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SENSITIVITY ANALYSIS OF A NATURAL GAS TRIETHYLENE GLYCOL DEHYDRATION PLANT IN PERSIAN GULF REGION

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Abstract

Natural gas TEG-dehydration is the process of removing water from the gas stream to lower the dew point of natural gas. Water is the most common contaminant of hydrocarbons and can form hydrates, which may block valves and pipelines. Also water can make corrosion in present of acid compounds in natural gas. In this paper comprehensive study of software simulator and investigate the effectiveness parameters in a TEG-dehydration plant in Persian Gulf region.

Keywords: sensitivity analysis; Triethylene glycol; dehydration.

1. Introduction

Natural gas to be transported by pipelines or processed, must meet certain specifications. In addition to specifications regarding delivery pressure, rate and possibly temperature, other specifications including maximum water content (water dew point), maximum condensable hydrocarbon content (hydrocarbon dew point) and allowable concentrations of contaminants such as mercaptans, carbon dioxide (CO_2) , hydrogen sulfide (H_2S), allowable solids content and minimum heating value [1].Water is the most common contaminant of hydrocarbons. It always is present in the gas and oil or their mixtures produced from wells [2] which it can make considerable problems especially in natural gas transmission and processing. The main reason for removing of water from natural gas is that water (which is mostly in vapor phase at natural gas) becomes liquid under low temperature and/or high pressure conditions. There are five major reasons for natural gas treating from water contents:

- Liquid water and natural gas can form hydrates which causes plug the pipelines and other equipments such as valves, collectors etc. (Gas Hydrate: are solids formed by the physical combination of water and other small molecules of hydrocarbons. They are icy hydrocarbon compounds of about 10% hydrocarbon and 90% water).
- Natural gas containing H_2S and/or CO_2 is corrosive when liquid water is present (corrosion often occurs when liquid water is present along with acidic gases, which tend to dissolved and disassociate in the water phase, forming acidic solutions).
- Water content of natural gas decreases of its heat value.
- Liquid water in natural gas pipelines potentially causes slugging flow conditions resulting in lower flow efficiency of the pipelines.
- In most commercial hydrocarbon processes, the presence of water may cause side reactions, foaming or catalyst deactivation.

To prevent such problems, natural gas treating is unavoidable. There are different methods for water treating of natural gas such as: adsorption [3], absorption [4], membrane process [5], methanol process [6] and refrigeration [7]. Among mentioned methods absorption, which is called dehydration and use liquid solvent as an absorbent, is mostly common technique for treating of natural gas [7-9]. The basis for gas dehydration using absorption is the absorbent; there are certain requirements for absorbents for gas treating: strong affinity for water to minimize the required amount of absorbent (liquid solvent), low potential for corrosion in equipments, low volatility at the process temperature to minimize vaporization losses, low affinity for hydrocarbons to minimize their loss during the process, low solubility in hydrocarbons to minimize losses during treating, low tendency to foam and emulsify to avoid reduction in gas handling capacity and minimize losses during regeneration, good thermal stability to prevent decomposition during regeneration and low viscosity for easily pumping and good contact between gas and liquid phases. Off course, the major critical property for a good absorbent is the high affinity for water. The others are used to evaluate potential absorbents practical applicability in the industry.

In practice, glycols are the most commonly used liquid absorbents in dehydration process (glycol is a common name for diols; with the two alcohol parts these substances have a high affinity for water) [10]. Among glycols solvents, triethylene glycol (TEG) is used in almost dehydration planets [11]. Properties of common glycols are listed in Table 1.

Table 1 Properties of common glycols which used in dehydration process [10].

