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Energy Optimization of the Sweetening Unit of Gachsaran Natural Gas Refinery by the Use of Vapor Recompression

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ABSTRACT

Globally, Iran ranks 6th in natural gas production. Producing over 1 billion cubic feet of dry natural gas, the Gachsaran gas refinery is a major revenue source for the country. Tens of thousands of barrels are sent to the Bandar-e-Emam petrochemical plant every day, and the Gachsaran oil and gas refinery always aims to partially supply the feed for this petrochemical complex by sweetening sour natural gas feed containing some H_2S and CO_2 . Due to the high energy consumption of the sweetening unit, energy optimization of this process is significant. Vapor Recompression Column was used for optimizing sweetening process energy in the Gachsaran gas unit, and the distillation column's top vapor was compressed to transfer its thermal energy to the bottom. The results show that Vapor Recompression Column consumed about 75% less energy than the conventional process mostly due to warm and cold utility savings. The output pressure of the compressor added in this process was calculated accurately. If the compressor output pressure increases excessively, this method becomes inefficient and uneconomical.

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1. Introduction

Nowadays, natural gas has become an important resource around the world and is increasingly being used as an energy carrier. In the last 10 years, natural gas accounted for 22% of the world's energy consumption. After the United States, Saudi Arabia, Canada, the United Arab Emirates and Russia, Iran ranks 6th in the production of natural gas in thousands of barrels per day (Dale, 2022). Natural gases often have impurities such as hydrogen sulfide, carbon dioxide, water vapor, heavy hydrocarbons, and mercaptan. Natural gas with over 4 ppm of hydrogen sulfide gas is considered sour. H_2S and CO_2 are removed to prevent corrosion and increase the thermal value of gas. There are different way of separating acidic gases from gas mixtures, such as chemical absorption, physical absorption, and membrane processes. Regardless, chemical absorption with amino-based solvents is one of the best currently available technologies for simultaneously absorbing H_2S and CO_2 (Darani et al., 2021; Karthigaiselvan and Panda, 2021; Moghadasi et al., 2021). Nejat et al. studied the effect of mixing a chemical amino solvent with a physical solvent on gas sweetening energy requirements and observed 30 to 42% savings using methyl diethanolamine (MDEA) with a physical solvent such as sulfinol compared to the chemical amino system (Nejat et al., 2018). In a gas sweetening project, M.A. Al-Lagtah et al. proposed an energy-saving design by evaluating the divided ring and removing and returning some enriched amino to the absorber, reducing operational costs by 50% (Al-Lagtah et al., 2015). Al-Amri & Zahid proposed two sweetening AGR units instead of AGR-AGE and reduced energy consumption over the base method by 22% (Al-Amri and Zahid, 2020). Making improvements to natural gas sweetening energy efficiency very important.

Despite the numerous studies on natural gas sweetening, its excessive energy consumption is a major problem. Gachsaran refinery's sweetening unit uses an absorption and a distillation column. The distillation column responsible for amin recovery consumes a great deal of energy, making process energy optimization a necessity. The thermal integration of gas sweetening has been studied extensively. Using the heat exchanger network (HEN), Othman et al. studied natural gas sweetening with the MDEA solvent and optimized energy by 62.6% (Othman et al., 2021). Using lean vapor compression (LVC), Al Hatmi et al. used the MDEA and MDEA-PZ solvents for natural gas sweetening in Oman oil field and reduced reboiler energy by 40-50% (Hatmi et al., 2018).

This study used the vapor recompression column (VRC) method for thermal integration of the solvent recovery column in the Gachsaran refinery. The vapor recompression method involves the steam that is released from the top of the tower entering the compressor, which causes a rise in the steam's pressure, temperature, and dew point. It is therefore conceivable to heat the bottom flow of the tower using a heat exchanger in this manner (Feng et al., 2017; Feng et al., 2020; Rix et al., 2023; Shrikhande et al., 2020). Since the VRC method allows for reducing or eliminating hot and cold utility, it could significantly reduce the energy consumption of the Gachsaran refinery sweetening unit. However, the VRC method uses a compressor that significantly affects energy consumption and total annual cost (TAC). To justify the process, the compressor's output pressure should be calculated accurately.

2. Case Study

Sour gas sweetening at Gachsaran unit was studied, and (Table 1) shows information about sour gas and amin.

