ISSN: 2688-8645

Brief Analysis on Research Progress of Recovery of Natural Gas Condensate

Kai Zhang[1,*], Liqiong Chen[1], Sisi Zhang[2], Weihe Huang[1]

[1]College of Pelroleum and Natural Gas Engineering, Southwest Petroleum University, Chengdu 610500, China

[2]School of Law, Southwest Petroleum University, Chengdu 610500, China

*Corresponding author

Abstract

In recent years, China has increasingly emphasized the utilization of natural gas due to its near-zero pollution characteristics upon combustion, making it widely favored. Natural gas primarily consists of methane and other hydrocarbon gases, forming an important mixture. Besides using methane as fuel, other gases in natural gas can be separated and recovered through specific technologies for use in the chemical industry. The development of natural gas condensate recovery technology is influenced by various factors, including technical requirements, recovery equipment performance, and process parameter settings. Common recovery methods include condensation, adsorption, membrane separation, and cryogenic distillation, each with its own advantages and disadvantages. Natural gas condensate recovery not only improves resource utilization and provides high-quality raw materials for the chemical industry but also promotes green development. Future technological innovations will continue to optimize the recovery process, reduce energy consumption and emissions, and further enhance the role of natural gas.

Keywords

Natural Gas; Condensate Recovery; Innovative Technology; Green Development.

1. Introduction

In addition to methane, natural gas (especially condensate gas and associated gas) also contains a certain amount of ethane, propane, butane, pentane and heavier hydrocarbons. In order to meet the quality index of commercial natural gas and the quality requirements of hydrocarbon dew point of gas pipeline, or to obtain valuable liquid fuel gas and chemical raw materials, it is necessary to separate and recover hydrocarbons in natural gas according to certain requirements.

Currently, ethane, propane, butane, pentane, and heavier hydrocarbons in natural gas are recovered as liquids, with the exception of ethane, which is sometimes recovered as a gas. The liquid hydrocarbon mixture recovered from natural gas is called natural gas condensate (NGL), referred to as liquid hydrocarbon or condensate hydrocarbon, and it is customary in China to call it light hydrocarbon [1]. The composition of natural gas condensate varies according to the composition of natural gas, the purpose and method of recovery of natural gas condensate. The process of recovering condensate from natural gas is called natural gas condensate recovery (NGL recovery), and our country is used to call it light hydrocarbon recovery. The recovered natural gas condensate is either directly used as a commodity or further separated into products such as ethane, liquefied petroleum gas and natural gasoline according to relevant product quality indicators. Therefore, the recovery of natural gas condensate generally includes the process of natural gas separation. Although the recovery of natural gas condensate is a very

ISSN: 2688-8645

important process, it is not economical to recover natural gas condensate in all cases. It depends on the type and quantity of natural gas, the purpose of condensate recovery, the method and the price of the product, and in particular on the economic benefits of those hydrocarbon components that can be recovered as liquid products or as commercial gas.

2. Research Status of Natural Gas Condensate Recovery Technology

At present, there are three main technologies for recovery of natural gas condensate: adsorption, oil absorption and condensation separation. In practical applications, adsorption method is rarely used, because this process conditions are strict, the application is inconvenient, and there are many defects. In the 1950s and 1960s, oil absorption method was a common method to recover natural gas condensate, which was divided into three types: normal temperature, moderate and low temperature. Among them, the low temperature oil absorption method has the highest C3 recovery, when the temperature is controlled at minus 40 degrees Celsius, the recovery rate can reach 85%. This method has unique advantages, such as low system pressure drop, no need for a large amount of special treatment of the feedstock gas, and high utilization of a single set of equipment [2].

However, this method also has obvious disadvantages, that is, it requires a large amount of investment, very large energy consumption, and high operating costs. With the emergence of condensation separation, it has gradually replaced the oil absorption method and become the main method of recovery of natural gas condensate. Condensation separation method uses the boiling point difference of different gases in natural gas, by adjusting the temperature to condense the gas, the hydrocarbons with higher boiling point are gradually separated, and different hydrocarbons can be made into other products after rectification. The key of this method is to provide enough low temperature environment, not only the process is simple, easy to operate, but also low cost, more importantly, the recovery rate of light hydrocarbons is very high, so it has been widely used.

