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Progress in Amine Reclamation Technology for High-Sulfur Natural Gas Purification

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Abstract: The efficiency and purification effect of amine solutions directly impact the overall cost and environmental performance of high-sulfur natural gas purification. In recent years, significant advancements have been made in amine reclamation technologies targeting high-sulfur natural gas purification, with notable achievements in research and industrial application. This paper reviews the latest developments and applications of amine reclamation technologies in high-sulfur natural gas purification and explores future trends in this field.

Keywords: High-sulfur natural gas; purification technology; amine reclamation; solvent treatment; environmental protection.

1. Introduction

Alcohol-based amine solutions are widely used in desulfurization and decarbonization processes in the petrochemical and natural gas industries due to their excellent absorption capabilities for acidic gases (e.g., H_2S and CO_2). High-sulfur natural gas, containing significant amounts of hydrogen sulfide (H_2S), must undergo amine desulfurization and decarbonization purification for industrial use. Over prolonged operations, amine solutions inevitably degrade due to external contaminants and self-decomposition reactions. This degradation leads to reduced efficiency in desulfurization and decarbonization, increased equipment corrosion, frequent foaming, and elevated energy consumption. Thus, amine reclamation technology plays a vital role in high-sulfur natural gas purification. This paper summarizes recent advances in amine reclamation technologies for high-sulfur natural gas purification and discusses future development directions.[1]

2. Current Research on Amine Reclamation Technologies

Amine degradation is inevitable. Apart from delaying degradation, treating degraded amine solutions is necessary to mitigate their adverse effects on the system. Traditional methods include replacing the amine solution, adding antifoaming agents, improving filtration, and introducing alkaline solutions. These approaches have drawbacks:

Solution replacement increases costs and waste disposal issues.

Antifoaming agents suppress foaming temporarily but may become ineffective or counterproductive.

Enhanced filtration cannot address soluble impurities like heat-stable salts.

Adding alkaline solutions releases active amines but generates inorganic salts, leading to corrosion.

In comparison, advanced amine purification technologies offer deeper purification with fewer negative effects and lower costs, making them widely used for purifying degraded amines. Below is an analysis of major amine purification technologies.

2.1. Distillation Recovery Technology

Distillation recovery is a traditional amine purification method, involving heating to distill active amines from degraded solutions. High-boiling degradation products, solid particles, and heat-stable salts remain at the bottom. To enhance recovery rates, alkalis are typically added before distillation to neutralize heat-stable salts and release free amines. Although mature abroad, distillation faces challenges like low recovery rates and high energy consumption.

2.1.1.

Zhao investigated the causes of the refractory foaming problem in the amine solution desulphurization system, and put forward the countermeasures. It is pointed out that the long-term accumulation of macromolecular hydrocarbons and complex polymer components in amine solution is the main cause of the refractory foaming. Diesel oil is the main source of macromolecular hydrocarbons, while 1, 3-butadiene is the main source of polymers. This paper introduces the method of on-line purification of amine liquid by vacuum distillation. The purified amine liquid is clear and transparent, foaming height is not more than 4 cm, defoaming time is not more than 5 seconds, oil mass concentration is not more than 100 mg/L, and the sulfur content of MTBE is effectively reduced. The problem of refractory foaming in the amine liquid system is solved effectively, and the stability and safety of the system are improved.

2.1.2.

Wang introduced the design and application of the on-line deep resurrecting device for amine solution, which aims to solve the problems such as reduced performance and frequent foaming of amine solution in the desulfurization unit of natural gas purification plant. The desulfurizing property of the amine solution is restored by removing heat stabilized salts and foaming substances. The technological principle, operation mode and the effect in practical application of the device are described in detail. The results show that the on-line deep reactivation device can significantly reduce the heat stable salt and foaming substance in the solution, reduce the foaming height from 500mm to 30mm, shorten the defoaming time from 110 seconds to 5 seconds, and significantly improve the operating stability and efficiency of the desulfurization device.

2.1.3.

