UDC 62-403:001(477)
DOI: 10.15587/2706-5448.2024.318926

Viktoriia Dmytrenko,
Taras Podoliak

RESEARCH OF METHANOL CONTENT IN TECHNOLOGICAL FLOWS OF FACILITIES THAT PROCESS GAS BY LOW-TEMPERATURE SEPARATION METHOD

The object of research is methanol as an inhibitor, which is used in the process of collecting and preparing products from gas, gas condensate, and oil fields to protect against hydrate formations. It is important to ensure the rational consumption of this inhibitor, taking into account its solubility in gas, water, and liquid hydrocarbons. This work is aimed at analyzing the use of the methanol hydrate formation inhibitor in the process of low-temperature gas preparation and determining ways to use it more effectively.

The work presents the results of modeling the distribution of the hydrate formation inhibitor along the technological flows of low-temperature gas separation units according to the following schemes:

– low-temperature separation with gas cooling due to the Joule-Thompson effect;

– compression of gas from wells using PCS (pressure compressor station) + low-temperature separation with gas cooling due to the Joule-Thompson effect;

– compression of gas from wells using PCS + low-temperature separation with gas cooling due to the operation of a turboexpander unit;

– compression of gas from wells using PCS + low-temperature separation with gas cooling due to the operation of an artificial refrigeration unit (propane refrigeration unit).

The use of a computer simulator allowed to track in detail the distribution of methanol during the gas preparation process. The iteration method determined the minimum values of methanol consumption at which the hydrate-free operation mode of the equipment is maintained. Based on the modeling results, an analysis of methanol content in technological flows was performed. And the patterns of inhibitor separation in the separation equipment were also determined, namely, the dependence of methanol distribution on gas pressure in separators, and the methanol content in the output lines of gas preparation units.

It was established that the results of the study can be applied in the development of technologies for the collection, regeneration and reuse of methanol in technological processes of low-temperature gas preparation. The practical value of the results lies in the possibility of improving typical methods of protecting equipment from hydrate formations by developing an automated inhibitor supply system that, by monitoring the parameters of the technological process, changes the inhibitor dosage and ensures its economical use.

Keywords: *natural gas, associated formation water, inhibitor, gas hydrates, computer modeling.*

Received: 27.09.2024
Received in revised form: 27.11.2024
Accepted: 17.12.2024
Published: 31.12.2024

How to cite

Dmytrenko, V., Podoliak, T. (2024). Research of methanol content in technological flows of facilities that process gas by low-temperature separation method. Technology Audit and Production Reserves, 6 (1 (80)), 46–53. https://doi.org/10.15587/2706-5448.2024.318926

1. Introduction

At oil and gas enterprises in various regions of the world, the most common methods of natural gas preparation are low-temperature separation or low-temperature absorption [1]. When using such technologies, one of the current problems is the formation of gas hydrate plugs in technological equipment [2].

The rapid development of the oil and gas industry requires research and the search for more effective solutions to protect equipment from hydrate formations (hydrates), which have the form of dense formations. These formations under certain thermobaric conditions can settle and accumulate in pipelines and devices, thereby complicating the preparation process, and in some cases lead to the cessation of gas production. This issue is relevant not only for installations on land, but also for facilities located on offshore platforms [3].

Considering the current trend of development and development of oil and gas fields on the sea shelf in increasingly deep-water areas and in colder climatic regions, it is worth noting that such low-temperature separation plants require a high consumption of thermodynamic inhibitors (usually methanol) [4]. But at the same time, they are limited in space for installing a park of the required volume for its accumulation and storage. Today, the demand for technologies that allow for more rational use of hydrate formation inhibitors is only growing.

The choice of the type of hydrate formation inhibitor depends on the operating parameters of the technological process and on the climatic conditions in which the oil and gas production facilities are located. The work [5] describes various options for preparing natural gas in low-temperature separation plants. The authors conclude that despite the wide range of hydrate formation inhibitors of various types and modes of action, one of the most common in the oil and gas industry remains the inhibitor – methanol.

Methyl alcohol (methanol) is popular due to its high efficiency, both in the process of preventing the formation of gas hydrates and in the event of the need to destroy hydrate plugs that have already formed [6]. However, a serious drawback of methanol is its low boiling point and high volatility, which leads to significant losses of methanol in the system of industrial gas preparation for transportation. The use of methanol is a source of environmental pollution. The authors of [7] argue that there is currently a trend towards the use of electrolyte solutions as hydrate formation inhibitors.