There are a variety of ways for the condensation separation process to provide cooling capacity, so it can be divided into three methods: refrigerant refrigeration, combined refrigeration and direct expansion refrigeration. Among them, the turbine expansion refrigeration method is the most widely used method, and the United States is in a leading position in this technology and has developed rapidly. The reason why this method is widely used is that its operation is relatively simple, and the input and output have high cost performance, so it is widely used at home and abroad. With the development of processing depth, hydrocarbon recovery technology continues to develop in the direction of deep cooling, and the processing temperature is kept below minus 100 degrees Celsius [3]. China began to study the field of cryogenic processing in the mid-1990s, and Xinjiang Qiudong Oil and Gas Treatment plant is one of the representative examples. The plant is designed to cool at temperatures up to minus 70 degrees Celsius, greatly increasing the recovery rate of C3 up to 90 percent. After entering the 21st century, natural gas cryogenic equipment has been built in China through the self-developed cryogenic process, and the C3 recovery rate has increased to 98%.

2.1. Adsorption Method

Adsorption method uses solid adsorbent to selectively adsorb specific components of natural gas, so as to achieve separation. Adsorbents usually have a large number of micropores that are able to adsorb gas molecules through physical or chemical interactions. Common adsorbents include molecular sieve, activated carbon, silica gel, etc. These materials can selectively adsorb different gas components according to their pore size and surface chemical properties [4].

Advantages:

ISSN: 2688-8645

High selectivity: By selecting the appropriate adsorbent, a specific component can be separated efficiently.

Low energy consumption: The adsorption process is usually carried out at room temperature and pressure, which requires low energy and saves energy.

Easy to operate: The equipment is relatively simple, easy to operate and maintain.

Cons:

Adsorbent regeneration is difficult: the adsorbent will gradually saturate during use, requiring regular regeneration, which is a more complex and costly process.

Limited adsorption capacity: The capacity of the adsorbent is limited and cannot handle the large-scale gas separation needs.

Complex operation: Although the equipment is simple, it requires precise control of parameters such as temperature and pressure to ensure the separation effect.

2.1.1. New Technologies

In practical applications, adsorption method performs well in the recovery of some high value-added chemical products. For example, important chemical raw materials such as ethylene and propylene can be efficiently separated through molecular sieve. In addition, in environmental protection projects, adsorption methods are also used to remove polluting gases from industrial waste gases, such as sulfur dioxide and nitrogen oxides. With the development of materials science, the performance of adsorbents continues to improve, and the emergence of new adsorbents will further improve the separation efficiency and economy of adsorption methods [2]. In the future, the application prospect of adsorption method in the recovery of natural gas condensate will be more broad, especially in the separation and recovery of highly selective and high value-added products, adsorption method is expected to play a greater role.

2.2. Suction Method

Absorption is one of the important methods to separate gas mixtures in chemical production, which is widely used in the separation of gas mixtures, gas purification and recovery of valuable components. The light hydrocarbon recovery process is essentially a multi-component gas-liquid two-phase equilibrium system. At a certain temperature and pressure, when the system reaches a state of gas-liquid equilibrium, the degree of gas liquefaction can be expressed by Henry's law:

$$K = \frac{y_i}{x_i} \quad (1)$$

Where: K: equilibrium constant

yi: The molar content of a component in the gas phase

xi: The molar content of a component in the liquid phase

At equilibrium, the vaporization rate of all components is equal to the condensation rate, so that the components of the gas phase and the liquid phase do not change, that is, the driving force in both directions must be equal. In a multi-component gas-liquid two-phase system at a specific cooling temperature and pressure, the existing equilibrium state must be destroyed to obtain more condensate.

2.2.1. Classification of Oil Suction Method

According to the different absorption temperature, the oil absorption method can be divided into normal temperature oil absorption method, medium temperature oil absorption method and low temperature oil absorption method (frozen oil absorption method).

Normal temperature oil absorption method: the absorption temperature is generally about 30℃.

ISSN: 2688-8645

Medium temperature oil absorption method: the absorption temperature is generally more than-20℃, and the C3 yield is about 40%.

Low temperature oil absorption method: the absorption temperature is generally about-40℃, C3 yield is generally 80%~90%, C2 yield is generally 35%~50%.

