The Applied Research of Heat Pump Technology in Natural Gas Desulfurization and Decarburization Device

Danyang Wang [a], Zhihong Wang [b]

School of Southwest Petroleum University, Sichuan 610500, China.

[a]1205413152@qq.com, [b]228298112@qq.com

Abstract

The natural gas alcohol amine desulfurization and decarbonization device is by simulates using HYSYS simulation software in this paper,and finds out the high energy consumption of unit process, the acid gas from regeneration tower top is used for low-temperature heat source, regeneration tower reboiler heat is provide by heat pump technology to reduce the heating steam demand. Based on the energy consumption analysis of each part, simulates the heat pump system by the paper, then the influence of temperature, pressure and other parameters analyzes by the heat pump system. Through simulation analysis, high-acid natural gas desulphurization and decarbonization device uses heat pump technology , energy consumption dropped from 17896.3kw to 16889.6kw, The energy consumption is reduced by 1006.7kW, the percentage of energy saving is 5.625%.

Keywords

Natural gas desulfurization; Alcohol-amine method; Optimization; Heat pump; Saving energy and reducing consumption.

1. Introduction

At present, domestic natural gas and petroleum processing industries generally use by alcohol amines and other solvents for acid gas removal. In some early desulfurization process installations, the sulfone amine method is widely used, MDEA solvent is more common used in oil refineries [1]. Sulfur-bearing natural gas from gas wells must meet commodity natural gas standards, desulphurization and decarbonization are the necessary steps in its processing. The alcohol amine technology is mainly applied to natural gas desulfurization and decarbonization process. When the process is used for desulphurization of high-acid natural gas, the required amount of alcohol amine solvent circulation is large, most amount of sour gas, and the reboiler load is high, the problems such as high energy consumption of desulfurizers are caused. Therefore, it is important for the energy saving of high-acid natural gas desulfurization devices to the natural gas processing process.The principle of energy conservation priority must be adhered in the production process, optimize the energy structure, increase the efficiency of energy use, more importantly, it enhances awareness of energy conservation [2].

2. The Introduction to Heat Pump Technology

The heat pump is an energy-saving device that transfers heat from a low-grade heat source to a high-grade heat source. It can convert low-grade heat sources (such as air, soil, heat in solar water, solar energy, industrial waste heat, etc.) into usable highs-grade heat source, the purpose of saving some high grade energy is achieved (such as coal, gas, oil, electricity, etc.) [3],see Fig.1.

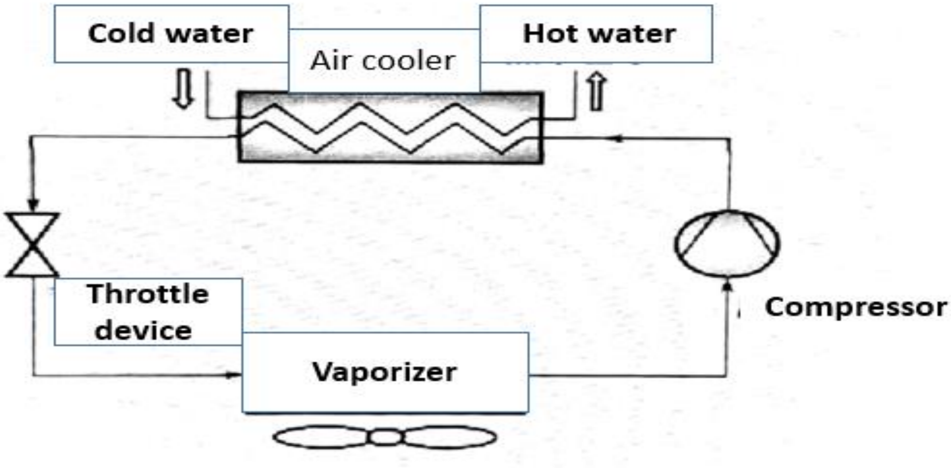

Fig.1 Schematic diagram of heat pump operation

The principle of heat pump technology is the phase change heat that the medium absorbs steam in the evaporator, then the pressure is increased by the compressor and used as a high-grade heat source to provide heat to the outside, the throttling expansion as a cold source of the condenser to form a cycle is performed, saving the utility usage. The essence of this cycle is the reverse Carnot cycle [4], its efficiency is represented by the heat pump performance coefficient:

$$\eta = \frac{T_H}{T_H - T_C} \tag{1}$$

TH: Condensation temperature for the working medium.

