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Article

Development of the Internal Structure of a Separator Unit for Natural Gas Purification

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Abstract: Natural gas extracted from underground reservoirs contains various contaminants, including mechanical impurities, dust particles, water vapor, condensate, and liquid droplets. The presence of these impurities negatively affects gas transportation, processing, and utilization by increasing equipment wear, accelerating corrosion and erosion processes, and reducing the operational efficiency of technological systems. Therefore, the development of effective gas purification equipment remains an important task for the oil and gas industry. The proposed separator incorporates a two-stage cleaning system consisting of Z-shaped vane baffles and a spiral static separator. The influence of particle size on purification efficiency was analyzed, demonstrating that larger particles are removed with significantly higher efficiency, while smaller particles require intensified centrifugal action. The results indicate that the proposed separator design improves gas cleaning performance while maintaining a simple and reliable construction. The developed solution can contribute to increasing the operational efficiency of gas treatment facilities, reducing maintenance costs, and improving the quality of natural gas supplied to transportation and processing systems.

Keywords: natural gas, gas purification, separator, Z-shaped vane baffles, static separator, spiral channel, dust particles, liquid droplets, centrifugal force, inertial force.

Introduction

Natural gas is one of the primary fuel resources that occupies an important place in the global energy balance. It is considered a relatively clean fuel and is widely used in industry, power generation, the chemical industry, and domestic applications [1]. However, when natural gas is extracted from reservoirs, it is not obtained in a pure form. Instead, it may contain various mechanical impurities, including sand, dust particles, water vapor, condensate droplets, and other liquid phases [2]. These impurities negatively affect the efficient operation of technological equipment during gas transportation and

processing [3]. In particular, solid particles and liquid droplets present in the gas can intensify erosion and corrosion processes in pipeline systems and reduce the service life of compressors and other processing equipment [4].

Research Methodology

Various types of separator units are widely used in industry for the separation of gas–liquid and liquid–liquid mixtures. Due to their relatively simple design and reliable operation, these devices are extensively applied in the purification of process gas streams from mechanical impurities. In the treatment of dust-laden gases, wet-cleaning methods are frequently employed, particularly separators operating through the irrigation of packed beds. However, at high gas flow velocities, the liquid film may be re-entrained into the gas stream, leading to droplet re-dispersion and a reduction in separator efficiency. The intensification of oil and gas production processes is achieved through the processing of associated petroleum gas and its transportation into main gas pipelines in accordance with technical specifications. Therefore, modern technologies should be aimed at improving energy efficiency in hydrocarbon processing while simultaneously preventing environmental pollution. Among the major challenges encountered during the later stages of field development are condensate accumulation, formation water production, and the presence of mechanical impurities. The centrifugal separation elements proposed by researchers are designed for specific operating ranges and enable the modernization of separator units without requiring complete replacement of the equipment. Furthermore, this issue is of considerable practical significance in the design and development of separation elements and separator systems. Separators play a vital role in the crude oil processing industry due to their simplicity and economic efficiency. The increasing water content in oil fields and the growing exploitation of heavy crude oil reserves have further enhanced the importance of separation processes. The formulation of such models requires numerous assumptions and involves various levels of complexity. Researchers have investigated separation processes involving droplet settling and coalescence.

Results

In this study, a horizontal separator equipped with a two-stage purification system is proposed [5]. The internal structure of the separator is designed to effectively remove liquid droplets and mechanical impurities from natural gas streams. The incoming natural gas first passes through Z-shaped vane baffles installed at the inlet section of the separator [6]. At this stage, the flow direction changes abruptly several times, resulting in an inertial separation process. Due to their greater density, liquid droplets and large solid particles are unable to follow the rapid changes in the gas flow direction and are separated from the stream under the influence of inertial forces [7]. After the preliminary separation stage, the gas stream is directed to the second stage of the separator, which consists of a spiral-shaped channel. As the gas flows through this channel, it undergoes a complex swirling or helical motion [8].

Discussion

When selecting the internal design of the separator, it is important to consider the particle size in the gas composition and the amount of liquid. If the particle size is large, the level of purification will be high [9].

Spiral channel separators are designed to remove solid and liquid particles from the gas stream, thereby cleaning the gas from fine liquid droplets [10]. They also help eliminate technically significant contaminant substances [11]. After the contaminants are removed, the finest particles (< 5 μm) are drawn into a vortex formed in the central region beneath the discharge disk and are then carried downward through a downward flow at the vortex core [12].

The graph illustrates how the efficiency of particle separation from the gas flow depends on particle size, which is directly explained by the operating principle of devices such as cyclone separators [13]. The analysis of the graph shows that when particle diameter is small, the purification efficiency is low because such fine particles move along with the gas flow and do not experience sufficient forces to be effectively separated [14][15].

Conclusions

The study showed that gas purification efficiency is directly dependent on particle diameter and gas velocity, while the cut size (d_{50}) is an important indicator of fractional separation efficiency. Large particles are almost completely removed due to inertial and centrifugal forces, whereas efficiency decreases for smaller particles. At the same time, an increase in gas velocity causes pressure losses to rise according to a quadratic relationship, which must be considered when determining energy consumption and the optimal operating regime of the system. The proposed design solution ensures high efficiency, simplicity, and reliability of the separator.

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