Conventional oil absorption method includes four stages of normal temperature absorption, desorption, stability and reabsorption. The process is long and high energy consumption, which requires a large amount of circulating absorption oil. The gas at the top of the absorption tower will contain a certain amount of absorption oil. The low temperature absorption method shows the advantages of high efficiency and energy saving when recovering the light hydrocarbons in natural gas (such as C3 and C4), but its equipment investment and operation cost are high, and the energy consumption is large. This method is widely used in the field of natural gas condensate recovery due to its efficient light hydrocarbon recovery rate and low energy consumption [5]

2.2.2. New Technologies

In the natural gas condensate recovery, the application technology of oil absorption method is constantly developing. The following are several latest technological developments:

1. Improved absorber

Research and develop new absorbent materials to improve the absorption efficiency and selectivity. For example, the use of nanotechnology-improved absorbers enables more efficient capture and separation of heavy hydrocarbon components in natural gas. This material has a higher surface area and a stronger adsorption capacity, which can significantly improve the recovery rate of light hydrocarbons.

2. Efficient absorption tower design

By optimizing the design of the absorber, the gas-liquid contact time is reduced and the absorption efficiency is improved. For example, using the rotating packing absorber (RPCT), you can increase the air-liquid contact area and contact time by rotating the filler to improve the absorption effect. This design also reduces operating pressure and energy consumption.

3. Combined absorption process

The traditional oil absorption method is combined with other separation techniques, such as membrane separation technology and deep cold separation technology, to form a combined absorption process. The combined process can utilize the advantages of different technologies to improve the overall separation efficiency. For example, during oil absorption, part of the light hydrocarbon is removed by membrane separation and then further purified by deep cold separation.

4. Dynamic absorption system

The dynamic absorption system optimizes the absorption process by monitoring and adjusting the operating parameters in real time. Using sensors and automatic control system, the flow rate and operating conditions of absorbent can be adjusted in real time according to the change of natural gas composition to ensure optimal absorption efficiency. This technology not only improves the absorption effects, but also reduces the energy consumption and operating costs.

5. Low-temperature absorption technology

The low-temperature absorption technology improves the solubility and absorption rate of heavy hydrocarbon by reducing the operating temperature. This technology requires efficient cryogenic refrigeration equipment such as turbine expanders and deep cold heat exchangers to provide the desired cryogenic environment. Low temperature absorption technology can significantly improve the recovery rate of C3 and C4, especially for natural gas with high content of heavy hydrocarbons.

ISSN: 2688-8645

The application of these new technologies not only improves the recovery efficiency of natural gas condensate, but also significantly reduces the energy consumption and operating cost, making the application of oil absorption method in natural gas condensate recovery more promising. With the continuous progress of technology, these new technologies will further promote the development of the natural gas condensate recovery industry.

2.3. Condensation and Separation Method

Condensing separation method is a technology based on the difference of boiling points of each component in natural gas. By lowering the temperature of the natural gas, the heavy hydrocarbon components (such as ethane, propane, butane, and heavier hydrocarbons) are condensed into a liquid to separate from the gas. These liquids can be further distilled into other chemicals. According to the different methods of providing cooling capacity, condensation separation method can be divided into refrigerant cooling method, combined cooling method and direct expansion cooling method [1]

The advantages of condensation separation method include relatively simple process flow, easy operation and maintenance, low cost, high recovery rate of light hydrocarbons, especially significant recovery effect of propane and butane, relatively mild operating conditions, and high safety. However, the disadvantage is that the need to provide a large amount of refrigeration energy to maintain a low temperature environment, high energy consumption, and the maintenance and operation of low temperature equipment such as cold boxes, condensers and heat exchangers need professional technology [5].

2.3.1. New Technologies

The application of condensation separation method in natural gas condensate recovery is constantly developing. Here are some new technologies and advances:

1. Turbine expansion and refrigeration technology

Turbine expansion refrigeration technology is one of the most widely used in condensation separation method, its core is to make adiabatic expansion of high pressure gas through the turbine expansion machine, so that the gas temperature is significantly reduced, so as to achieve condensation separation. This technology is simple, efficient and cost-effective, so it is widely used in natural gas treatment plants at home and abroad.

