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EFFICIENCY OF GAS PREPARATION TECHNOLOGY USING A BLOCK DRYING PLANT

Oleksandr Petrash
PhD
Department of Mechanical and Electrical Engineering*

Stanislav Popov
PhD, Associate Professor, Senior Researcher
Department of Mechanical and Electrical Engineering*

Ruslan Petrash
Corresponding author
PhD, Associate Professor
Department of Construction and Vocational Education*
E-mail: ruslan.petrash@pdaa.edu.ua

Yuliia Levchenko
PhD, Associate Professor
Department of Mechanical and Electrical Engineering*

Anton Kelemesh
PhD, Associate Professor
Department of Agricultural Engineering and Road Transport*
*Poltava State Agrarian University
Skovorody str., 1/3, Poltava, Ukraine, 36003

The object of research is the technology of gas drying using a mobile block installation. The task to ensure compliance of the composition of natural gas with the values of a number of basic characteristics before its supply to main pipelines has been solved. The results of a complex analysis of the gas preparation technology of the deposit, which is located in an agricultural area and is at a late stage of exploitation, are reported. It was established that in order to ensure the supply of conditioned gas to the system of main gas pipelines under the conditions of low gas pressures, the construction of gas treatment plants is required, first of all, for its drying.

The method of ensuring gas quality considered in the current paper involves the use of a block-type gas drying installation as part of a low-temperature separation installation and a source of artificial cold. As the latter, it is envisaged to use a freon-refrigerating unit. The study shows that the proposed block gas drying units can be unified for different gas productivity and are characterized by relatively low capital and operating costs. The main advantages of the introduction of gas preparation block installations and the scheme of connecting the installation to the existing line are presented.

Based on the results of the economic efficiency indicators, it was established that the use of a block gas drying unit is a profitable project with the value of the accumulated reduced free cash flow of almost 843 thousand conditional units; the investment payback period is 3 years. The results could be effectively used in the gas distribution sector, provided that the gas is extracted from a field close to exhaustion, which is characterized by low reservoir pressures

Keywords: freon refrigeration plant, gas drying, separation, payback period, gas distribution system

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1. Introduction

In 2015, the National Board, which provides state regulation in the fields of energy and communal services, approved the Codes of gas transportation and gas distribution systems. This determines the need to ensure the dew point temperature of gas for moisture and hydrocarbons before supplying gas to consumers. Some regulatory documents, along with the dew point temperature, also regulate the heat of combustion of gas supplied to consumers, including the population. Thus, the requirements for the minimum permissible value of the lower calorific value of natural gas are 7600 kcal/m^3 (31.8 MJ/m^3). The permissible range of the higher Wobbe number is regulated from 9840 kcal/m^3 (41.2 MJ/m^3) to 13020 kcal/m^3 (54.5 MJ/m^3) with a maximum deviation from the nominal value of ±5 %. This standard does not regulate the content of methane, nitrogen, hydrogen, or heavy hydrocarbons in natural gas. The actual lower calorific value of natural gas in deposits close to depletion is 8300±300 kcal/m^3 (maximum deviation ±3.6 %).

Fields in active development are depleted to the extent of up to 70 % of initial reserves. As a result, there is a significant decrease in formation pressures in the wells. Therefore, the use of existing equipment at gas preparation plants does not make it possible to ensure compliance of gas quality indicators with established requirements.

The complex gas preparation plant in question is located in an agricultural area. The discovery of a significant number of hydrocarbon deposits in this area led to the active development of the mining industry. Multilayered gas fields and light processing industry are also common in the area.

Minerals of this territory include loess loam, clay, sand, which can be used as building material for local needs. Groundwater from Cenozoic sediments is widely used for drinking and technical water supply. The main mineral in this area is natural gas [1].

Paleozoic, Mesozoic, and Cenozoic erathem sedimentary formations take part in the geological structure of the studied deposits of the examined area [2]. At the time of the study, 4 exploratory wells were drilled in the first field and 1 exploratory well with 24 operational wells in the second field.

Natural gas extracted from deposits has a large amount of moisture and mechanical impurities, which has a serious negative effect on pipelines and equipment, causing their strong corrosion. Also, non-compliance of the physical and chemical parameters of the gas supplied to the gas distribution or gas transportation system with the requirements of the Codes leads to the application of fines to mining enterprises.

Due to the significant degree of exhaustion of the fields, the existing equipment of CGPP does not make it possible to ensure the supply of conditioned gas. Therefore, the topic of modernization of surface systems for collecting well products in order to extend the economically feasible exploitation of deposits close to exhaustion is relevant, in particular for countries whose subsoils have been developed for a long time.

