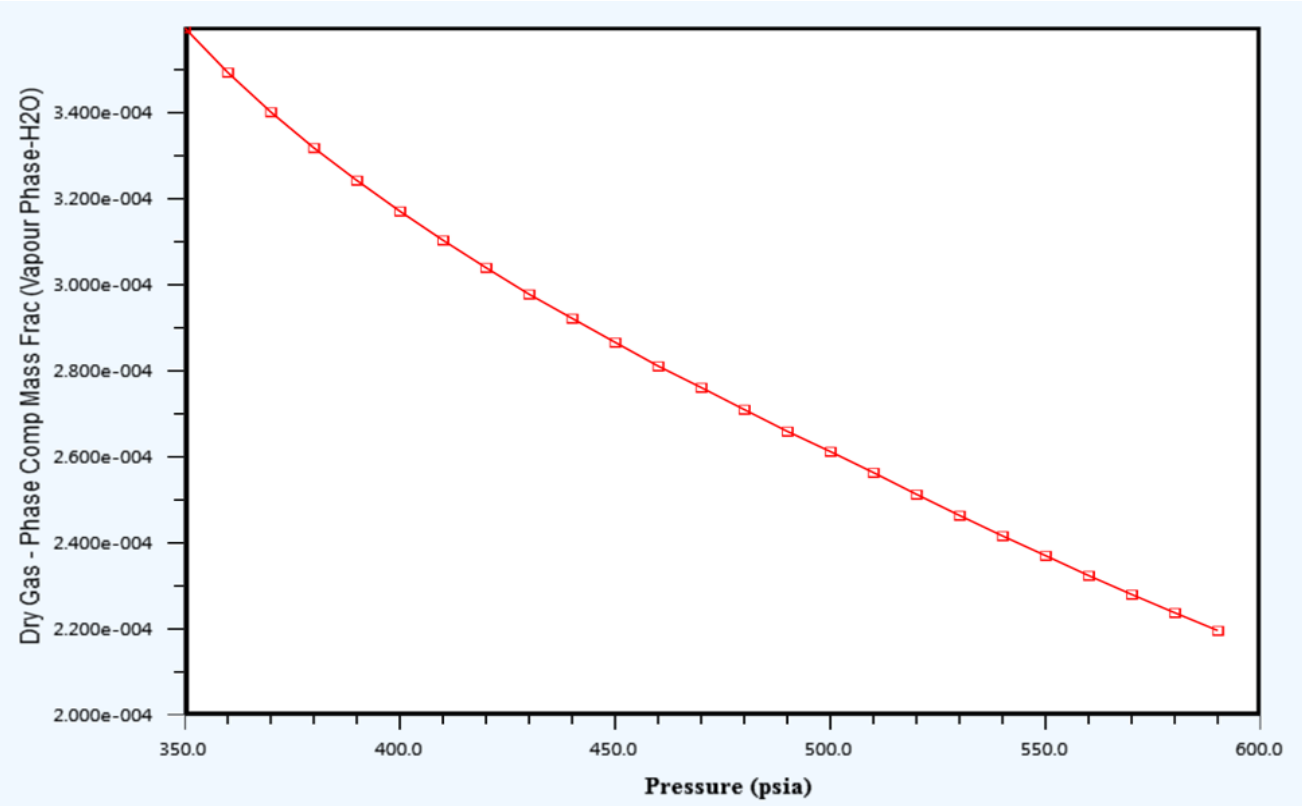

Fig. 5. Effect of feed gas pressure on the water mass fraction in dry gas.