One of the areas of application of hydrate formation inhibitors is their combination during use. In [8], the effectiveness of the use of highly mineralized formation waters to protect oil and gas equipment from hydrate formations was analyzed using the example of the Zakhidno-Radchenkovske field. This technology is promising when used in combination with other hydrate formation inhibitors, such as methanol. For many years, a search has been underway for substitute reagents, among which glycols and salts (calcium dichloride, magnesium dichloride) are distinguished. However, to date, no full-fledged analogue of methanol has been found in the technological processes of natural gas extraction and preparation. In practice, the actual consumption of methanol at gas production enterprises is often overestimated (in some cases by 15–20 % or more) due to its irrational use. Therefore, the question of optimizing its consumption and the most effective use in hydrocarbon raw material collection and preparation systems still arises [9].

In addition to ensuring the rational consumption of the hydrate formation inhibitor, the possibility of its regeneration and reuse plays an important role. In [10], a technological solution for the extraction of a thermodynamic inhibitor from natural gas using supersonic separators is described. This proposal involves the installation of supersonic separators in series, after which the gas passes through an anti-hydrate separator, and the separated liquid passes through the extraction stage and the distillation unit of the thermodynamic inhibitor. This technology allows solving a number of problems: controlling the dew point of the gas for moisture and hydrocarbons, the possibility of producing C3+ marketable products, and the regeneration of almost all of the thermodynamic inhibitor, which would otherwise be lost through removal together with the marketable natural gas. Among the disadvantages of this technology are the relatively high capital costs for installing such equipment, as well as the sensitivity of the operation of supersonic separators to the actual parameters of their operation (pressure, temperature, gas flow rate).

Recent scientific research [11] has confirmed that methanol in ultra-low concentrations has a dual effect; under certain thermobaric conditions it can work not only as an inhibitor of hydrate formation, but also as an activator of gas hydrate formation. Experiments [12] have been conducted which have shown that for methane (CH_4), nitrogen (N_2) and carbon dioxide (CO_2), low concentrations of methanol in gas (1–5 wt. %) promoted the formation of gas hydrates. This phenomenon is important to take into account when determining the optimal inhibitor consumption for protecting the technological equipment of low-temperature separation plants from gas hydrate deposits.

To ensure reliable and economical hydrate-free operation of gas industry equipment and pipelines, it is necessary to reliably determine the conditions for natural gas hydrate formation.

The equilibrium parameters of hydrate formation for natural gases are determined experimentally or by calculation, which, however, does not allow obtaining approximate results, since it is based on significant assumptions and conventions.

The equilibrium parameters of hydrate formation can be estimated using the well-known graph [13], where the conditions of hydrate formation of gases are approximately correlated to their relative density with respect to air. However, the density of the gas does not determine its composition, so this nomogram does not sufficiently reproduce the actual equilibrium conditions of hydrate formation.

In 1934, an attempt was first made to mathematically describe the equilibrium conditions of hydrate formation for natural gas [14]. However, these calculations cannot obtain a satisfactory result for all gases, since they reflect hydrate formation only for gases of a certain composition.

According to [15], equilibrium pressures at a given temperature, calculated by different methods, can differ by more than two times. This is due to the fact that experimental data may be overestimated by pressure (by 15–29 %). Comparison of empirical methods shows the need to develop a more reliable, but fairly simple method for calculating equilibrium parameters of hydrate formation.

There are several more methods for determining equilibrium conditions of hydrate formation. However, the more reliable is the experimental method for determining equilibrium parameters of formation and destruction of hydrates of gas mixtures and natural gas.

Modern software (such as OLGA, Aspen HYSYS, ProMax, UniSim Design, etc.) allows for research of technological processes in the oil and gas industry. As well as determining the effectiveness of the use of thermodynamic inhibitors, selecting parameters of low-temperature gas preparation, which greatly simplifies the search for optimal solutions for protecting equipment from hydrate formation. Similar calculation methods have repeatedly confirmed the high correspondence of the results obtained in software complexes and simulators to the real parameters of operation at operating oil and gas production facilities when implementing technological solutions or changing operating parameters [16].

With the data [17], the Aspen HYSYS software package allows modeling the processes of low-temperature gas preparation in various variants. And also, to determine the need for the consumption of methanol hydrate inhibitor under specific modes of gas purification from condensate and associated formation water. The predictive models of the specified stimulator are based on fundamental thermodynamic principles and the application of the equation of state when calculating equilibrium conditions. These predictive models provide more accurate calculation results than when performing calculations using empirical formulas or diagrams [18].

Taking into account the above, *the aim of research* is to analyze the distribution of methanol hydrate inhibitor using a modern software package to ensure the possibility of more effective use of the inhibitor.