2. Literature review and problem statement

In work [3], the process of natural gas preparation was investigated. The produced gas had a significant content of nitrogen, helium, and carbon dioxide. In order to meet market requirements, a gas purification and drying plant was included in the technological line of gas preparation, which made it possible to meet the requirements of regulatory documents. The fact of gas purification was confirmed by chromatographic research. The effectiveness of the gas drying installation during extraction from depleted deposits remains an unresolved issue.

The authors of work [4] note that it is possible to achieve a reduction of harmful emissions to the atmosphere from the combustion of accompanying gas in the flare barn, for which gas drying using the low-temperature separation method and additional compressor units are used. The economic expediency of using additional compressors remains out of consideration. In [5], the operation of a three-section oil and gas adsorption plant for gas purification and drying is considered. The work also provides an approximate calculation of capital costs for the construction of an adsorption plant and shows its economic efficiency. Nevertheless, this work did not consider the option of a mobile installation instead of capital construction, which would obviously reduce costs.

In [6, 7], the features of the technical solutions of pump-compressor units and their influence on the efficiency of carbon dioxide separation were analyzed but the research context did not include conditions of low formation pressures. In work [8], the amount of operating costs for the operation of gas drying installations is given, which is useful for the selection of equipment but at the same time, the joint operation of the drying installation with the existing technological line, which will take place in practice, remained unexplored. Work [9] highlights the positive experience of using by-products of hydrocarbon extraction and transportation for the own needs of local territorial communities, in particular for underground gas storage and grain drying. Emphasis is on the feasibility of using mobile departments for quick response to breakdowns that occur in the production line. The main conclusion from the cited work concerns the advantage of the possibility of servicing several objects with one mobile installation. However, there is no practical case with efficiency calculations. Work [10] examines in detail the complications that may arise in the plumes of production wells in the event of unfavorable combinations of temperature and pressure and a significant content of impurities in the production gas, which occur in deposits that are at the final stage of development. The given information proves the relevance of the issue of bringing the gas to the required condition. However, the focus is on phase transitions of hydrocarbon mixtures, and technical solutions to ensure gas condition can only be proposed in the future based on the identified patterns.

Our review of the literature [4, 5, 8, 9] showed that the extracted and associated gas can and should be used for the economic needs of the industry but at the same time, there is a problem of bringing the gas parameters to regulatory requirements. For this, the gas drying technology is used [3, 6, 7]. It is implemented in installations of various configurations, among which mobile installations are poorly researched, although they obviously have a number of potential organizational advantages. An unsolved problem is the technique of evaluating the effectiveness of the use of mobile block gas drying units under conditions of depletion of deposits at low reservoir pressures. Under such conditions, it is traditionally difficult to maintain a balance between the costs of improving the technological line and the income from more rational use of mining raw materials. The latter justifies the necessity of our research.

3. The aim and objectives of the study

The purpose of this study is to determine the effectiveness of gas preparation technology by introducing a block-type drying unit under conditions of low formation pressure, which occurs in most deposits at the late stage of development. Our study solves the practical problem of ensuring the dew point temperature of gas for moisture and hydrocarbons before supplying it to consumers.

To achieve the goal, it is necessary to solve the problems:

– to research the core material and carry out technological calculations of the required temperature of low-temperature separation;

– to devise recommendations regarding the improvement of the existing gas preparation system in view of the requirements of the gas transportation system (GTS) code for deposits close to exhaustion;

– to determine the economic feasibility of introducing the proposed improvements to the technological line of gas preparation.

4. The study materials and methods

The focus of attention is on the gas drying process at complex gas preparation plants. The object of this study is the process of drying gas to the required quality parameters for supplying distribution networks. The gas quality was assessed, in particular, by the humidity indicator. The concept of «natural gas quality» means compliance of its composition with certain values of the following basic characteristics: calorific value, moisture content, and the presence of corrosive-active components (hydrogen sulfide, carbon dioxide).

The hypothesis of the study assumes that the capital conversion of the gas preparation line can be abandoned in favor of the periodic use of a mobile unit, which will also ensure gas quality parameters. This hypothesis is supported by the fact that gas quality parameters depend on the efficiency of production intensification measures, which are carried out at the research field and are always temporary in nature.

As part of the study, a comprehensive critical analysis of the regulatory framework and the latest gas quality assurance research was conducted. Technological calculations were carried out and an engineering solution to the applied problem of evaluating the effectiveness of the improved gas drying technology was achieved using the example of an experimental installation of complex gas preparation. In the course of the calculations, actual indicators of the development of the experimental deposit and geological maps of the productive horizons were used.

The factors related to the transportation and consumption of natural gas, which are taken into account by the requirements for the quality of gas preparation, are as follows:

– during transportation by any gas pipelines, the gas must be in a single-phase state, i.e., there must be no condensation of droplet liquid in its environment;

– gas components should not contribute to corrosion of pipelines, gas equipment, control and measuring devices, etc.;

– consumer properties of gas must ensure its efficient and safe use.