3- Effect of lean glycol flow rate to contactor

The flow of lean tri ethylene glycol to the contactor is designed to achieve the absorption of the water from the gas so as to obtain the desire dew depression. It is designed to absorb all the water for maximum flow of gas. There are two ways to operate the unit:

a) Operating the unit with maximum flow of lean TEG that is designed to absorb the water content of the maximum flow of the process gas. This will ensure absorbing the water from the gas with less interference of the operator to control the flow.

b) Operating the unit with a suitable flow of lean glycol to suit the amount of water that should be absorbed by the lean glycol to obtain the desired dew point. This is achieved by a by-pass pipe controlled by hand valve to control the flow from the discharge of the main glycol pump. The flow of the glycol must be controlled precisely to obtain the desired dew point.

Figure (6) shows the proper rate of lean tri ethylene glycol to the mass of water in the wet process gas. The rate of the lean tri ethylene glycol must be controlled according to this relation. As the gas flow rate changes the lean TEG flow must change by controlling the flow of the glycol by the by- pass valve of the main pump.

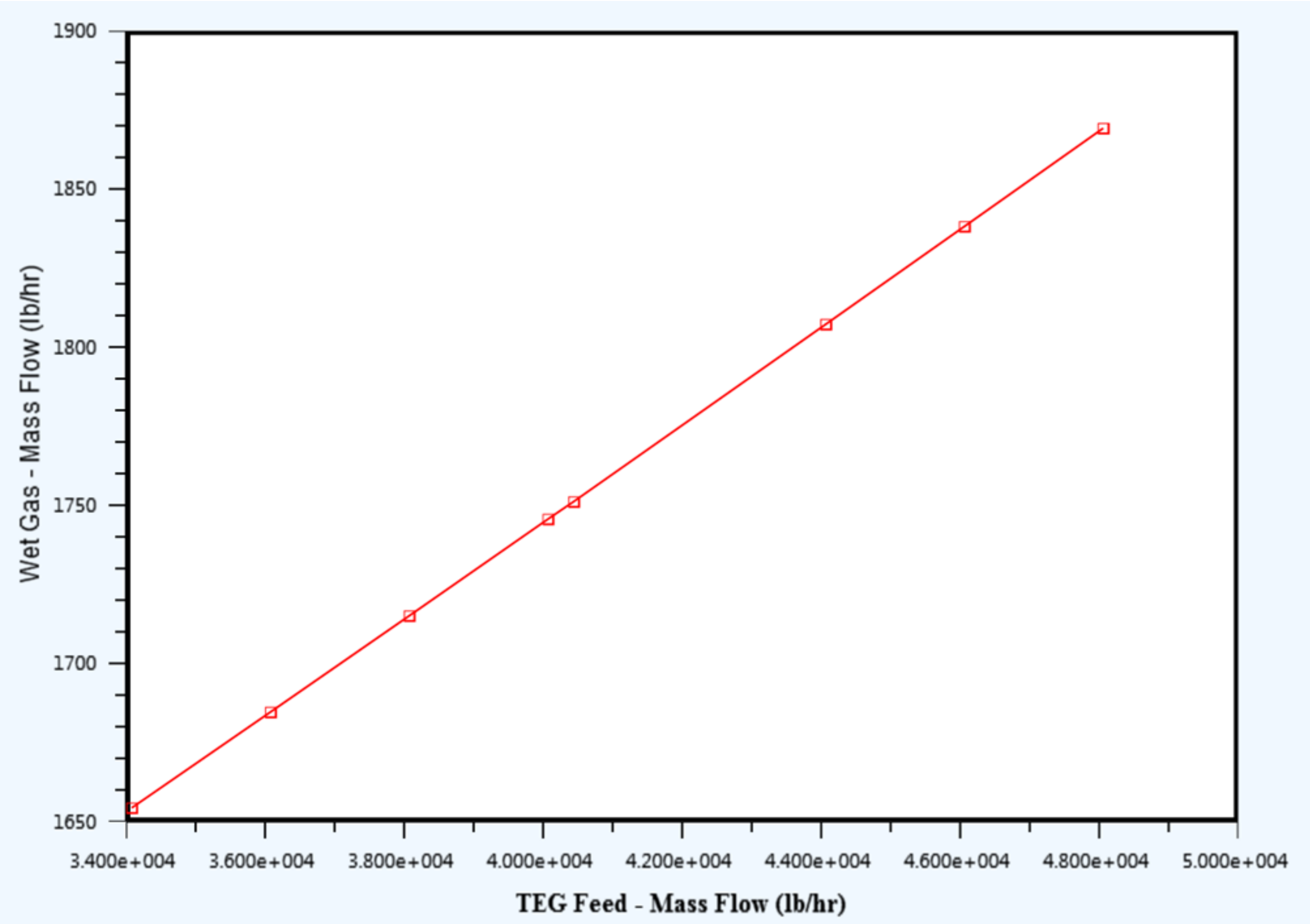

Fig. (6): Circulating mass flow rate of TEG to the mass of water in wet gas.