Name	Triethylen glycol (TEG)	Tetraethylen glycol (TREG)	Monoethylen glycol (MEG)	Diethylen glycol (DEG)
Formula	$C_6H_{14}O_4$	$C_5H_{18}O_5$	$C_2H_6O_2$	$C_4H_{10}O_3$
Molar mass [kg/kmol]	150.17	194.23	62.07	106.12
Normal boiling point [°C]	288.0	329.7	197.1	245.3
Vapor pressure @ 25°C [pa]	0.05	0.007	12.24	0.27
Density @ 25°C [kg/m^3]	1122	1122	1110	1115
Viscosity @ 25°C [cp]	36.73	42.71	17.71	30.21
Maximum recommended regeneration temperature [°C]	204	224	163	177
Onset of decomposition [°C]	240	240	-	240

In this work, a sensitivity analysis study of a TEG-dehydration plant carried out. At the first, a survey to selection of suitable simulator software and the best thermodynamic model has done among tree common commercial software. In the next step; the effects of equilibrium stages, reboiler temperature, stripping gas, temperature of inlet gas to absorption column, CO_2 and H_2S content of inlet gas and the effect of TEG circulation rate on water content have studied. In addition to valuable study and better result, data design of an existed TEG-dehydration plant in the Persian Gulf region (Iran oilfield) has been used.

2. TEG-dehydration process

A typical TEG-dehydration process can be divided into two major parts, gas dehydration and solvent regeneration. In dehydration, water is removed from the gas using TEG and in the regeneration, water is removed from the solvent (TEG); before it can back to the absorption column.

Generally a TEG-dehydration unit is contains: absorption column, flash tank, heat exchangers, inlet scrubber and regenerator, as it shown in Figure 1.

During the process, lean TEG enter to the absorption column at the top side which rich solvent is collected at the bottom of the column and will send to the regenerator. Wet gas enters to the absorption column after passed through inlet scrubber. The scrubber removes free liquid and liquid droplets in the gas, both water and hydrocarbons (removing liquid in the scrubber decrease the amount of water that has to removed in the absorption column, and this also decrease the size of the column and therefore decrease the TEG needed in process). Heat exchanger uses for cooling of wet gas before enter to scrubber. Rich TEG passes through a coil, which is used as reflux at the top of the absorption column; to increase its temperature. A tree phase flash tank uses for removal of absorbed acidic gases and hydrocarbons in TEG before rich solvent enter to the regenerator, which is a distillation column, and separate the TEG and water content. Off course, rich TEG is preheated in another heat exchanger before it fed to the regeneration section. At the end of the process cycle, the regenerated TEG will cool in the third step of heat exchanger and will back to the dehydration column for reuse.

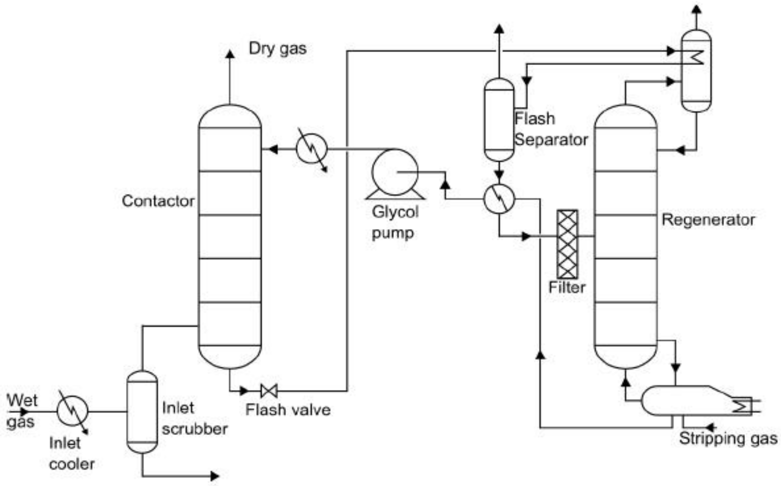

Figure 1 A typical dehydration unit [1].

3. Survey on the best software for simulation

In practice, to simulate such kind of processes, it is necessary to select a suitable thermodynamic model and suitable software simulator which use this model. Therefore, an initial survey on three commercial software simulator based on the predicted absorbed water and phase behavior of different compounds has done; and suitable software for this work selected. Aspen-Hysys, Chemcad and Pro II are well known software which used in wide range of practical and design studies of chemical industries. They are tested in this work because of their special thermodynamic package (glycol package) for dehydration process; however other thermodynamic equations of state can be used.