2. Materials and Methods

In this work, the study of methanol content in the technological lines of low-temperature gas separation plants was carried out using the Aspen HYSYS simulator (Aspen Technology, Inc., USA). The simulation was carried out in the static modeling mode. Aspen HYSYS has built-in thermodynamic models, which, using the Hydrate Formation utility, allow to accurately predict the thermobaric conditions of hydrate formation in the pipelines of the gas processing plant (complex gas preparation plant). This utility calculates the starting point of hydrate crystal formation [19]. The predictive models of the specified stimulator are based on fundamental thermodynamic principles and the application of the equation of state when calculating equilibrium conditions. These predictive models are used for different component compositions of technological streams and provide more accurate calculation results than when calculating using empirical formulas or diagrams.

When choosing the equation package for Aspen HYSYS calculations, the calculation based on the Peng-Robinson equations was chosen, since they are most suitable for modeling technological processes at oil and gas industry facilities, which are also related to methanol [20].

During the modeling of each possible method of gas preparation, the same volumes of natural gas, gas condensate and associated formation water (AFW) production were used:

- natural gas production – 200 thousand m^3/day;
- gas condensate production – 20.0 t/day;
- associated formation water production – 2.0 t/day.

The feed points and inhibitor flow rates for different gas preparation options were determined by analyzing the operating parameters (pressure, temperature) of each of the technological streams at which gas hydrate deposits begin to form:

- Methanol injection 1 – Gas outlet line from the well into the gas pipeline-loop to the gas processing facility (GPF);
- Methanol injection 2 – Well inlet node to the GPF;
- Methanol injection 3 – Gas inlet line to the tube space of the heat exchanger of the low-temperature separation unit (LTSU).

The following output streams from the GPF were analyzed:

- Stream 1 – gas output from the GPF to the main gas pipeline;
- Stream 2 – gas output line from the first stage separator (R-1);
- Stream 3 – gas condensate output line from the first stage separator (R-1);
- Stream 4 – AFW output line from the first stage separator (R-1);
- Stream 5 – gas output line from the second stage separator (R-2);
- Stream 6 – gas condensate output line from the second stage separator (R-2);
- Stream 7 – AFW output line from the second stage separator (R-2).

Symbols: Q – daily supply of hydrate formation inhibitor (methanol), t/day; C_1 – methanol content in the process stream relative to the total used inhibitor volume, wt. %; C_2 – amount of methanol relative to the total volume of liquid in the process stream, wt. %.

To conduct this study, the component composition of the gas from the Chutove field well (Ukraine) was used:

- methane – 92.51 mol %;
- ethane – 3.86 mol %;
- propane – 1.09 mol %;
- iso-butane – 0.16 mol %;
- n-butane – 0.28 mol %;
- neopentane – 0.01 mol %;
- iso-pentane – 0.09 mol %;
- n-pentane – 0.08 mol %;
- n-hexane and higher – 0.12 mol %;
- nitrogen – 1.69 mol %;
- CO_2 – 0.11 mol %.

The composition of natural gas is one of the important factors affecting hydrate formation.

3. Results and Discussions

Thermodynamics provides a powerful tool for predicting the temperature and pressure at which hydrate formation occurs for a gas of known composition [21]. However, even when gas hydrates can form thermodynamically, they may never form. The kinetics of hydrate formation are complex and poorly understood, in part because the crystal growth process depends on many variables [22]. Because of this uncertainty, the operating parameters for the process must be outside the hydrate formation region.

An important condition for hydrate formation is that a certain percentage of water is present in the hydrocarbon stream (which is in the liquid or gas phase). Once the favorable pressure and temperature (high pressure or low temperature) are reached, a mixture of hydrate-forming hydrocarbon molecules and water molecules forms a non-stoichiometric solid phase [23]. The thermobaric conditions for gas hydrate formation can be well above the freezing point of water [24].

Thermodynamics predict that gas hydrates can form even when the gas phase is unsaturated with water. There have been reports of hydrates in gas pipelines without free water, but this phenomenon is extremely rare. The difficulty of hydrate formation without liquid water can be explained by mechanistic arguments. Nominally, six water molecules are required for each guest molecule. However, 20 or more water molecules are required to form a hydrate cell around a gas molecule, and many cells must combine to form a hydrate lattice. Therefore, the probability of recruiting enough water molecules at the extremely low concentrations in the gas phase to form a hydrate lattice is low [25]. The models used to determine the pressure and temperature at which hydrate formation begins are usually based on the original hydrate equilibrium model proposed by Van der Waals and Platteu, with modifications proposed by Parrish and Prauschnitz. These models were applied and supplemented by Aspen Tech to calculate hydrate formation points. Hydrate prediction models used in the Aspen Hysys software are: 2-Phase Model, 3-Phase Model, SH Model, and Assume Free Water Model.