TC: evaporation temperature of the working medium.

The above equation shows that the efficiency of the heat pump must be greater than 1, If the evaporation temperature of the medium is different from the condensation temperature, the higher the heat pump efficiency is higher [5-6].

3. Optimization of Contras

3.1 Basic Date

Taking the natural gas desulphurization and decarbonization device of a domestic natural gas purification plant as the research object in the article, and its natural gas composition is shown in Table 1.

Table .1 The composition of raw material natural gas

component	CH4	C2H6	C3H8	CO2	H2S	N2	He	H2
cotent/%	89.702	1.208	0.177	8.3022	0.055	0.438	0.021	0.005

Raw gas processing capacity: 400×104Sm3/d

Gas inlet temperature: About 20° C

Natural gas inlet pressure: About8.0Mpa

The gas quality requirements of natural gas national standard is satisfied by the desulfurization and decarbonization of purified gas [7] GB17820-2012[1], the H2S content is less than 6mg/m^3, the CO_2 content is less than 2% (V).

3.2 The Analysis of Natural Gas Desulfurization and Decarbonization Process Simulation

Based on HYSYS consists of four systems, the natural gas desulfurization and decarbonization purification process is established: absorption system, flash evaporation system, heat exchange system and regeneration system. Through the logistics transfer module, the transfer of logistics parameters is realized by the system. There is a link between processes, when a certain material parameter or operating parameter changes in the process, the model will recalculate each unit model , finally, the entire process model is converged [8].

Firstly,The raw natural gas (8 MPa, 20° C.) is filtered and separated by a raw material gas filter separator to remove impurities (such as doped solid particles and free water) in the raw material gas. In order to simplify the Aspen HYSYS simulation process, Raw material gas contains mechanical impurities, free water and residual droplets is not considered. According to the process flow, the Common and Columns module is used [9] in the Aspen HYSYS menu, the corresponding module and logistics are selected, and a flow chart of natural gas purification and removal as follows is built, see Fig.2.

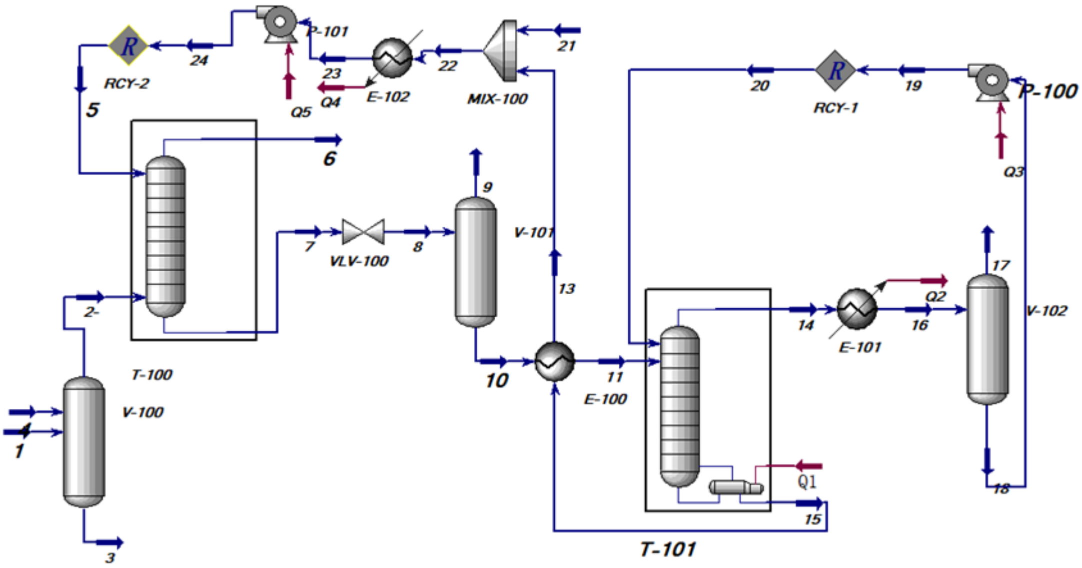

Fig.2 Natural gas desulfurization and decarbonization process flow chart

The simulation results of natural gas desulfurization and decarbonization process under the original conditions are shown in Table 2.