First, the ratio of removed water (W_{in}-W_{out})/W_{in} versus TEG circulation rate gal/Lb(water removed) compared with basis data [12] in specific conditions (figure 2).

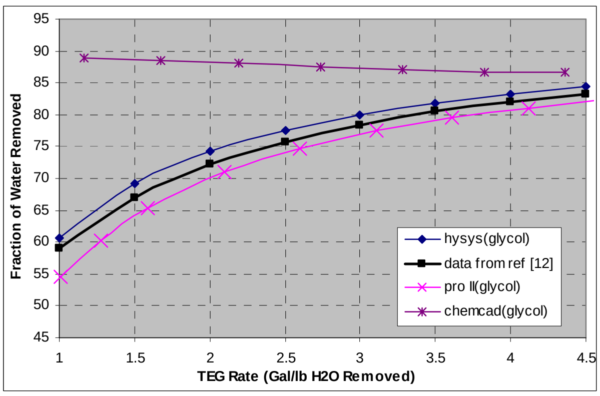

Fig. 2 Comparison of software simulation results and reference data

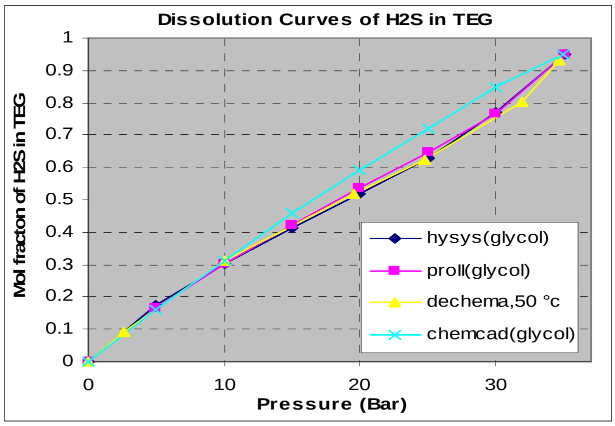

Fig. 3 Solubility of H_2S versus pressure

In all cases, glycol package for each softwares used to reach comparable results. As it shown in figure 2, Chemcad did not present good result and had unusual behavior, so that the ratio of removed water decreased when TEG circulation rate increased. Comparison of the results using Aspen-Hysys and ProII with basis data shown that Aspen-Hysys is more effective than ProII and had better results, specially in low TEG circulation rates. Another comparison to predict the phase behavior of three major compounds, CO_2, H_2S and methane (CH_4) in TEG done using DECHEMA data [13] in 50°C. Figure 3 refer the solubility of H_2S in TEG based on pressure change, and it is clear that Aspen-Hysys by use of glycol package had better result.

Figures 4 and 5 are referred to solubility of CO_2 and CH_4 in TEG respectively. In figure 4 both Aspen-Hysys and ProII had good results, but in case of CH_4 ProII had better result comparing to other softwares; specially in higher pressures.