In [26], an equation of state was presented, which is a function of pressure, volume, and temperature. This is an incomplete equation of state, since not all thermodynamic properties can be obtained with it. The minimum additional requirement for calculations using the Peng-Robinson equations is to know the heat capacity of an ideal gas as a function of temperature. The equations of state relate the variables for a fluid in the liquid-gas phase region and are used in modeling technological processes in Aspen Hysys.

In contrast to the well-studied thermodynamic properties of gas hydrates, the kinetics of gas hydrate formation remains a challenging task that requires additional efforts in terms of studying the process. That is, predicting and even measuring the rate of gas hydrate formation are difficult and unsolved due to the problems of obtaining reproducible and instrument-independent kinetic data. The stochastic (random) nature of hydrate formation is usually observed in laboratory-scale experiments, where the induction time of hydrate nucleation can vary under identical testing conditions from minutes to hours and even days [27]. The induction time of hydrate nucleation is usually defined as the time until spontaneous hydrate growth begins. In practice, this time is usually taken as the time that causes measurable changes, such as pressure drop, gas flow, temperature increase, or the appearance of crystals that can be observed visually.

Four variants of computer models of gas preparation facilities using low-temperature separation (LTS) technology, which were developed during this study:

Variant 1 – low-temperature gas separation, where gas cooling is carried out due to the Joule-Thompson effect (Fig. 1).

This variant of the GPF operation is usually used at the initial stages of field development, when the wells have high reservoir pressure. Due to throttling (adiabatic expansion), the natural gas is cooled to the required temperature and then undergoes appropriate separation from the liquid [28]. Also, this variant of the GPF operation often involves partial throttling of the gas not only at the GPF, but also at the wellhead and at the inlet string node, which necessitates the supply of a hydrate formation inhibitor to each of these points [29].

Variant 2 – gas supply from the wells to the preparation unit using a PCS (pressure compressor station) + low-temperature gas separation, where the gas is cooled due to the Joule-Thompson effect (Fig. 2).

When the reservoir pressure in the wells gradually decreases during the field development process, at a certain point the pressure drops during throttling and, accordingly, the degree of gas cooling becomes insufficient to ensure proper gas separation and high-quality preparation. To solve this problem, pressure compressor stations are installed at the GPF inlet before the low-temperature separation unit, and sometimes separate compressors near the wellhead [30]. For this variant of the GPF operation, the need to supply a hydrate formation inhibitor to the wellhead and to the input string node is often absent, the only point of inhibitor injection is the inlet line to the low-temperature separation unit (LTS).

Variant 3 – gas supply from the wells to the preparation unit using PCS + low-temperature gas separation, where gas cooling is carried out on a turboexpander unit (Fig. 3).

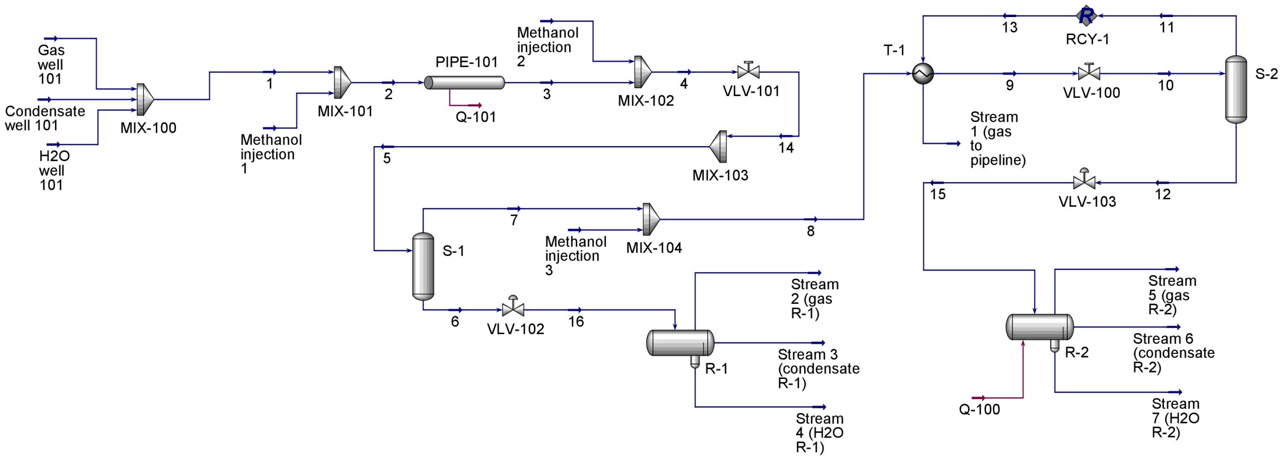

Fig. 1. Model of the low-temperature separation process using the Joule-Thompson effect