Process Simulation: Aspen HYSYS V.10 was used for process simulation, and Modified HYSIM inside-out was used for accurately solving columns. The thermodynamic acid gas-chemical solvents package was used in gas sweetening.

In this process, first the sour gas and amine respectively enter the absorption column from the bottom and the top to remove carbon dioxide and hydrogen sulfide from the top product. Then, the amine is transferred to the amine recovery unit and re-enters the process.

Table 1. Properties of Sour Gas and Amine in Gachsaran Natural Gas Refinery

a) Chemical composition of Sour Gas (%Mole fractions)

H_2O	H_2S	CO_2	Methane	Ethane	Propane	i-butane	n-butane	i-pantane:	n-pantane	n-hexane
0.0022	0.0082	0.0202	0.6913	0.1331	0.0872	0.0121	0.0282	0.0063	0.0064	0.0048

b) Chemical composition of Amine (%Mole fractions)

H_2O	DEAmine
0.9305	0.0695

c) Sour Gas operating conditions

Temperature (°C)	Pressure (kPa)	Molar Flow (kmol/h)
43.3	35500	6477.7

d) Amine operating conditions

Temperature (°C)	Pressure (kPa)	Molar Flow (kmol/h)
60	6152	6477.7

2.1. Conventional Simulation

(Figure 1) shows the conventional simulation of the Gachsaran gas sweetening unit.

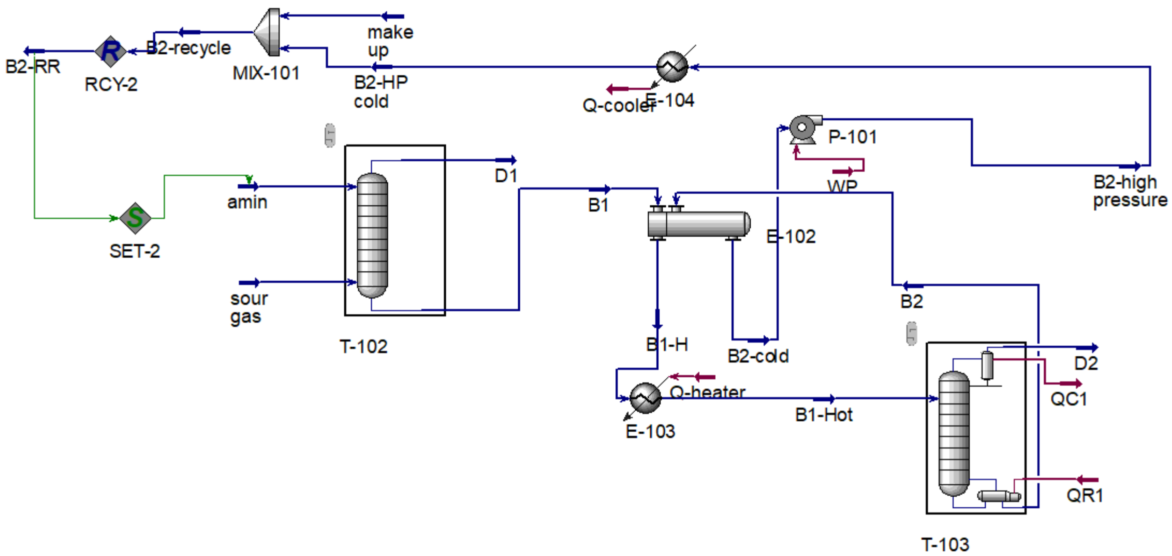

Figure 1. Simulation of conventional gas sweetening in Aspen Hysys

(Figure 1) shows the top amine flow and bottom sour gas flow in the absorption column. There are 30 trays, and the absorption tower's top and bottom pressure are respectively 3500 and 5100 kPa.

The combined carbon dioxide-hydrogen sulfide content in the absorption column's top product will be zero, and the bottom product will be transferred to the distillation column's recovery unit after reaching 100 °C. The distillation column has 25 trays and 13 feed trays with 107.6 kPa of top pressure and 138 kPa of bottom pressure.

2.2. VRC Simulation

The vapor out of the top of the distillation column enters the compressor to increase its pressure and temperature. Then, a heat exchanger provides the necessary heat for evaporating the distillation column's bottom liquid output.