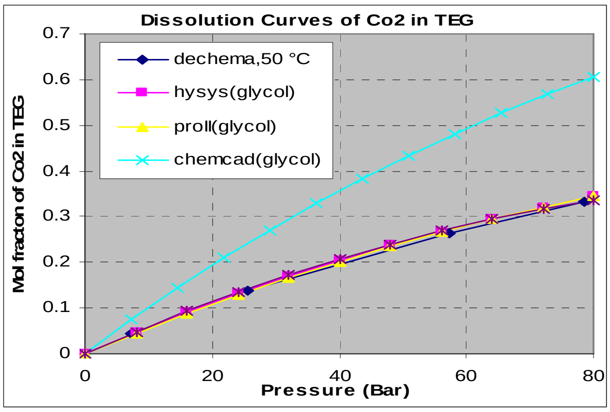

Fig. 4 Solubility of CO_2 versus pressure

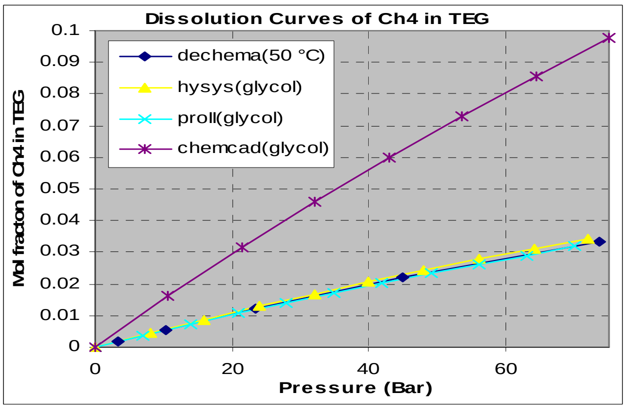

Fig. 5 Solubility of CH_4 versus pressure

4. Process description and simulation

In practice, for design and optimization of a TEG-dehydration unit, following parameters must be considered: number of trays in absorption column, TEG circulation rate in absorption column, reboiler temperature, and regenerator pressure.

Among mentioned parameters, the first three of them are changeable. Also some anothere parameters such as temperature of the inlet gas to column are effective on water content of outlet gas (dried gas) [14]. In present work, a TEG-dehydration plant simulated using Aspen-Hysys software. Recently, Aspen-Hysys used a new equation of state in its glycol package to modeling of TEG-water systems, which gave better results. Table 2 shows the feed composition and design parameters of the simulated unit.

Table 2: Feed composition and design parameters.

Composition	Mol%	Composition	Mol%	Composition	Mol%
H_2S	11.9	Propane	4.254	n-Hexane	0.741
CO_2	7.234	i-Butane	0.7851	n-Heptane	0.403
N_2	1.6	n-Butane	1.708	n-Octane	0.117
H_2O	0.865	i-Pentane	0.912	n-Nonane	0.032
Methane	59.29	n-Pentane	1.6	n-Decane	0.007
Ethane	8.555	Inlet gas temperature = 36 °C		Absorption column pressure =65.6 bar	
Regenerator pressure = 1.3 bar		Rich TEG flash pressure =3.013 bar			

5. Results and discussion

Increasing of equilibrium stages lead to equilibria the water content of wet gas and inlet TEG to the absorption column at low TEG circulation rates. As it is shown in figure 6, for four and three equilibrium stages, TEG circulation rates were 18 (kg TEG/ kg (water absorbed)) and 20 (kg TEG/ kg (water absorbed)) respectively. It is clear that for two equilibrium stages higher TEG circulation rates are necessary to reach equilibria.

Reboiler temperature affect water content of inlet gas with modifying of regenerated TEG. Figures 7 to 9 are represent the effect of reboiler temperature on required equilibrium stages for dehydration. In reboiler temperature of 195°C and 204°C, three and four equilibrium stages are sufficient to reach 96% absorption efficiency. At reboiler temperature of 204°C, TEG circulation rate were 12 (kg TEG/ kg (absorbed water)) and 20 (kg TEG/ kg (absorbed water)) for four and three equilibrium stages respectively. Furetheremore, at reboiler temperature of 195°C, the TEG circulation rate of 14 (kg TEG/ kg (absorbed water)) for four and at least 25 (kg TEG/ kg (absorbed water)) for three equilibrium stages were needed. It should be considered that these results obtained for inlet gas temperature of 36°C and higher temperature will increase of the water content at same TEG circulation rates.

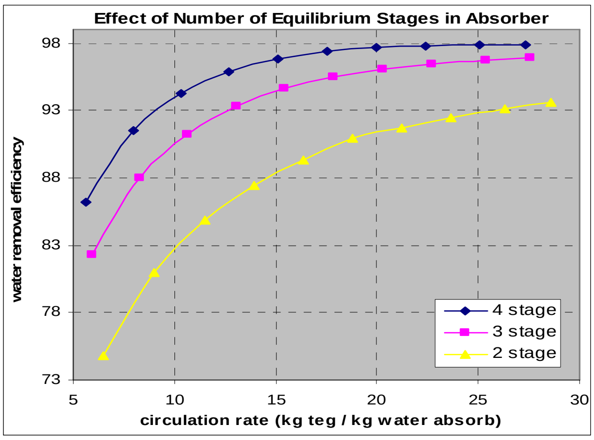

Fig. 6 Effect of equilibrium stages of absorption column on water removal efficiency (reboiler temperature = 204 ^oC)