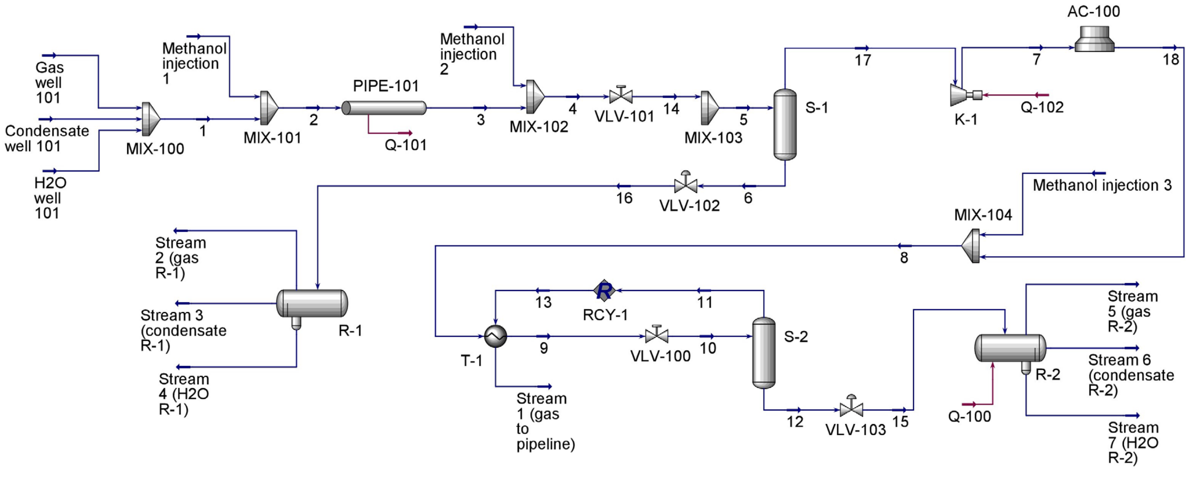

Fig. 2. Model of the low-temperature separation process using PCS and the Joule-Thompson effect

This variant of the GPF operation is identical to variant 2, the only difference is that to ensure the required degree of gas cooling, it is necessary to provide a smaller pressure drop across the expander turbine compared to adiabatic expansion at the throttle.

Variant 4 – gas supply from wells to the preparation unit using PCS + low-temperature gas separation, where gas cooling is carried out in an artificial refrigeration unit (propane refrigeration unit) (Fig. 4).

For this variant of the GPF operation, the only point of inhibitor injection is the inlet line to the low-temperature separation unit (LTS).

In the course of discussing the research results, the following patterns can be noted (Table 1). In the case of the need to supply methanol to the plume and to the wellhead input string node, the main part of the methanol supplied to the system is separated in the first-stage separators and enters the associated formation water (AFW) purge line from the R-1 separator (about 75 % by weight of the methanol used). However, the methanol content at the outlet of the first-stage separator is about 20.0 % by weight, which complicates the possibility of regenerating such an inhibitor due to its low concentration, which significantly increases the energy consumption for the methanol distillation process.

The methanol flow rates in the input and output streams are summarized in Table 1.

At the later stages of field development, when, due to the decrease in reservoir and working pressures in the wells, there is no need to supply hydrate formation inhibitor to the well plumes and to the GPF input string node. The only methanol injection point in this case is the low-temperature gas separation unit. For such options, not less than 85.0 % by mass of the used hydrate formation inhibitor enters the R-2 separator.

The separation of hydrate formation inhibitor from gas condensate from the R-2 purge line is complicated by the fact that the methanol concentration in such a stream is no more than 4 % by mass, and due to the fact that the densities of methanol and gas condensate are close, separation by gravity is not effective enough.

One of the streams that is most suitable for the regeneration process and subsequent reuse of methanol is the AFW purge line from the R-2 separator, where the methanol content according to the modeling results for a number of options is over 50 % by weight. As the simplest option, the associated formation water from the II stage separator can be accumulated in a separate consumption tank, from where it can be directed to the appropriate points of the technological process by dosing pumps, only with greater productivity, compared to the supply of pure methanol. Another option is to direct the associated formation water from the II stage separator to the methanol regeneration unit, where methanol is separated from the associated formation water in the distillation column.