Wang Tongbin discussed the effect of amine foaming on the operation of sulfur recovery unit, and proposed a new process of vacuum extraction distillation to purify amine. The process has achieved remarkable results in dealing with the foaming of amine solution. The foaming height of the purified amine solution is reduced to less than 10 mL, the defoaming time is less than 5 seconds, and the diesel component is separated, significantly reducing the oil content. The economic and environmental benefits of the process are also analyzed, and its application value in sulfur recovery system is emphasized. The purification effect of the amine solution is greatly improved, the operating cost of the system is reduced, and it has significant economic and environmental benefits.

2.2. Ion Exchange Technology

Ion exchange relies on cation and anion exchange resins to remove heat-stable salts and degraded products from amine solutions. The resins can be regenerated for reuse, making the process cost-effective. However, frequent resin regeneration and significant waste liquid treatment are required.

2.2.1.

Sun applied TRIZ theory in the process of organic amine desulfurization, especially how to reduce the concentration of sodium ions to solve the problem of equipment clogging caused by the enrichment of amine solution. Two methods of sodium removal, freezing crystallization method and ion exchange method, were proposed by establishing a matter field model. After laboratory and field pilot tests, the ion exchange method was finally determined as the best solution, and WZG-1C resin was selected as the preferred material. Results: The study proved that the application of TRIZ theory effectively optimized the sodium removal process, successfully solved the problem of sodium ion enrichment in the organic amine desulfurization unit, and ensured the normal operation of the sulfuric acid system.

2.2.2.

Narendra Verma discussed the application of ion exchange technology in the improvement of amine systems. This technology significantly improves the operational efficiency of amine systems by removing heat stabilized salts (HSS) in line. While traditional thermal regeneration methods have problems such as high energy consumption, frequent equipment maintenance and long downtime, ion exchange technology provides a more efficient, economical and environmentally friendly solution. This technology utilizes resin exchange materials to capture and remove HSS in an amine solution, thereby restoring the amine's purification capacity. The results show that the foam, corrosion and amine loss of the system have been effectively alleviated after the application of ion exchange technology, and the quality of the treated gas is stable. Compared to traditional methods, this technology can save about $2 million per year, while the equipment investment payback period is less than one year. This paper provides practical experience and theoretical guidance for refining and natural gas purification industry, and shows the broad prospect of ion exchange technology in the improvement of amine system.

2.3. Electrodialysis Technology

Electrodialysis uses a direct current field to selectively remove charged ions from amine solutions. This technology avoids the need for extensive chemical reagents and is particularly effective for high concentrations of heat-stable salts.

2.3.1.

Chen found that in practical applications, the electrodialysis equipment was installed online without affecting the normal operation of the device. Studies have shown that the HSS content in the amine solution can be reduced from 5% to less than 1%, and the H2S content can be reduced from 5000 mg/L to less than 500 mg/L after electrodialysis treatment. This technology significantly improves the quality of the amine solution, reduces the corrosion of the equipment, and provides a guarantee for the safe and stable operation of the desulfurization system.

2.3.2.

Li's paper shows that in practical application, an electrodialysis device treating 730 m^3 MDEA solution reduces the HSS mass fraction from 3% to 0.5%, the Cl^- concentration from 1300 mg/L to 200 mg/L and the Na + concentration from 4200 mg/L to 700mg/L, while the MDEA loss rate is only 3.23%. The technology is simple to operate, occupies small space, does not need acid and base regeneration, reduces waste liquid discharge, and meets environmental protection requirements. Electrodialysis not only effectively improves the purification efficiency of amine solution, but also guarantees the safe operation of equipment and the long-term recycling of solvent, showing its good prospects in the gas purification industry.

3. Summary

Significant progress has been made in amine reclamation technologies for high-sulfur natural gas purification, including novel foaming inhibitors, optimized regeneration processes, and automated control systems. Future developments will focus on multifunctional amine solutions, eco-friendly solvents, and intelligent control technologies, advancing the efficiency, sustainability, and intelligence of high-sulfur natural gas purification processes.

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