For the constant flow of gas, the efficiency of the contactor increases by increasing the flow of lean TEG. The typical flow of lean TEG is assumed to be 3 gallons of TEG to1 bound of water in the gas [9], the design TEG flow rate in Central Rumailah dehydration unit is 35275.06 lb/hr. Increasing the flow of lean TEG will increase the absorption rate and the water in the dehydrated gas will decrease as a result the dew point decreases also but this fact must compromise with losses of TEG due increasing the entrainment of the TEG out with dehydrated gas.

Figure (7) shows that decreasing the amount of the water in the dehydrated gas with the increase of the lean TEG flow to the absorber. The flow of the glycol to the flow of the gas must be control since the losses of tri ethylene glycol excess in increasing the flow of the gas. The losses of Glycol due increasing the ratio of TEG liquid pumped to contactor to the volumetric flow rate of the gas to be processed.

4- Flow Rate of Stripping Gas

Stripping gas can enhance the purification of lean glycol without increasing the operating temperature up to the decomposition limit by using stripping gas stream to decrease the partial pressure of water vapor in gas phase over the glycol solution in the reboiler. Figure (8) shows the flow rate of outlet water from the stripping column does not effect by the concentration of lean TEG. The result shows increase in the concentration of the regenerated lean glycol up to 99% wt percent.

