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The Impact of Stripping Gas Flow Rate on Triethylene Glycol Losses from Glycol Regeneration Unit: Simulation Study

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Abstract

Natural gas can be considered as one of the most important fossil fuels that is increasingly consumed around the world. It is an environmental friendly fuel of high heating value. However, the unrefined natural gas produced from deep reservoirs may contain some impurities including sulfur and nitrogen compounds as well as water vapour. The presence of these undesirable compounds may induce corrosion and environmental pollution, because of that it is necessary to minimize or remove those impurities from natural gas streams. Triethylene glycol (TEG) with 99 wt.% is typically utilized to reduce the water vapor contact to less than 1 ppm. Indeed, glycol purities up to 99.9 wt% can be achieved by using stripping gases include Nitrogen. However, glycol losses is behind some technical problems in the dehydration process. The research is aimed at simulation the prospective gas dehydration process using Aspen HYSYS simulator. The effect of Nitrogen stripping rate on TEG losses from glycol regenerator tower, TEG lean wt.%, and water content in natural dry gas were investigated and correlated. The design of the dehydration system was simulated adequately to achieve a reduction in natural gas water content to less than 0.1 ppm.

Keywords: Natural gas dehydration; Aspen hysys; Process optimisation; Stripping rate; Triethylene glycol losses

Introduction

Natural gas is a major industrial and domestic fuel worldwide. Water vapour is probably the most common undesirable impurity in natural gas streams. Usually, it is not the water vapour itself, but rather the liquid or solid phase that may precipitate from the gas when it is compressed or cooled. Water condensation and solid gas hydrates formation in natural gas pipelines may cause blocking of the pipeline flow. Thus, natural gas should be dehydrated to a controlled water content to avoid hydrates, as well to minimize the corrosion problems due to the acids formed by carbon dioxide or hydrogen sulphide regularly found in natural gas streams [1].

The industrial dehydration process is carried out using several methods including direct cooling (condensation), adsorption and absorption [2]. Recently, membrane dehydrators are used. However, It is no doubt that absorption is the most important dehydration processes [3-5].

In direct cooling or (condensation), natural gas can be efficiently cooled using the Joule-Thompson effect [2]. Compression of the hot gases saturated with water at the lowest temperature value will resulted in prevention further condensation of water. Thus, well removing of water could be carried out [5]. In adsorption dehydration, removal of water vapour from a gas stream is conducted by using solid desiccant [6,7] The solid desiccants commonly used are molecular sieves [8]. In membrane dehydration, thin film polymer composite membranes are used in order to overcome the problem of emissions of hazardous volatile organic compounds (VOCs) may result using glycol dehydrators [9,10]. Liquid desiccants are used in absorption dehydration to remove water vapour from the gas. The desiccants used most frequently in absorption processes are solvents which have physical or chemical constituents. The physical solvents are glycols, methanol, and (a mixture of dimethyl ethers of polyethylene glycol (DEPG). The chemical solvents include amines, potassium carbonate and caustic. Hybrid solvents include both physical and chemical constituents are also used [11]. However, Glycols are used primarily to dehydrate gas streams [12]. Glycols are the favourite solvents because they have low solubility in natural gas, high hygroscopic characteristics, low vapor pressure and low volatility [13]. The glycols mostly used include ethylene glycol (EG), diethylene glycol (DEG) and triethylene glycol (TEG). However, triethylene glycol (TEG) is the most effective common sorbents for natural gas dehydration [14]. The advantage of using (TEG) is that, it can greatly reduce the emission of benzene, toluene, ethyl benzene and xylene (BTEX).

On the other hand, designing and optimization of TEG dehydration processes is widely carried out using simulation. In general, the more effective simulation software should enable to evaluate the operating conditions and optimize the design configurations and to allow solving many problems within a reduced time and a minimum investment [15]. The available commercial process simulators can offer different facilities to examine the entire process easily and with short time. Aspen HYSYS and ProMax are commonly used process modelling and simulation software in gas dehydration [16-18] as well as other gas processing operations [19]. Using [20,21] the component based framework could be easily customized, updated and maintained to meet the requirements of users. Moreover, implantation of other models of separation processes could be run along with its solution procedure by using computer programs such Visual Basic (VB), C^{++} subroutine, etc. The present work focuses on the study of the effect of stripping gas flow rate on TEG losses. The main platform used for this study was the simulation software: Aspen HYSYS. An adopted case study was conducted with a proposed stripping gas circulation rates. The TEG system operates at

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atmospheric pressure, and it is of 98% purity. The aim of the work is to study the effect of the flow rate of stripping gas on glycol loss takes place in glycol still of regenerator.