Table.2 Natural gas desulfurization and decarbonization process simulation results

Stream name	Feed gas	Clean gas	Barrn solution	Rich liquid	Acid gas
Vapour/ Phase Fraction	1.0000	1.0000	0.0000	0.0000	1.0000
Temperature [C]	19.66	41.65	39.93	51.81	38.11
Pressure [kPa]	8000	7950	7950	8000	130
Molar Flow [kgmole/h]	6576	6116	7969	8429	480.3
Mass Flow [kg/h]	1.224×10^5	1.023×10^5	2.366×10^5	2.567×10^5	2.043×10^4
Heat Flow [kJ/h]	6.997×10^7	7.362×10^7	-1.705×10^8	-1.705×10^8	4.729×10^6
Liq Vol Flow [m^3/h]	1.551×10^5	1.442×10^5	232.1	232.9	27.27
CO_2[kg/h]	23709.1926	3801.9878	1195.3397	21102.5545	19857.1791
H_2S[kg/h]	63.9293	0.8490	39.7044	157.3586	117.3516
CO_2 Fraction(V)	0.0819	0.0141	0.0034	0.0569	0.9395
H_2S Fraction(V)	0.0005	0.0000	0.0001	0.0005	0.0072

According to the process simulation, the purified natural gas H2S content is 0.8490 kg/m^3, the total volume flow rate is 1.442×105 m^3/h, and the volume fraction of CO_2 is 1.41%.

$$\frac{0.8490\text{kg/m}^3}{1.442\times10^5\text{m}^3\text{/h}}=5.8877\text{mg/m}^3<6\text{mg/m}^3 \qquad (2)$$

After calculating, H_2S concentration is 5.8877 mg/m^3, which is lower than the purified gas requirement of 6 mg/m^3; the volume fraction of CO_2 is 1.41%, which is lower than that of the purified gas requirement of 2%. Therefore, the preliminary simulation process meets the demand for purification.

3.3 Heat Pump Technology Simulation and Analysis in Natural Gas Desulfurization and Decarbonization Process

According to the process flow diagram, the Common and Columns module under the Aspen HYSYS menu is used to select the appropriate modules and logistics, build the natural gas purification desulfurization and decarbonization flow chart is built by heat pump shown in Fig.3. The acid gas outlet gas at the top of the regeneration tower is compressed and heated by the compressor, it is used to heat the bottom material of the regeneration tower to achieve energy saving and consumption reduction of the reboiler[10].

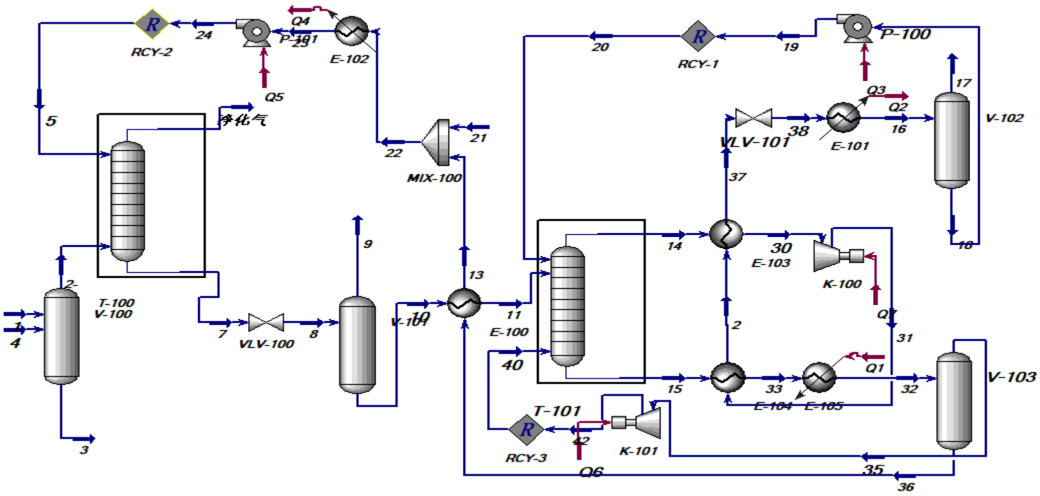

Fig.3 simulation results of heat pump technology in natural gas desulfurization and decarbonization process flow chart

simulation results of heat pump technology in natural gas desulfurization and decarbonization process are shown in Table 3.