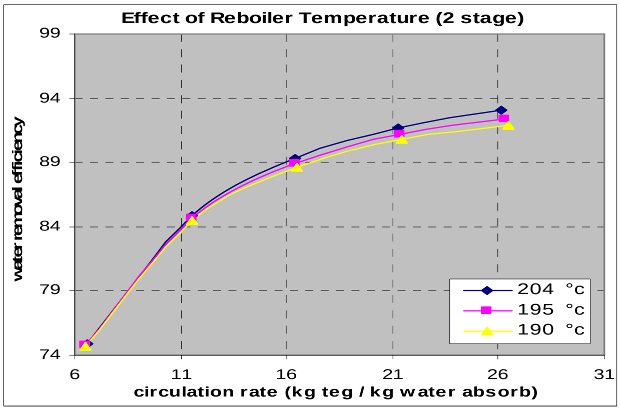

Fig. 7 Effect of reboiler temperature on water removal efficiency using 2 equilibrium stages

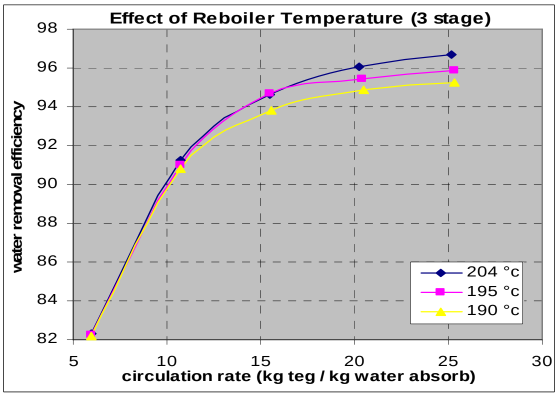

Fig. 8 Effect of reboiler temperature on water removal efficiency using 3 equilibrium stages.

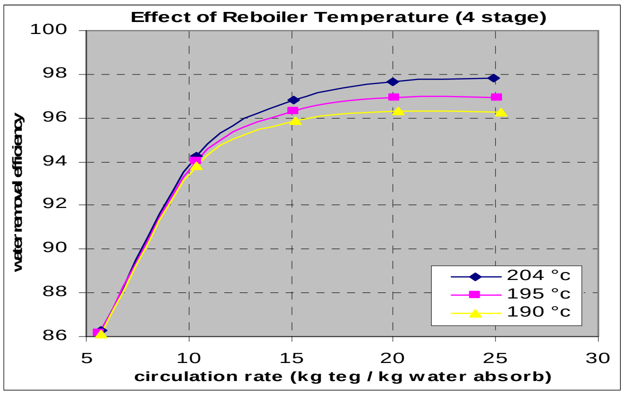

Fig. 9 Effect of reboiler temperature on water removal efficiency using 4 equilibrium stages

If lower dew point is require, stripping gas and TEG with purity of 99.9 %wt should be used. Increase of reboiler temperature is not sufficient, because TEG can degraded in temperatures above 204°C [10]. To effectiveness use of stripping gas for increase of dehydration efficiency, it should be contact to TEG in a short tower when TEG leaved reboiler [9]. Figure 10 shows the effect of stripping gas on dehydration efficiency.

Use few amount of stripping gas; about 50 (S.m^3/Kg TEG) lead to large difference in amount of removed water; however, the effect of higher rate of stripping gas more than100 (S.m^3/Kg TEG) is negligible.

On of the important which should be considered is the temperature of inlet gas, because it can affect the TEG circulation rate and also decrease gas density, which lead to higher volumetric flow of inlet gas. All of these happen because higher temperature of inlet gas increases its water content exponentially (figure 11).