2. Deep-cold treatment technology

Deep cold treatment technology through the very low temperature environment to improve the recovery of light hydrocarbons. For example, deep cooling treatment technology at the Qiudong oil and gas treatment plant in Xinjiang, China, reduced the cooling temperature to minus 70 degrees Celsius, greatly improving the recovery rate of C3. In the 21st century, the C3 recovery rate has increased to 98% through the self-developed deep cooling process.

3. Combined refrigeration system

The combined refrigeration system combines a variety of refrigeration methods, such as refrigerant refrigeration and direct expansion refrigeration, to improve the overall refrigeration efficiency. This system reduces the limitations of a single method by optimizing heat exchange and energy utilization, significantly improving the separation effect and energy efficiency.

4. Advanced heat exchanger design

The development of an efficient heat exchanger is one of the keys to improve the condensation separation efficiency. By optimizing the design of the heat exchanger and the use of materials, the heat exchange efficiency can be significantly improved and the energy consumption reduced. For example, heat exchangers made from nanomaterials and novel composites have higher thermal conductivity and corrosion resistance.

5. Process simulation and optimization

ISSN: 2688-8645

Using advanced computer simulation technology (such as Aspen HYSYS software), to simulate and optimize the condensation separation process. Through the sensitivity analysis and optimization of the key parameters, the recovery efficiency and economy of the system can be significantly improved. For example, energy consumption and recovery throughout the process can be optimized by adjusting the cooler outlet flow temperature and expander outlet pressure of the process.

6. Renewable energy-assisted refrigeration

In order to further reduce energy consumption and environmental impact, some new technologies have begun to explore the use of renewable energy to assist refrigeration. For example, the use of solar or wind energy to drive refrigeration equipment can effectively reduce the dependence on traditional energy sources and improve the environmental performance of the system.

3. Summary

China's natural gas resources are mainly distributed in the central and western regions, while the southeast coastal areas have the largest energy consumption area. The completion and operation of the "West-east Gas Transmission" pipeline marks the beginning of the wide application of natural gas in China. In order to adapt to the characteristics of China, speed up the research of natural gas liquefaction plant technology, and increase the investment in related application technology, has become an important topic in the field of natural gas application, and has a broad development prospect. Promoting the progress of natural gas condensate recovery technology is conducive to improving the hard power of China's energy utilization and moving to a higher international stage.

References

[1] Liu Gang. The development status of natural gas condensate recovery technology [J]. Oil and gas field surface engineering, 2008, (05): 1-2.

[2] Li Mingyu, Song Jie. Analysis of the development status of natural gas condensate recovery technology [J]. China Petroleum and Chemical Industry Standards and Quality, 2013,33 (13): 245.

[3] Wang Pingang. Natural gas condensate recovery process [J]. Oil and gas field surface works, 2009 (08)

[4] Liao Tao, Wang Yifu, Luo Wei. Reasonable determination of natural gas condensate recovery operating points [J]. Xinjiang Petroleum Science and Technology, 2010 (04).

[5] Jiang Hong, Zhu Cong, Lian Zhanghua Improve the liquid hydrocarbon yield of light hydrocarbon recovery unit Oil and gas field surface project, 2001.3.

[6] Santos, S.O., Collodi, G., Azzaro, G., et al., Techno-Economic Evaluation of SMR Based Standalone (Merchant) Plant with CCS.2017.

[7] He, T., Lin, W., Du, Z.Measurement and Theoretical Calculation of CO2 Solubility Data in Liquid CH4 + C2H6 Mixtures at Cryogenic Temperatures %J Journal of Chemical & Engineering Data.2022, Vol.67(No.10).3222-3233.

[8] Liang Yuanqiao. Study on the conveying function and safety of the mixed-air light hydrocarbon gas pipe net [D]. Xi'an Petroleum University, 2021.

[9] Wang Jian. Negative pressure wave technology was applied to detect the leakage of light hydrocarbon pipeline [J]. Oil and gas fields surface works, 2007, (6): 15-16.

[10] Feng Guan. Discussion on the safe distance of oilfield light hydrocarbon transportation pipeline [J]. Encyclopedia Forum e-magazine, 2021, (5): 471.

[11] Qi start of winter. Study on the safety and operation regulation of light hydrocarbon gas pipe network [D]. Hebei University of Engineering, 2022.