Materials and Methods

The absorption dehydration unit

In TEG absorption process, the wet gas is brought into contact with dry glycol in an absorber (a tray column or packed bed) [22]. Water vapour is absorbed in the glycol and consequently, its dew point reduces. The wet rich glycol then flows from the absorber to a regeneration system in which the entrained gas is separated and fractionated in a column and reboiler. The heating allows boiling off the absorbed water vapour and the water dry lean glycol is cooled by a heat exchange and pumped back to the absorber [22]. The entire process is illustrated in Figure 1.

Nevertheless, stripping gas is used when very pure glycol (up to 99.9% TEG) is required and cannot be achieved by the standard regeneration system. Stripping gas is typically dry fuel gas. It strips the remaining water from the glycol when bubbled through the hot glycol. Stripping gas can be introduced directly into the reboiler vessel or it can be admitted at a base of a packed column installed between the reboiler and the surge drum [23]. This method improves the stripping efficiency. It prevents the oxidation of glycol by prevention air from coming into contact with the dry glycol. The most important prerequisite for the cost effective operation of a glycol dehydration unit is the avoidance of glycol losses. In fact, there are several causes for glycol losses or carryover including the excessive foaming in absorber, glycol ageing, as well as due to technical problems relevant to equipment corrosion and, inaccurate absorber temperature and pressure. The use and rates of stripping gas should be adequately evaluated because the stripping gas that is added to the glycol in the regeneration unit is typically emitted from the still vent with the released water vapour into the atmosphere, it may significantly affect greenhouse gas emissions due to its high methane concentration [24]. The aim of the work is to study the impact of stripping gas flow rate on TEG loses, the concentration of the regenerated lean TEG, and dry gas water content using Aspen HYSYS. The importance of the study is the application of the simulation software Aspen HYSYS in modeling and optimization the parameters affecting the efficiency of one of the units in natural gas processing plants (regeneration unit).

Natural gas composition and operating conditions

Table 1 shows the sweet natural gas composition and operating conditions as well. It seems from Table 1 that the given natural gas stream is loaded with considerable amounts of water vapor that should be removed from the gas stream.

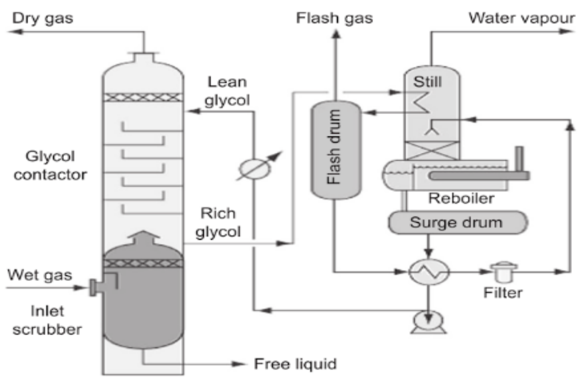

Figure 1: Scheme of absorption dehydration process (Bahadori).

Components	Mole %
Methane	0.7164
Ethane	0.1565
Propane	0.0606
i-Butane	0.0153
n-Butane	0.0276
i-Pentane	0.0114
n-Pentane	0.0083
n-Hexane	0.0013
Water	0.0023
Carbon dioxide	0.00004
Nitrogen	Trace
Hydrogen sulphide	Trace
Operation Condition	
Pressure	3555 kPa
Temperature	40°C
Flow rate	250 Million standard cubic feet of gas per day (MMSCFD)

Table 1: Natural gas composition and operation conditions.

Natural gas dehydration process simulation

The expected gas dehydration process is simulated by adopting Aspen HYSY software. The TEG is adopted as an absorbent to absorb water vapor that exists in the gas stream. Firstly, the first simulation step can be achieved by adding the gas stream compositions and operation conditions as given in Table 1. Figure 2 shows Hysys components list menu. Secondly, the Hysys fluid package can be chosen which should be (Glycol Pkg). Figure 3 shows Hysys fluid package menu.