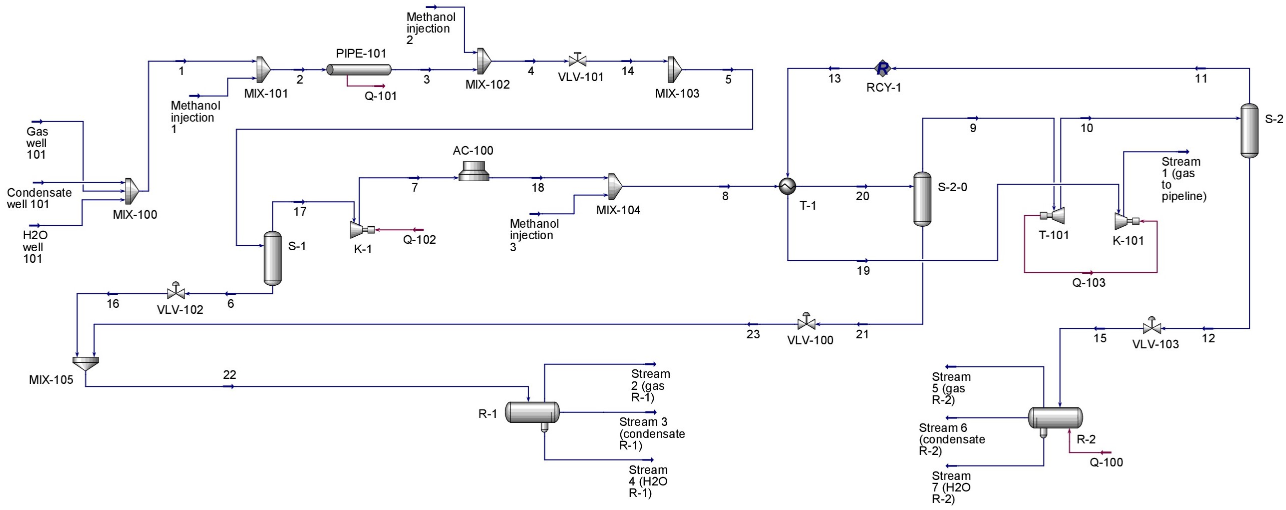

Fig. 3. Model of the low-temperature separation process using PCS and a turboexpander unit

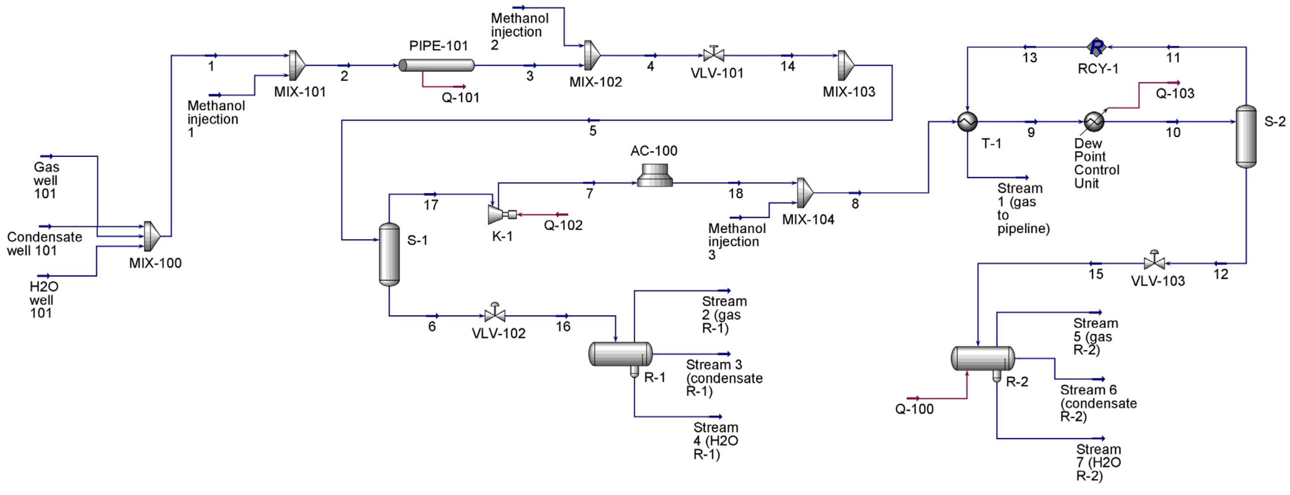

Fig. 4. Model of the low-temperature separation process using PCS and artificial refrigeration unit

