FEATURES OF THE APPLICATION OF MEMBRANE TECHNOLOGIES IN NATURAL GAS PROCESSING

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Summary. Natural gas is a critical modern energy resource requiring effective impurity removal to meet high-quality standards and safety regulations. Traditional purification methods like adsorption and cryogenic processes are limited by high energy costs and complexity. Membrane technologies offer an efficient alternative, with economic and operational advantages. Membrane systems enable selective impurity removal, ensuring high-quality gas. Research focuses on polymer, inorganic, and mixed membranes. Hollow fiber membranes are notable for their large surface area and low maintenance, but their low tensile strength under high pressure suggests using reinforced versions.

Natural gas is one of the most important energy resources of modern times. The high quality requirements for natural gas, driven by the need to comply with technical standards, safety regulations, and the Gas Transmission System Code of Ukraine, necessitate effective methods for removing various impurities such as carbon dioxide (CO₂), hydrogen sulfide (H₂S), water, and other components. Traditional purification methods, such as adsorption, absorption, and cryogenic processes, have certain limitations associated with high energy costs, the complexity of the technological process, and significant maintenance requirements.
In this context, membrane technologies emerge as an effective alternative due to their economic efficiency, low energy consumption, and ease of manufacturing and operation. Membrane systems allow for the selective removal of impurities, ensuring high-quality purified natural gas. Current research in this field is focused on the development and improvement of various types of membranes, including polymer, inorganic, and mixed-type membranes, which significantly expand their applications.

Membranes are used in processes such as: separation of nitrogen or oxygen from air for subsequent use (usually up to 99.5%), hydrogen concentration from gases such as nitrogen and methane, hydrogen recovery in oil refining processes, removal of water vapor from gases, and removal of SO$_2$, CO$_2$, and H$_2$S from natural gas [1].

Membrane modules are classified by the type of membrane element and the type of matrix. By the type of membrane element, there are flat membrane elements, tubular membrane elements, spiral-wound membrane elements and hollow fiber devices (Fig. 1, 2).

![Classification of membrane modules](image_url)

All membranes are divided into two groups by the type of matrix: porous and non-porous (dense) matrices. In porous membranes, the transport of substances is carried out by convective flow through the pores. In non-porous, dense
membranes, the transport of substances is carried out by diffusion flow. Membrane systems with porous membranes can be gas-diffusion and sorption-diffusion, while those with non-porous (dense) membranes can be sorption-diffusion and reaction-diffusion.

The membrane separation of gas mixtures is based on the use of membranes that possess the property of selective permeability to the components of the gas mixture, meaning that the components of the original mixture permeate through the membrane at different rates. During gas preparation in a membrane module, the original raw flow is divided into two streams - a low-pressure stream (permeate) and a residual stream (retentate) that penetrates through the membrane. The driving force of the process is the difference in partial pressures of the gas components in the high and low-pressure voids (Fig. 3).

The high-pressure stream (retentate) becomes enriched with complex components (methane, ethane) and in gas processing tasks, typically serves as the target output.

Fig. 2. Schematic illustration of (a) membrane materials, (b) asymmetric membrane structures, (c) asymmetric membrane modules [2]
Fig. 3. **Membrane separation of gas**

The permeate stream (low-pressure stream) formed is enriched with water, hydrogen sulfide, carbon dioxide, heavy hydrocarbons, and can be used as fuel gas or further processed (for example, through additional membrane stages to increase the yield of prepared gas, or through additional installations to obtain liquid products). The efficiency of membrane technology application depends on the specific task and site conditions, typically achieving a utilization degree of associated petroleum gas of over 95%, and in some cases, achieving complete drying of natural gas to water content below 100% (excluding the liquid phase).

Typical scheme of an industrial membrane plant depends on the type and quality of the feed gas, gas preparation objectives, and the volume of gas being processed can be easily adapted to the specific task at hand. When the pressure of the feed gas exceeds the pressure of the permeate, a boosting compressor is used to return the permeate for suction by the feed gas compressor. If the target component is a gas with high permeability (for example, in the task of extracting and concentrating helium from natural gas), a two-stage scheme is applied, and the boosting compressor for the permeate is used to create a pressure sufficient for the reprocessing of the permeate at the membrane unit of the second stage.

The schematic diagrams of a typical membrane unit for comprehensive preparation of natural and associated petroleum gas are shown (Fig. 4, 5) [3].
Fig. 4. **Schematic diagram of a single-stage membrane installation**

Fig. 5. **Schematic diagram of a two-stage membrane installation**

Single-stage schemes (Fig. 4) are the simplest but are characterized by lower recovery of the target stream with fixed properties. Multi-stage schemes (Fig. 5) achieve high purification of the target complex component of the mixture, especially when a high concentration is required. The use of parallel-series schemes of membrane block connection allows for high recovery and purity of the target product across a wide range of loads. Multi-stage schemes are most widely used in configurations with partial gas recycle.

The volume of prepared gas obtained from a single membrane module increases with an increase in the selectivity of the applied membrane for the...
removed components, with an increase in the pressure drop across the membrane, with an increase in the ratio of these pressures. An increase in the preparation temperature, as a rule, leads to an increase in the specific productivity of the prepared gas (while maintaining the pressure values), but at the same time, the required amount of raw gas also increases.

**Conclusions.** Particular attention is drawn to hollow fiber membranes, which are gaining increasing popularity due to their large specific surface area and low maintenance requirements. However, issues related to low tensile strength under high-pressure conditions limit their use. The solution to this problem could be the application of braced reinforced hollow fiber (BRHF) membranes, which have increased mechanical strength and durability. At the same time, it is advisable to choose two-stage membrane purification for the purification of natural (associated oil gas) gas.

**REFERENCES:**