The simulation environment is considered the main simulation area, that deals with the plant and shows the FPD for the process. The gas inlet separator should be added to remove any undesirable impurities for instance, solid particulars and liquids. Glycol absorber tower is also important part from the plant that it also require some specifications for instance, streams pressure and the TEG concentration (99% is used). Figure 4 shows glycol absorber menu. Rich glycol needs to be regenerate and that could be achieved by adding a regenerator. Figure 5 shows regenerator menu (Figure 6).

Finally, the simulation process has been run successfully. Figure 7 shows process flow diagram of natural gas dehydration process. The fresh TEG from the regenerator is cooled up and sends to the absorber tower. That can be achieved by installing a logical recycle operator that can be inserted between the two streams. Indeed, some of the process TEG could be lost from several process units for example separator and absorber. The lost TEG need be replaced. In the component splitter the TEG is separated from the dried gas and creating a stream of pure TEG that can be transferred back to the TEG stream. A mixer is also required to mix the pure TEG that recovered by the splitter with the fresh TEG from the regenerator. Figure 6 shows the splitter element menu.

The process regenerator possesses five trays and provided with a condenser and a boiler as well. Glycol purities up to 99.9 wt. % can be achieved by using stripping gas from the top of the stripping column. The stripping gas is usually nitrogen [25]. Water can be removed from the stripping gas by cooling it well below waters dew-point [26].

Results and Discussion

Researchers have envisioned the reasons of glycol carryover from natural gas dehydration units focusing on the various operation parameters

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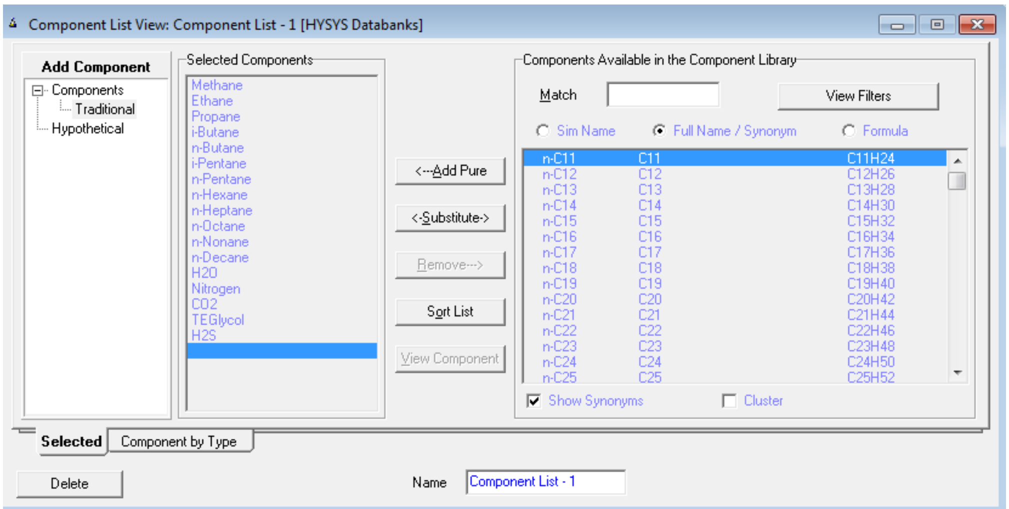

Figure 2: Hysys components list menu.

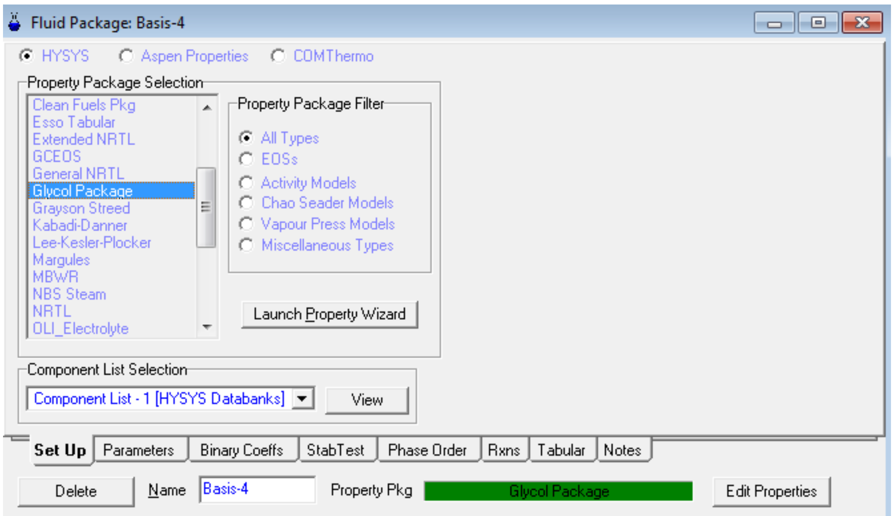

Figure 3: Hysys fluid package menu.

