The Austrian Journal of Technical and Natural Sciences, No 1 – 2
ISSN 2310-5607

PREMIER Publishing
ppublishing.org

DOI:10.29013/AJT-24-1.2-85-89

SELECTION OF A METHOD FOR PREPARING NATURAL GAS FOR TRANSPORTATION BY MAIN GAS PIPELINES

Makhmudov Mukhtor Dzhamolovich [1], Yomgirov Sa'dulla Ataboy u gli [1]

[1] Bukhara Institute of Engineering and Technology Bukhara, Uzbekistan

Cite: *Makhmudov M.D., Yomgirov S.A. (2024). Selection Of A Method For Preparing Natural Gas For Transportation By Main Gas Pipelines. Austrian Journal of Technical and Natural Sciences 2023, No 11-12.* https://doi.org/10.29013/AJT-24-1.2-85-89

Abstract

When designing natural gas drying equipment, the ability to implement an integrated approach to determine rational technical and economic indicators of the technological devices under consideration is of great importance. This makes it possible to achieve maximum energy efficiency from the equipment in use for each specific field.

One of the important tasks solved during the development of gas fields is the choice of method and appropriate technological equipment according to many criteria, including operating costs and cost of devices, installation productivity, metal consumption, replicability of the technology in question, etc. One of the ways to solve such a problem is to use mathematical methods of system analysis in complex decision-making problems, in particular, the method of hierarchy analysis.

Keywords: *natural gas dehydration, absorption, low-temperature separation, membranes, hierarchy analysis method*

Introduction

In terms of its physical and chemical characteristics, the prepared combustible natural gas (FNG) must comply with the criteria and standards of STO Gazprom 089–2010 "Flammable natural gas supplied and transported through main gas pipelines. Technical specifications" (Shimekit, B., Mukhtar, H. et al. 2009).

In accordance with STO Gazprom 089–2010 of a cold macroclimatic region, the water dew point temperature at an absolute pressure of 3.92 MPa (40.0 kgf/cm^2) should not be higher than: in winter — minus 20 °C; in summer — minus 14 °C, which is required for strict compliance with the conditions of its single-phase transportation in all sections of the main pipeline. Also, for a cold macroclimatic region, the dew point temperature for hydrocarbons at an absolute pressure of 2.5 to 7.5 MPa should not be higher: in winter — minus 10 °C; in summer — minus 5 °C.

The dryable gas is gas that has undergone preliminary cleaning from mechanical impurities and droplets of moisture in the gas separation shop of an integrated gas treatment plant, as well as an increase in pressure at the booster compressor station. The residual content of droplet moisture and mechanical impurities in the purified gas is determined by the requirements for the technical characteristics of separation equipment and should not exceed: droplet moisture — 20 mg/m ^{3} of gas; mechanical impurities with particle sizes of no more than 20 microns — 5 mg/m ^{3} of gas (Makhmudov, M. J., Emgurov, S. A., 2023).

The gas industry knows a sufficient number of different types of natural gas drying, which provide solutions to local problems of deep extraction of droplet moisture from a raw gas flow, but do not solve the problem as a whole, these include: absorption gas drying, gas drying by low-temperature separation, low-temperature absorption drying gas, adsorption gas drying, gas drying using membrane technology. Each of the methods has both its advantages and disadvantages, which generally determine the main technical and economic indicators (Shimekit, B., Mukhtar, H. et al. 2011; Makhmudov, M.J., Emgurov, S.A., 2023). Which method to choose is one of the most important tasks in making pre-project decisions and, despite the fact that it is determined by the total maximum positive effect with minimal economic requirements, it is not always obvious and is often a compromise decision.

A mathematical solution to the presented problem can be achieved through the use of systems analysis methods and, in particular, the method of hierarchy analysis. The main methods of gas drying we will consider the features of the main technological methods of drying natural gas.