Table 1

Study of methanol content in the technological lines of low-temperature gas separation plants

Variants of GPF with LTS	Variant 1			Variant 2			Variant 3			Variant 4		
Output flows from the GPF	Q, t/day	C_1, %	C_2, %	Q, t/day	C_1, %	C_2, %	Q, t/day	C_1, %	C_2, %	Q, t/day	C_1, %	C_2, %
Methanol injection volume												
Methanol injection 1	0.4549	63.33	–	0	0.00	–	0	0.00	–	0	0.00	–
Methanol injection 2	0.2035	28.33	–	0	0.00	–	0	0.00	–	0	0.00	–
Methanol injection 3	0.0599	8.33	–	0.2454	100.00	–	0.1616	100.00	–	0.2394	100.00	–
Total	0.7183	100.00	–	0.2454	100.00	–	0.1616	100.00	–	0.2394	100.00	–
Volume of methanol in the GPF output line												
Stream 1 (gas in MG)	0.0246	3.42	–	0.0255	10.39	–	0.0241	14.91	–	0.0252	10.52	–
Stream 2 (gas from R-1)	0.0001	0.01	–	0	0.00	–	0	0.00	–	0	0.00	–
Stream 3 (condensate from R-1)	0.0768	10.69	–	0	0.00	–	0	0.00	–	0	0.00	–
Stream 4 (AFW from R-1)	0.5427	75.55	–	0	0.00	–	0	0.00	–	0	0.00	–
Stream 5 (gas from R-2)	0.0009	–	–	0.0016	0.65	–	0.0009	0.55	–	0.0016	0.66	–
Stream 6 (condensate from R-2)	0.0489	6.80	–	0.0902	36.75	–	0.0535	33.10	–	0.0877	36.63	–
Stream 7 (AFW from R-2)	0.0243	3.38	–	0.1281	52.20	–	0.0831	51.42	–	0.1249	52.17	–
Total	0.7183	100.00	–	0.2454	100.00	–	0.1616	100.00	–	0.2394	100.00	–
Total volume of liquid in the AFW output lines from the separators of the first and second stages												
Stream 4	2.554	–	21.24	1.903	–	0.00	1.903	–	0.00	1.903	–	0.00
Stream 7	0.0494	–	49.19	0.2358	–	54.32	0.1865	–	44.55	0.2323	–	53.76
Total liquid volume in the condensate outlet lines from the first and second stage separators												
Stream 3	20.39	–	0.37	18.49	–	0.00	18.49	–	0.00	18.49	–	0.00
Stream 6	1.753	–	–	2.609	–	3.45	2.329	–	2.29	2.593	–	3.38

There is a dependence of the amount of associated formation water that enters the second stage of the GPF separation on the gas pressure at the wellhead and at the I stage of separation. The higher the pressure at the first stage of separation, the less associated formation water enters the second stage of separation, since this water is more effectively separated in the first stage separator.

Discussion. In the last two decades, there has been significant progress in increasing the efficiency of methanol use, which is most widely used in the gas industry. However, today, in practice, the actual consumption of methanol at gas production enterprises is often overestimated (in some cases by 15–20 % or more) due to its irrational use.

Modern software (such as OLGA, Aspen HYSYS, ProMax, UniSim Design, etc.) has become an indispensable tool for process engineers in the oil and gas industry. It allows for detailed studies of technological processes, their optimization, and the development of effective solutions to protect equipment from hydrate formation. This increases production efficiency, reduces the risk of accidents, and reduces costs.

Based on the results of the study of methanol content in the technological lines of low-temperature gas separation plants using the Aspen HYSYS simulator, which are presented in the article, methanol consumption was identified. However, this study is limited by the thermodynamic behavior of natural gas and liquid hydrocarbons, phase transitions of specific components depending on thermodynamic parameters. The modeling took into account the distribution of associated formation water and methanol along technological streams, which affects the occurrence of conditions for the formation of gas hydrates. However, it did not take into account the period of time over which gas hydrates will be formed, which may also affect the practical decision regarding the volume of use of the hydrate formation inhibitor.

These issues are of important practical importance. Research and development of economical technologies for the use of methanol will allow improving the efficiency indicators and environmental characteristics of gas and condensate systems, which is relevant for the gas industry.