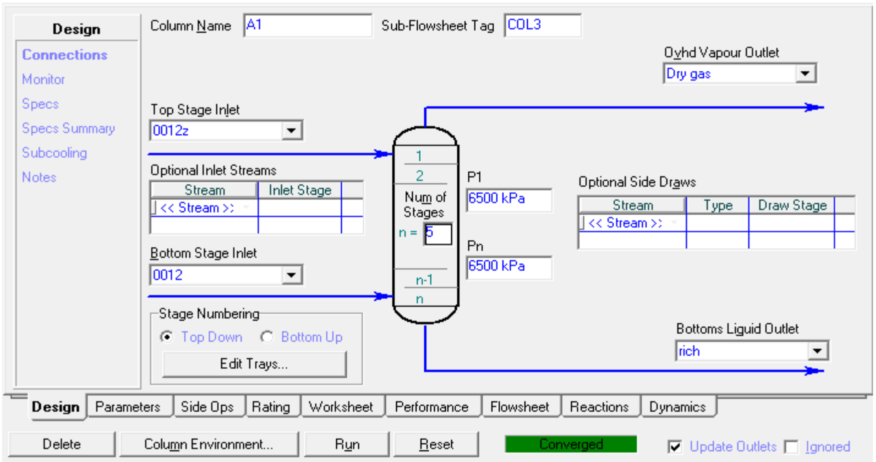

Figure 4: Hysys column design menu.

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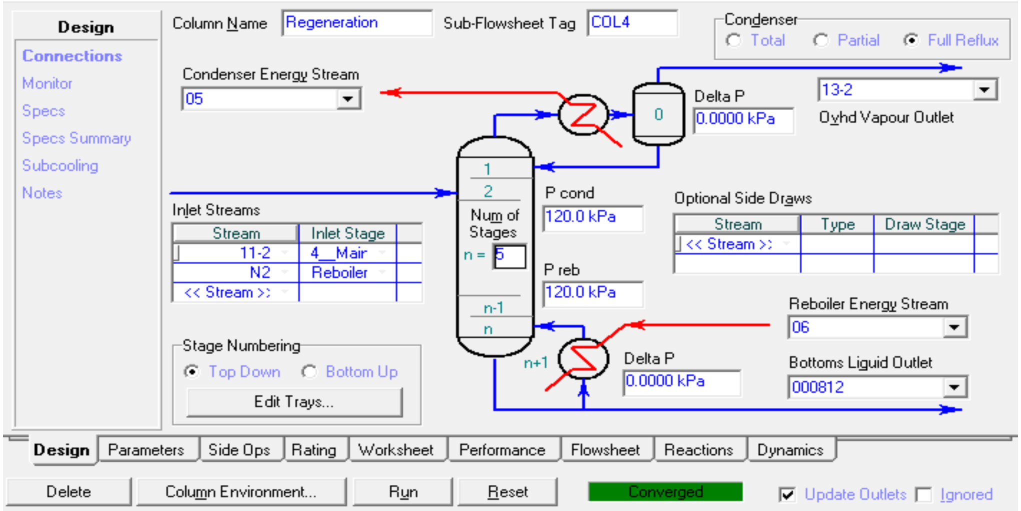

Figure 5: Hysys amine regenerator menu.