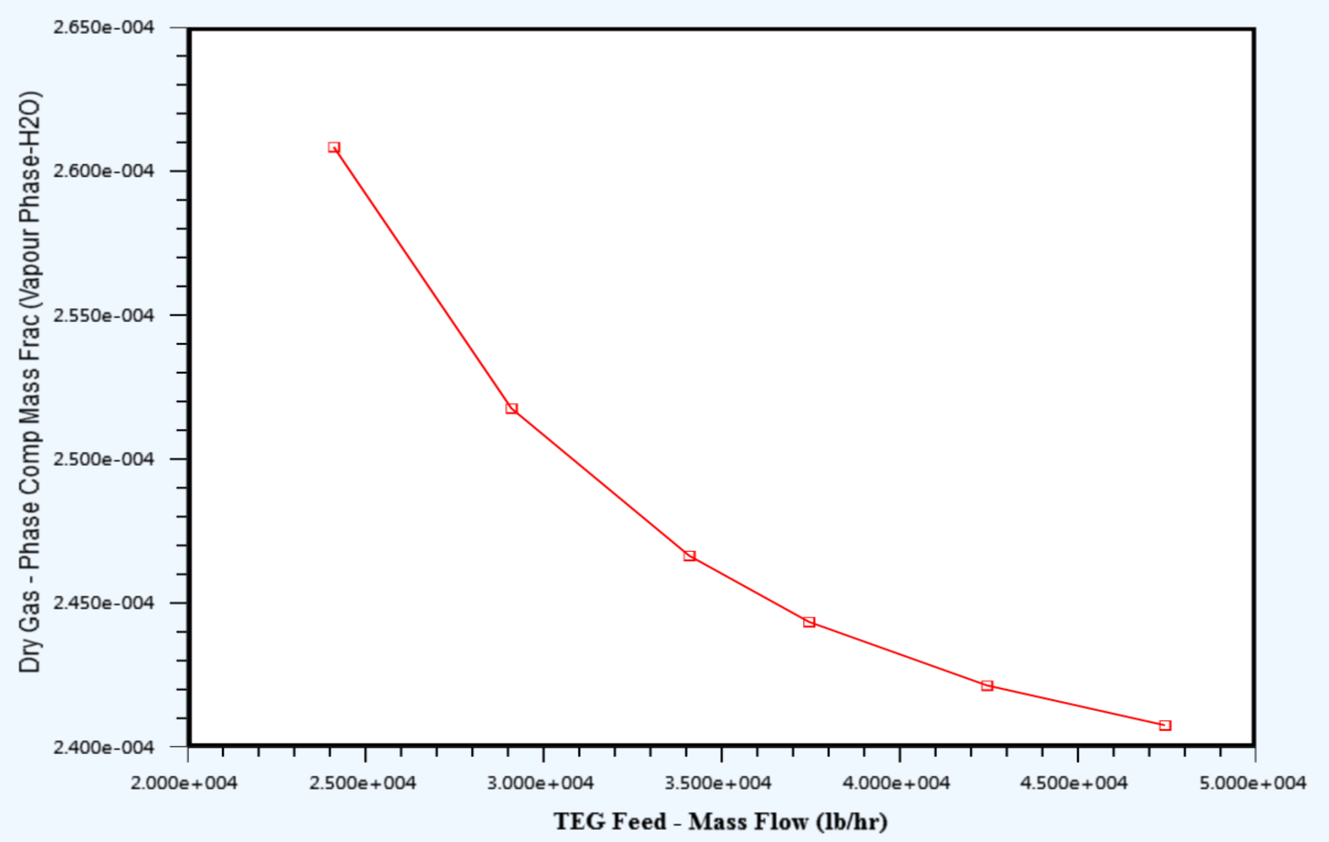

Figure (7): Decrease the water content with increasing the circulating rate of the lean TEG.