(Figure 2) shows the natural gas sweetening simulation in the Gachsaran unit using the VRC method.

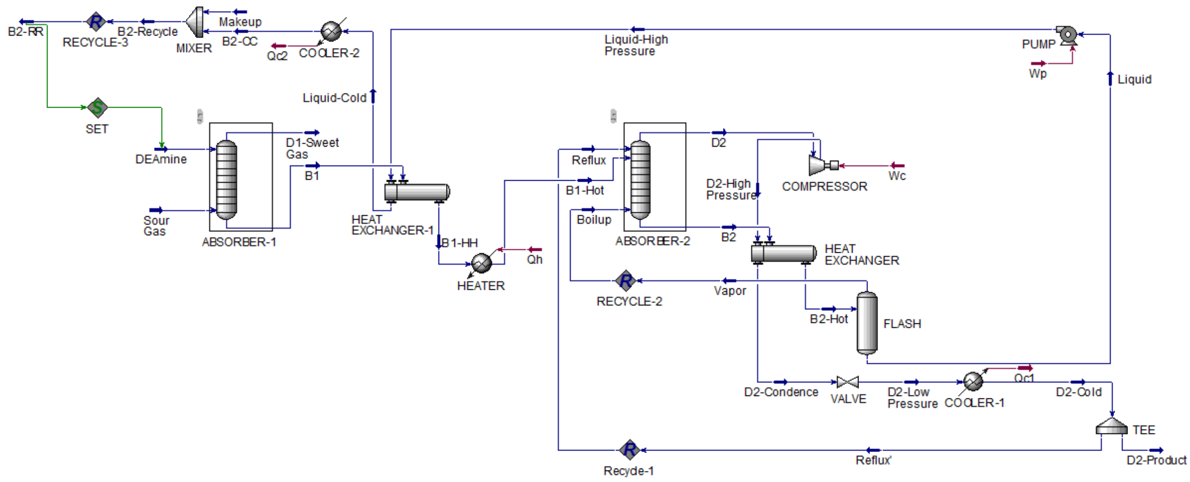

Figure 2. VRC sweetening simulation in Aspen Hysys

(Figure 2) shows that the feed first enters tray 13 of the distillation column. The column's top output vapor enters the compressor and is compressed up to 315 kPa, and the pressure increase raises flow temperature to 248.5 °C. This flow and the liquid from the bottom of the column enter a heat exchanger. After reaching the intended temperature and pressure, the heat exchanger's output flows are divided into two; one returns to the distillation column as the return flow, and the other is transferred to the heat exchanger to preheat the absorption column's bottom product for minimizing the cooler and heater's thermal load, which will significantly affect energy consumption.

3. Results and discussion

This study used VRC for natural gas sweetening in Gachsaran unit. Distillation tower energy consumption is obtained using Eq. 1.

$$Q = Q_R + Q_C \quad (1)$$

Where Q , Q_C , and Q_R respectively represent distillation column energy consumption, cold utility, and hot utility.

Since the VRC method also uses a compressor, the distillation column's energy consumption is calculated using Eq. 2.

$$\bar{Q} = Q_R + Q_R + 3W_C \quad (2)$$

Where $\bar{Q}$, Q_C , Q_R , and WC respectively represent column energy consumption, cold utility, hot utility, compressor work consumption. The VRC method is utilized to increase the hot utility from 71234.535 MW to 1.259 MW and the cold utility from 71228.23 MW to 7898.8285 MW in comparison to the conventional method, Which this work has been done to lower the heat load of the condenser and reboiler of the column. Eliminating the condenser and reboiler of the distillation column have been able to save 99% of the energy that is used in the hot utility and 88.91% of the energy that is used in the cold utility.