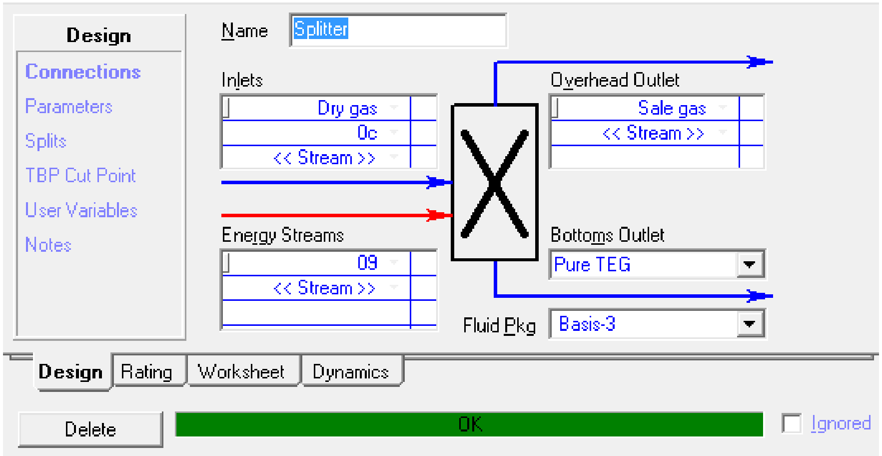

Figure 6: The splitter element menu.

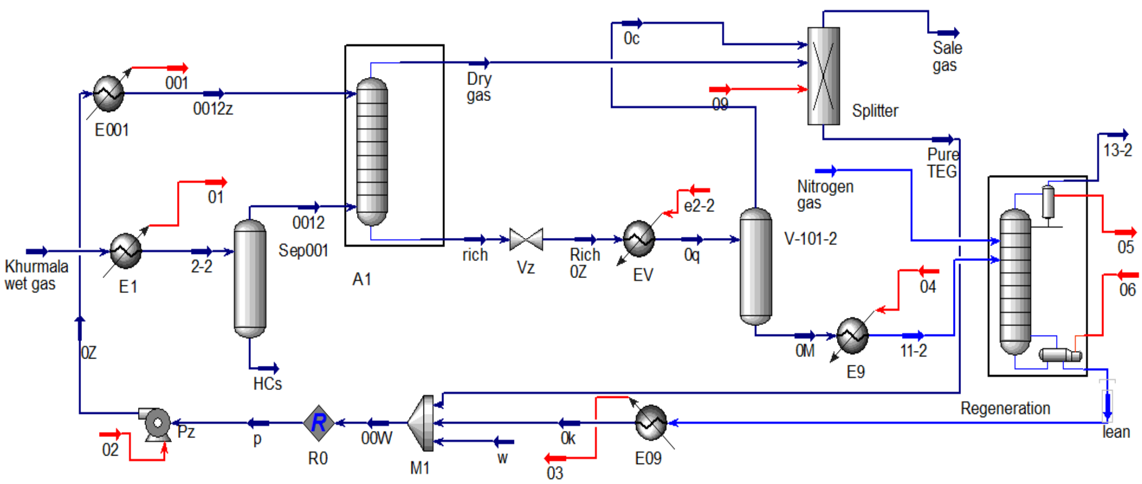

Figure 7: Process flow diagram of gas dehydration plant.

affecting the dehydration process including TEG circulation rate, lean TEG temperature and the dehydration operation conditions. However, studies about the effect of stripping gas flow rate on TEG losses from gas dehydration unit are still rare. In order to study the effect of the flow rate of the stripping gas on TEG losses from the top head stream of glycol regenerator, different flow rate values for Nitrogen as stripping gas have been applied in HYSYS software. They are: 28, 84, 160 and 420 Kg/hr.

The results of the plant simulation are illustrated in plots that correlate the design variables. Figure 8 shows the relationship between stripping gas flow rate and TEG losses from glycol regenerator top stream. It is well noticed that increasing the stripping gas flow rate will result in increasing the TEG losses from glycol regenerator outlet top stream. Moreover, the TEG loses could be excessive and could reach 2 Kg/hr at a stripping gas flow rate of about 400 kg/hr. A TEG flow rate of about 450 kg/hr could be applied to achieve a water content value in the dry gas of less than 1 ppm.

Variation of stripping gas flow rate and lean amine wt.% produced from the regnartor tower down stream is shown in Figure 9. It is illustrated that incresing stripping gas flowrate resulted in ncreasing the lean amine wt.%. However, the lean amine weight percent reaches equilibrum at a stripping gas flowrate of about 300 kg/hr The correlation between stripping gas flow rate (kg/hr) and water vapor amount in dry gas stream that produced from glycol absorber tower top stream is shown in Figure 10.