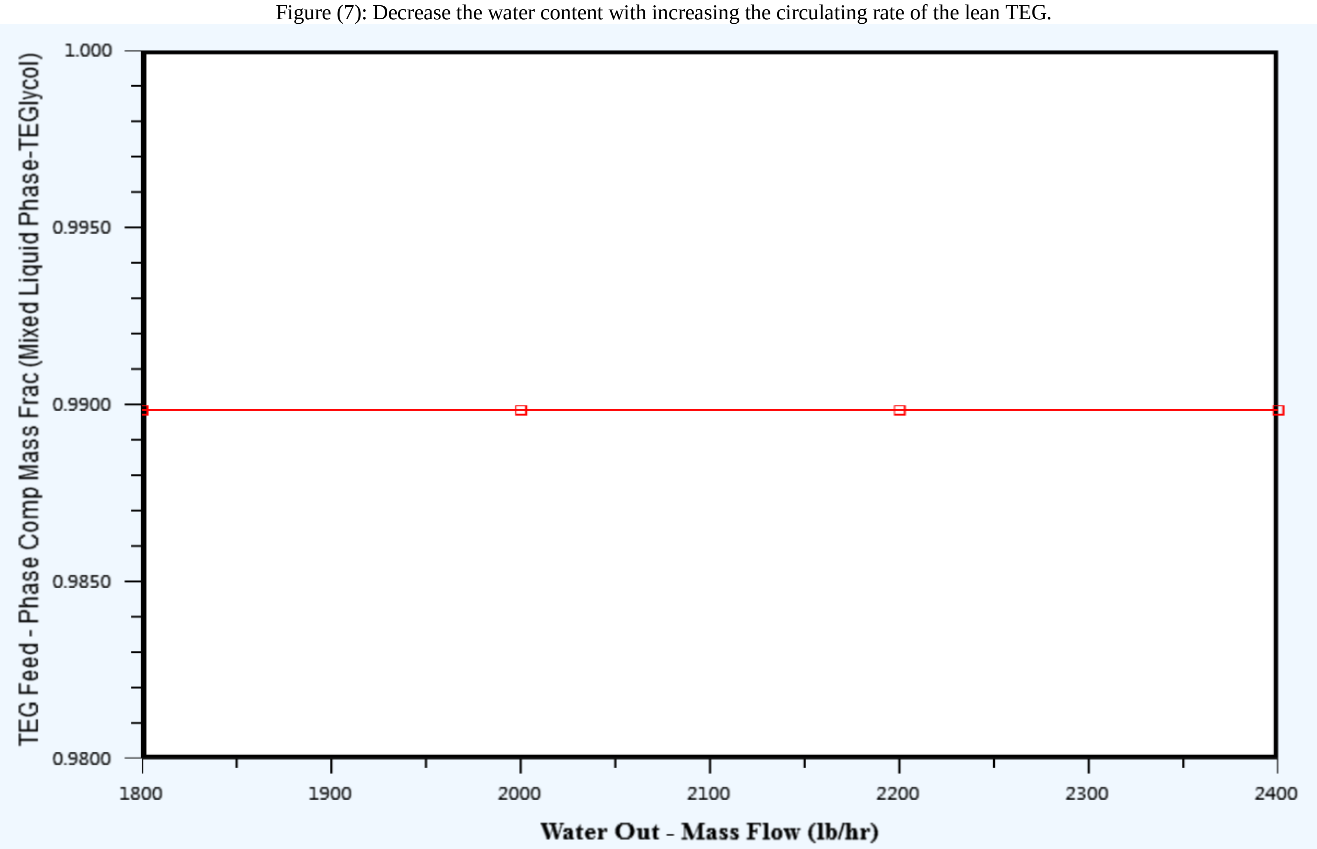

Figure (8): Stability of the concentration of TEG with the flow rate of removed water.

V. Conclusions

The effect of process variables (TEG flowrate, inlet natural gas temperature and flowrate, the dry gas composition and temperature at top of the glycol concentration towers, etc. and the following results were obtained.

1. The absorber should be run as low as possible. Lowering the temperature from 130 F to 120 F will reduce the mass fraction of water in the dry gas stream from 0.000076 to 0.00002. The preferred temperature range is 80-100 F, below 70 F the glycol is too viscous and will reduces tray efficiency, promotes foaming, and increases glycol losses. Absorber temperatures are

affected by decreasing feed stream temperature at absorber inlet, this is can be done easily with the aid of air fan cooler for the first stage gas and the after cooler of the high pressure compressor.

2. Increasing the absorber pressure from 549.7 psia (design pressure) to 600 psia will also reduce the water content in the outlet dry gas from 0.000076 to 0.000022 as mass fraction. Increasing the absorber pressure decreases the ratio of water gas partial pressure to total pressure in the absorber overhead which results in lowering vapor water concentrations in the top dry gas product thus improves water removal by the TEG solution. The pressure of the inlet natural gas is determined by the reservoir engineering and it is inevitable to avoid the depleting of the reservoir pressure. However, it can be increased by throttling the suction valve which affects the pressure and the flow of the first stage gas.
3. The flow rate of outlet water from the regeneration column does not effected by the concentration of lean TEG. The results shows that the concentration of the regenerated lean glycol is 99% wt. percent. The temperature at the top of regeneration column should be kept around 210ºF. If the temperature drops much below 200ºF, water vapor condensation accurses.
4. The flow rate of the circulation lean glycol must be controlled according to the linear relation as illustrated in figure (6). Increasing the TEG mass flow rate above the design flow rate (35275.08 lb/hr) will increase wet gas mass flow rate at the top of the regeneration column. But the excess flow rates of lean glycol increase the entrainment of glycol molecules with hydrocarbons

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