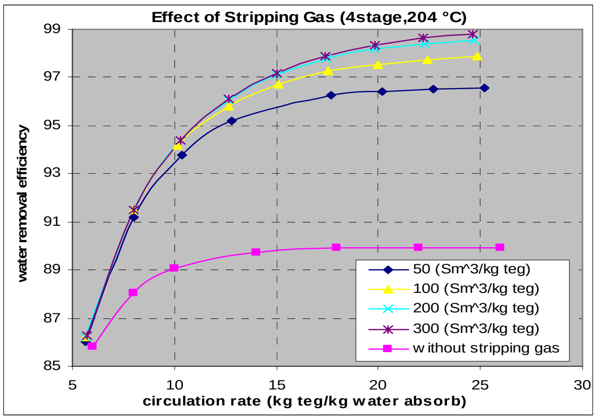

Figure 10: Effect of stripping gas circulation rate on water content of outlet gas (for four stages and reboiler temperature of 204°C)

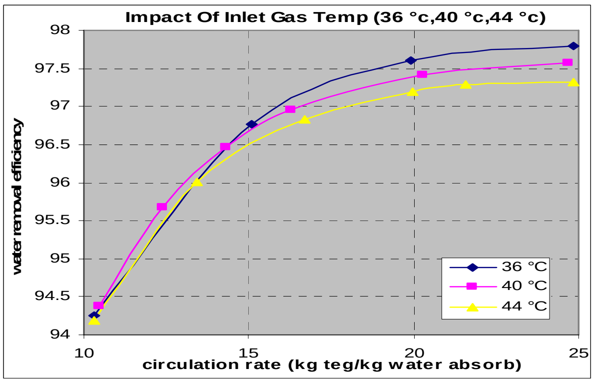

Figure 11: Effect of inlet gas temperature on water removal efficiency

Acid gas water content is a very complex subject and both CO_2 and H_2S contain more water at saturation than sweet gas mixtures [9].

Therefore, existing of acid compounds in feed can affect of dehydration efficiency which it is shown in figures 12 and 13. Also it is clear that H_2S content is more effective than CO_2 on dehydration.

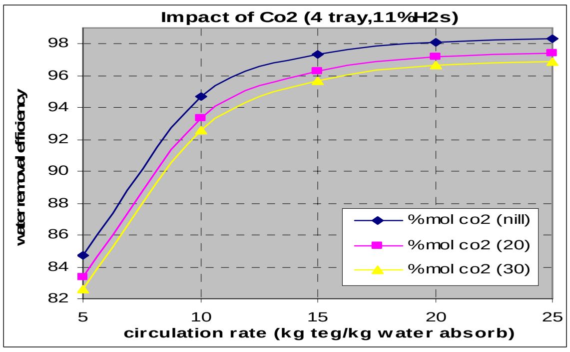

Fig. 12 Effect of CO_2 content of inlet gas on removed water (for 4 equilibrium stages and 11% H_2S).

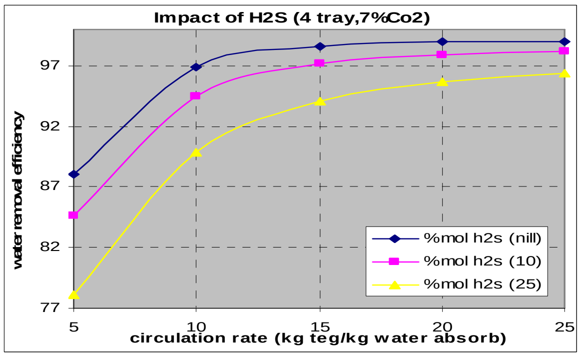

Fig. 13 Effect of H_2S content of inlet gas on removed water (for 4 equilibrium stages and 7% CO_2).

6. Conclusions

Process simulation is a powerful method which can guide to determine optimum conditions for maximum efficiency. In this work, at first a feasibility study for selection a suitable software simulator with considering of specific thermodynamic package for dehydration process has carried out.

In design of a natural gas dehydration unit, several major parameters existing which can be varied to achieve a specified dew point depression for prevent of hydrate formation. Sensitivity analysis and study of the effectiveness parameters such as TEG circulation rate, equilibrium stages of absorption column, and operating conditions should be investigated for a reliable, available and maintainable dehydration unit with economical considerations.

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