Scientific research on optimizing methanol consumption in technological flows of facilities that prepare gas by the low-temperature separation method will contribute to the implementation of the strategic goals defined in:

1) the priority topics of applied scientific research approved by the order of the Ministry of Education and Science of Ukraine dated 07.09.2023 No. 1104, namely, related to the scientific topic of the Ministry of Environmental Protection and Natural Resources "Development and improvement of methods of geological exploration for all types of minerals, in particular strategic and critical ones. Conducting scientific research aimed at focused support for the exploration of minerals required for the implementation of a "green" transition to the promising needs of the digital economy, its decarbonization";

2) the National Action Plan for Environmental Protection for the period until 2025, approved by the order of the Cabinet of Ministers of Ukraine dated April 21, 2021 No. 443-r;

3) Energy Strategy of Ukraine for the period until 2035 "Security, Energy Efficiency, Competitiveness", approved by the order of the Cabinet of Ministers of Ukraine dated August 18, 2017 No. 605-r (section 2, clauses 2.2. and 2.5).

Based on the above modeling results, it can be concluded that the most promising areas of work in increasing the efficiency of technologies used at the GPF using low-temperature separation technology (LTS) are the development of technological and technical measures to reduce methanol losses with condensate and associated formation waters. This will allow predicting real methanol consumption, reducing environmental risks due to possible accidental spills, reviewing the operating mode of gas preparation plants, preventing environmental pollution, etc. At the same time, due to the reduction of methanol in liquid hydrocarbons, their commercial quality will improve, and in formation waters – it will reduce environmental pollution.

The results of the work will be useful for managing the technogenic safety of the oil and gas complex and related critical infrastructure, which is especially important for national security during military operations and economic reconstruction.

The prospect of further research is aimed at developing technologies for reducing methanol consumption to ensure a hydrate-free gas preparation process by using technological solutions for reusing the inhibitor in the technological process. It is also aimed at technical solutions that minimize the inhibitor entering the main gas pipeline and liquid hydrocarbon collection systems.

Practical significance. The results obtained during the study can be used in the design of new or in the modernization of existing natural gas preparation plants. Reducing the consumption of hydrate formation inhibitor while maintaining stable hydrate-free operation of technological equipment will reduce operating costs and the cost of natural gas production and preparation.

Research limitations. This study is limited by the thermodynamic behavior of natural gas and liquid hydrocarbons. The distribution of associated formation water and methanol across process streams was taken into account, which affects the occurrence of conditions for the formation of gas hydrates. However, it did not take into account the period of time over which gas hydrates will be formed, which may also affect the practical decision regarding the volume of use of the hydrate formation inhibitor.

Impact of martial law conditions. Currently, Ukraine does not have its own production of methanol hydrate formation inhibitor; it is completely imported from other producing countries.

Under martial law conditions, failures or interruptions in the supply of methanol to enterprises of the oil and gas industry of Ukraine are possible, which in some cases may lead to the suspension of the operation of such enterprises or their transfer to work with other hydrate formation inhibitors.

4. Conclusions

The study shows that avoiding methanol losses and ensuring better gas preparation requires the development of measures for more delicate gas purification from non-target components. Since for typical technological schemes of gas preparation at the GPF, about 3–15 wt. % of the used methanol together with the prepared gas enters the main gas pipeline. Potential solutions may be the use of the process of low-temperature absorption or adsorption or low-temperature condensation.

It is found that 17–37 wt. % of the used methanol enters the liquid hydrocarbon collection system. Excessive methanol content worsens the quality of final liquid hydrocarbon products, such as LPG, for example. This can be eliminated by applying the process of methanol extraction from liquid hydrocarbons by dissolving it in water with its subsequent separation from the water-methanol mixture.

It is found that methanol losses in the condensate weathering gas utilization line are about 1% wt. from used methanol. The condensate weathering gas can be directed into the main gas preparation flow using an ejector or compressor unit, which will reduce the total gas losses during the technological process.

It is necessary to provide for the purification of associated formation water (AFW) from impurities in the gas and condensate preparation process before returning it to the reservoir, including methanol, since 50–80 % by weight of the used methanol enters the associated formation water collection and disposal system. In addition to mechanical purification of the AFW from impurities, it is possible to pass it through a distillation unit, where methanol is separated from water.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship or other, which could affect the study and its results presented in this article.

Financing

The study was conducted without financial support.

Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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Viktoriia Dmytrenko, *PhD, Associate Professor, Department of Oil and Gas Engineering and Technology, National University "Yuri Kondratyuk Poltava Polytechnic", Poltava, Ukraine, ORCID: https://orcid.org/0000-0002-1678-2575*

✉***Taras Podoliak,*** *PhD Student, Department of Oil and Gas Engineering and Technology, National University "Yuri Kondratyuk Poltava Polytechnic", Poltava, Ukraine, e-mail: office@tehnogas.com, ORCID: https://orcid.org/0009-0008-5287-0880*

✉*Corresponding author*