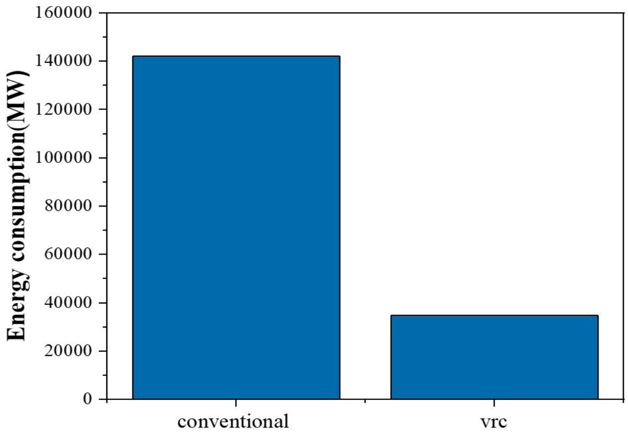

Figure 3. Compares the energy consumption of the conventional and VRC gas sweetening processes

Despite using a compressor, the VRC method significantly reduces energy consumption.

4. Conclusion

Globally, Iran ranks 6th in natural gas production. Producing over 1 billion cubic feet of dry natural gas, the Gachsaran gas refinery is a major revenue source for the country.

The natural gas sweetening unit of Gachsaran refinery has a distillation and an absorption column. Using the diethanolamine solvent, the absorption column completely eliminates H2S and CO_2 from natural gas, and the distillation column fully recovers the used solvent. However, Gachsaran gas refinery's sweetening unit, especially its distillation column, consumes a great deal of energy. To reduce energy consumption, the distillation column's hot and cold utility requirement should be reduced. The conventional unit of the Gachsaran gas refinery has been simulated. In this simulation, the hot and cold utilities were estimated to be approximately 71234.535 MW and 71228.23 MW, respectively; therefore,the VRC method was used for reducing the distillation column's energy consumption. The hot utility and cold utility have decreased by about 99% and 88.91% respectively by the VRC method. Despite using a compressor, VRC reduced energy consumption by 75% compared to the conventional method mostly due to the significant reduction in hot and cold utility. The output pressure of the compressor added in this process was calculated accurately. If the compressor output pressure increases excessively, this method becomes inefficient and uneconomical..

Nomenclature

HEN	heat exchanger network
LVC	lean vapor compression
MDEA	methyl diethanolamine
TAC	total annual cost
VRC	vapor recompression column

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بهینه‌سازی انرژی واحد شیرین‌سازی گاز طبیعی پالایشگاه گچساران با استفاده از روش تراکم بخار

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چکیـــــــده

ایران دارای ششمین جایگاه در تولید گاز طبیعی در جهان به شمار می‌رود .پالایشگاه گاز گچساران با تولید بیش از یک میلیارد فوت مکعب گاز خشک در روز سهم عمده‌ای در تأمین درآمدهای اقتصادی کشور دارد.

شیرین‌سازی گاز ترش که به‌صورت مایع وجود دارد، همواره جهت تأمین بخشی از خوراک مجتمع‌های پتروشیمی بندر امام، یکی از مهم‌ترین اهداف پالایشگاه نفت و گاز گچساران بوده است. به‌طوری‌که روزانه ده‌ها هزار بشکه به پتروشیمی بندر امام ارسال می‌شود. گازترشی که به‌عنوان خوراک ورودی مورد استفاده قرار می‌گیرد، دارای مقداری سولفید هیدروژن و دی‌اکسید کربن است. به دلیل انرژی مصرفی بالای شیرین‌سازی، بهینه‌سازی انرژی این فرآیند از اهمیت بالایی برخوردار است .در این مطالعه، از روش تراکم بخار به‌منظور بهینه‌سازی انرژی فرآیند شیرین‌سازی واحد گاز گچساران استفاده شده است. در این روش به کمک کمپرسور، بخار بالای برج تقطیر فشرده می‌شود و این امکان را پیدا می‌کند که انرژی گرمایی خود را به جریان پایین برج منتقل کنند. نتایج نشان می‌دهد که روش تراکم بخار نسبت به فرآیند مرسوم ۵۷ درصد کاهش مصرف انرژی داشته است که مهم‌ترین دلیل آن کاهش مصرف یوتیلیتی گرم و یوتیلیتی سرد است. البته در این فرایند یک کمپرسور اضافه می‌شود که فشار خروجی آن به‌طور دقیق محاسبه شده است. چنانچه فشار خروجی کمپرسور بیش از حد افزایش یابد، این روش کارایی خود را از دست می‌دهد و غیراقتصادی می‌شود.

واژگان کلیدی: شیرین‌سازی گاز ترش، گاز طبیعی، تراکم بخار، بهینه‌سازی انرژی