It is well noticed that when stripping gas flow rate increases, the water vapor amount in dry gas stream decreases, However, the glycol loss from glycol regenetor top stream increases (Figure 10).

TEG concentration required at the absorber to meet the dry gas dew point specification, and at the regenerator are crucial parameters for efficient dehydration. TEG vaporization loss may take place both in glycol contactor as well as in glycol still of regenerator. The vaporization loss from contactor is primarily due to higher gas inlet temperature, while the vaporization loss in glycol regenerator still is due to higher still temperature and high stripping gas rate [27,28].

Optimization the regenerator temperature as well as the stripping gas flow rate are key factor to minimize the TEG loss. The parameters will be optimized in a future study in order to realize what flow rate of stripping gas to use in order to minimize the TEG loss, and not to exceed the water content limit in natural gas stream.

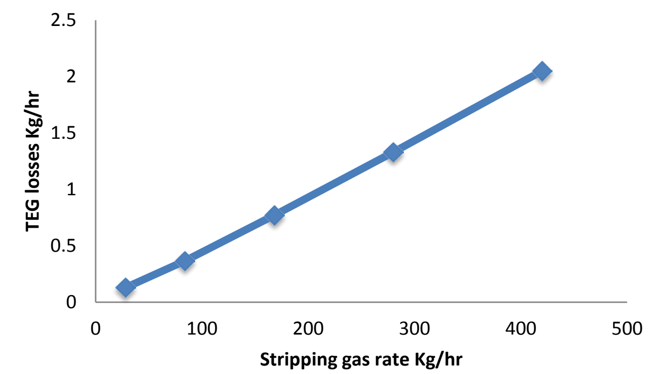

Figure 8: Variation of stripping gas flow rate and TEG losses from glycol regenerator top stream.

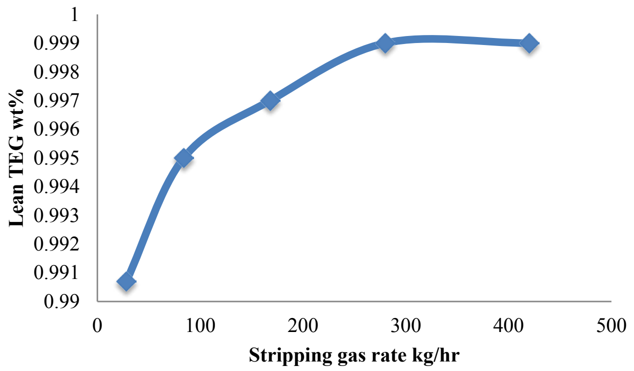

Figure 9: Stripping gas flow rate (kg/hr) versus the lean TEG wt. %.

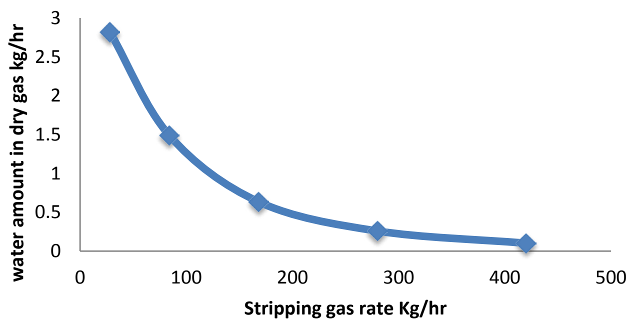

Figure 10: Effect of the stripping gas flow rate (kg/hr) on amount of water in dry gas stream.

Conclusions

In the current work, the impact of stripping gas flow rate on TEG loses, the concentration of the regenerated lean TEG, and dry gas water content was studied and correlated using Aspen HYSYS modeling and simulation software. To achieve the desired level of the parameters under investigation, series of plots and graphical correlations are prepared and demonstrated. The charts presented are based on the intensive calculations carried out by computer simulations which can be used for pilot plant TEG dehydration units to optimization the operating conditions as well as trouble shooting may face the operating units. The results obtained confirmed that increasing of stripping gas flow rate to 400 kg/h resulted in increasing the concentration of lean glycol up to 0.999 wt.%, and decreasing the water content value in the dry gas of less than 1 ppm, but increasing the TGE loss to about 2.2 kg/hr.

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