Absorption gas drying

A typical scheme for drying gas with glycol is based on contact of dry glycol with raw gas and absorption of moisture from the latter at feed temperatures from + 10 to + 35 °C. Raw gas, previously separated, enters the absorption column from the bottom up. From the top of the column, through the distribution section, 98–99% glycol is supplied in a countercurrent direction to the gas movement. Thanks to the mass transfer section of the absorption column, maximum contact of gas with glycol is ensured, thereby causing the process of glycol gas dehydration. The dried gas enters the upper part of the column, passes through the glycol recovery section and is supplied to consumers. The moisture-saturated glycol flows by gravity from the bottom of the column to the regeneration unit.

Gas drying by low temperature separation

The essence of low-temperature separation is pre-cooling the gas to subzero temperatures, followed by separation of the condensed droplet liquid in a low-temperature separator. The raw gas from the wells, under its own pressure, enters the first stage gas separator, where the primary separation of the dropping liquid, the resulting condensate and mechanical impurities takes place, which are sent to the drainage tank. Next, the gas, freed from the droplet liquid, enters the gas-gas heat exchanger for pre- cooling with the reverse flow of gas coming from the second stage separator (low-temperature separator). To prevent the formation of hydrates, a hydrate formation inhibitor (methanol, diethylene glycol) is supplied to the gas before the heat exchanger. Next, the gas is throttled by the valve, being cooled due to the Joule-Thomson effect to the required negative temperatures. The cooled gas is supplied to the second stage gas separator, where the condensate with a water-saturated inhibitor solution is separated from the gas. The dried gas is heated by raw gas by feeding it to the above-mentioned gas-to-gas heat exchanger and sent to the commercial gas metering unit.

Low temperature absorption gas dehydration

In essence, the technological scheme of low-temperature absorption gas drying is a combination of the two methods of natural gas drying described above, but is a more technologically complex system. Raw gas under pressure enters the first stage gas separator. Next, the gas, with a small content of droplet liquid, enters the gas-liquid heat exchanger for pre-cooling by the reverse flow of the absorbent coming from the low-temperature absorber, which is a multifunctional apparatus that combines both a separation section (the lower part of the column) and an absorption section (top of the column). The pre-cooled gas enters the subsequent gas-to-gas heat exchanger, in which it is further cooled by the reverse flow of dried gas supplied from the low-temperature absorber.

To prevent the formation of hydrate plugs, a hydrate formation inhibitor is supplied to the gas before each heat exchanger. Next, the gas, which has passed through two successive heat exchangers, is throttled by a valve to the required negative temperatures and sequentially, through the separation section, is fed into the absorption section of a low-temperature absorber for deep extraction of condensed moisture. The gas dried in the low-temperature absorber is, in turn, heated by raw gas in the above-mentioned gas-to-gas recuperative heat exchanger and sent to the main gas pipeline.

The system uses gas condensate separated in the first-stage separator as an absorbent, which, before being fed into a low-temperature absorber, is sent for degassing and subsequent cooling with a cold stream of absorbent from the low-temperature absorber in a liquid-liquid heat exchanger.

Adsorption gas drying

The adsorption scheme for gas drying is similar in structure to the absorption scheme, with the only exception that an adsorbent (silica gel, zeolite) is used as a desiccant. The raw gas, separated from droplet moisture and mechanical impurities, enters an adsorption column filled with a composite water vapor adsorbent in the direction from top to bottom. The gas leaving the adsorber is dried and meets all the requirements for its transportation through main gas pipelines. As soon as the gas drying depth begins to decrease, the feed gas flow is switched to the adsorber that was in the standby stage to ensure continuity of drying, and the adsorber with saturated adsorbent is switched to regeneration. Since the adsorbent, unlike the absorbent, does not circulate through a closed gas drying system and is constantly located in the adsorber, built-in heat exchange elements of a spiral-radial type are provided in the adsorbers for its regeneration.