According to the process simulation, the purified natural gas H_2S content is 0.5463 kg/m^3, the total volume flow is 1.448×105 m^3/h, and the volume fraction of CO_2 is 1.71%.

$$\frac{0.5463\text{kg/m}^3}{1.448\times10^5\text{m}^3\text{/h}}=3.7728\text{mg/m}^3<6\text{mg/m}^3 \qquad (3)$$

After calculating, H_2S concentration is 3.7768 mg/m^3, which is lower than the initial flow of 5.8877 mg/m^3 and lower than the purified gas requirement of 6 mg/m^3. The volume fraction of CO_2 is 1.71%, which is lower than the requirement of 2% for the purified gas. Therefore, the simulation process using heat pump technology also meets the demand of purification [11].

Table.3 simulation results of heat pump technology in natural gas desulfurization and decarbonization process

Stream name	Feed gas	Clean gas	Barrn solution	Rich liquid	Acid gas
Vapour/ Phase Fraction	1.0000	1.0000	0.0000	0.0000	1.0000
Temperature [C]	19.66	45.51	40.28	54	38.08
Pressure [kPa]	8000	7950	7950	8000	130
Molar Flow [kgmole/h]	6576	6139	4217	4654	459.6
Mass Flow [kg/h]	1.224×10^5	1.032×10^5	2.057×10^5	2.249×10^5	1.956×10^4
Heat Flow [kJ/h]	6.997×10^7	7.494×10^7	-3.811×10^6	-8.780×10^6	4.524×10^6
Liq Vol Flow [m3/h]	1.551×10^5	1.448×10^5	191.5	202.4	26.03
CO_2[kg/h]	23709.1926	4623.2925	49.6962	19135.5963	19014.4701
H_2S[kg/h]	118.5032	0.5463	4.5881	122.5450	114.6644
CO_2 Fraction(V)	0.0819	0.0171	0.0003	0.0934	0.9401
H_2S Fraction(V)	0.0005	0.0000	0.0000	0.0008	0.0073

3.4 Comparison of Heat Pump Technology Optimization

The energy consumption of natural gas desulfurization and decarbonization process in the original working condition is shown in Table 4:

Table.4 Energy Consumption of Natural Gas Desulfurization and Decarbonization Process

Serial number	Name	The size of energy consumption
Q1	Regeneration tower reboiler	16510kW
Q2	Regenerative lean condenser	1386kW
Q3	Regenerative top reflow pump	0.2626kW

The energy consumption of the original process regeneration system is:

$$16510+1386+0.2626=17896.3 \text{ kW}. \tag{4}$$

Energy consumption of heat pump technology in natural gas desulfurization and decarbonization process is shown in Table 5:

Table.5 Energy consumption of heat pump technology in natural gas desulfurization and decarbonization process

Serial number	Name	The size of energy consumption
Q1	Regeneration tower reboiler	14450kW
Q2	Regenerative lean condenser	1192kW
Q6	The tower bottom booster	268.5kW
Q7	Heat pump compressor	979.1kW

Heat pump regeneration system energy consumption:

$$14450 + 1192 + 268.5 + 979.1 = 16889.6\text{kW}. \quad (5)$$

Energy saving power:

$$17896.3 - 16889.6 = 1006.7\text{kW}. \quad (6)$$

Energy saving efficiency

$$1006.7 \div 17896.3 \times 100\% = 5.625\%. \quad (7)$$

4. Conclusion

Common and Columns module under is used by Aspen HYSYS menu to select the corresponding module and logistics, a natural gas desulfurization and decarbonization process flow chart is built. Through the optimization of operation and regulation, the natural gas desulfurization and decarbonization process is converged. According to the simulation result of the process flow, the energy consumption is reduced by 1006.7kW, and the percentage of energy saving is 5.62%, the purpose of saving energy and reducing consumption is achieved.

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