Gas drying using membrane technology. The method of separating natural gas from hydrocarbon raw materials that meets the requirements of the standard for its preparation using membrane technology is based on the difference in the partial pressures of the components on the outer and inner surfaces of the hollow fiber membrane. Gases that "quickly" penetrate the polymer membrane exit through the membrane cartridge structure through the retentate outlet (purified gas). Gases and liquids that «slowly» or do not penetrate the membrane layer exit the unit through the permeate outlet. Thanks to the selective properties of the separating layer of membranes, so-called "slow" components, such as moisture, heavy hydrocarbons, mercaptans, sulfur compounds and carbon dioxide, are extracted from the gas that has undergone preliminary separation. And "fast" prepared natural gas, with a slight loss of pressure at the installation, is supplied to the main gas pipeline.

The membrane element is a non-regenerable component of the gas treatment system, which requires replacement if the requirements for gas treatment specified in the technological regulations for the operation of the installation are not met.

Approbation of the method. The basis of the hierarchy analysis method is the hierarchical representation and pairwise comparison of the main technical and economic indicators of natural gas preparation methods (Sridhar, S., Smitha, B., et al. 2007; Murin и другие. 2002). The result is the creation of an appropriate matrix, which is based on a six-point scale with the comprehensive advantages of each criterion from the compared methods. At each stage of comparison, the independence of the indicators under consideration must be achieved, which must have clear differences from each other (Makhmudov, M.J., Akhmedov, U.K. 2020; Makhmudov, M.J., 2020).

As a result, a rational method for drying natural gas is determined with the best technical and economic indicators for each specific case, which allows you to interactively find an option that best matches the requirements for solving the problem and ultimately contributes to its solution, while preventing unjustified economic expenses. The proposed method is tested for five methods of drying natural gas: absorption drying, low-temperature separation, low-temperature absorption, adsorption and drying using membrane technologies.

In modern conditions in which power engineering is developing, the key factor influencing the prevalence of technologies is their cost. The lower the costs of their implementation, the more accessible they are, and the more accessible the technologies, the more researched they are and, accordingly, have undergone more changes in order to optimize them. More advanced technologies do not require high operating costs and have high efficiency along with productivity. The operating costs indicator is inversely proportional to the reliability parameter, because The more perfect the system, the less resources it requires for maintenance. In addition, for hard-to-reach operating areas, an important criterion for the use of technology is its metal consumption, because The more mobile the system, the less costs are required for its transportation and installation. As a rule, the more innovative the system, the lower its metal consumption, but the higher its cost.

Based on the above, the analysis of natural gas drying systems was carried out according to six selection criteria: cost (A) — potential costs (in financial terms) for the implementation of the selected technology; efficiency (B) — the ability to achieve the required in accordance with STO Gazprom 089–2010 "Combustible natural gas supplied and transported through main gas pipelines" under changing thermobaric operating conditions; approbability (C) — prevalence, knowledge, reliability and possibility of application in the field; metal intensity (D) — the amount of metal consumed for the manufacture of a natural gas drying installation; operating costs (E) — a general indicator of the costs incurred by the organization to ensure the operation of the natural gas drying plant; productivity (F) — the amount of gas prepared by a gas drying installation to the required values over a certain period of time.

Conclusion

Calculations based on the hierarchy analysis method and subsequent analysis of the information obtained clearly indicate that, according to the technical and economic characteristics presented in the work, despite the high metal consumption of the structure and average efficiency indicators, absorption dehydration of natural gas is the most preferable method over the methods discussed in the article natural gas treatment (significance factor 0.361). The key calculation criterion for selection when determining the method was the approbability criterion of the technology used; its significance was 55.9%.

The justifiably chosen method of absorption drying of natural gas makes it possible to achieve the required preparation of raw materials with relatively low operating costs and insignificant pressure losses of the drying gas. This method is high-tech and energy efficient, since the glycol used in drying and saturated with moisture vapor, having gone through a closed cycle of purification and regeneration, after restoring its commercial qualities, is again supplied to the absorption equipment. In addition, the positive characteristics of this method include its high productivity in the context of one production line and time-tested reliability.

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submitted 10.02.2024;
accepted for publication 22.02.2024;
published 18.03.2024

Contact: makhmudov.mukhtor@inbox.ru