To ensure the correctness of the comparison and the objectivity of decision-making regarding the feasibility of projects, uniform principles of economic efficiency assessment were used. The assessment of the economic efficiency of the project is based on the net cash flow from operating and investment activities (the difference between receipts and payments), adjusted for tax deductions.

Cash flows from financial activities (with the exception of accrued interest), which are related to the implementation of the project, were not taken into account during the formation of net cash flow. Income tax is calculated taking into account the cost of financing the project (including interest).

The net cash flow is formed only due to the economic effects caused by the implementation of the project and takes into account all the changes caused by the project, including working capital and project closing costs. In addition, the net cash flow took into account the cash flow at all stages of the project: the stage of evaluation, implementation, and closing of the project.

For the analysis of the projects, nominal cash flows were used, that is, cash flows adjusted for the level of inflation. Forecast inflation indices are determined by market research and enterprise analysis. No other inflation indices were used. Accounting for changes in the value of money over time is carried out by applying a discount factor to the net cash flow. In addition, the impact of depreciation on the cash flows of the project is taken into account. Depreciation is calculated only for investments considered in the project in accordance with the terms of tax accounting used by the enterprise.

Income tax was also taken into account, which was calculated taking into account the result from operating activities, reduced by the amount of depreciation. When calculating income tax, the current income tax rate is applied. Accounting for income tax in the cash flow is carried out in the period of actual payment of the tax, and not in the period of its accrual. All cash flows are net of value added tax (VAT). Rent for the use of subsoil for the extraction of minerals for hydrocarbon extraction projects was also taken into account.

The technical characteristics and cost of the freon-refrigerating unit (FRU) are accepted in accordance with commercial offers. The main indicator of the economic efficiency of the development is the reduced free cash flow, which is calculated over the years as the difference between the amount of net profit and depreciation deductions and the amount of capital investments, which makes it possible to objectively assess the dynamics of cash flows. To take into account the decrease in the value of future cash flows, the discounting method is used.

The core samples were studied under atmospheric conditions in the research petrophysical laboratory at UkrNDIgaz, Ukraine. A set of laboratory studies was carried out on the selected samples, which included the determination of open porosity, volumetric weight, gas permeability, carbonation, and residual water saturation. A total of 543 samples were examined at the deposits, of which 45 samples were from the productive horizon, including 8 samples from the permeable part.

The gas-condensate characteristics of the formation systems of the productive horizons of the deposit were obtained based on the results of current gas-condensate studies, which were carried out in the period from 2007 to 2015.

Data on the modes of operation of the wells of the experimental field, the conditions of gas and condensate sampling, and the specific yields of condensate when conducting gas condensate studies of the wells are given in Table 1.

Table 1

Data on gas condensate studies of the experimental field

Indicators, units of measurement	Borehole Number			
	1	2	3	4
Productive horizon	C-5	C-5	C-5	C-5
Formation pressure, MPa	54.6	54.6	44.7	37.6
Formation temperature, K	403	403	401	401
Mode of operation of the well:	–	–	–	–
– temperature at the mouth, K	314	321	299	299
– breakout pressure, MPa	–	45.8	39.6	22.6
– gas flow rate, thousand m^3/day	403.9	300	135	135
Sampling conditions:	–	–	–	–
– pressure, MPa	5.88	5.88	5.88	5.88
– temperature, K	288	280	263	274
Specific condensate output, cm^3/m^3:	–	–	–	–
– stable	2.5	4.28	10.0	5.0
– unstable	2.8	4.81	12.0	6.3
Water factor, cm^3/m^3	5.2	4.8	–3.0	–20.0

According to the research results, the extracted gas is quite dry with a high methane content of 91.74–92.12 % by mol., the content of ethane-propane-butane fractions is insignificant and amounts to 4.60–4.33 % by mol. The content of C5+ hydrocarbons is not high – up to 13.6 g/m^3. According to the nitrogen content (0.13–0.30 % mol.), the produced gas is classified as low-nitrogen. The content of carbon dioxide is 2.98 and 3.02 %, at high working pressures it can cause corrosion of the equipment. Hydrogen sulfide was not recorded in the samples.

The samples were taken after establishing the stable operation of the separator, which was evidenced by the established constant values of pressure, temperature, and specific condensate yield. The component composition of separation gas and degassing gas is determined by the method of chromatographic analysis. The composition and physicochemical properties of extracted gases are determined on the basis of industrial research data, analyzes of gas and condensate samples, as well as the results of degassing samples of unstable condensates.

Retrograde condensation became a factor that significantly influenced the physicochemical properties and component composition of the extractive gas condensate system. As a result of precipitation of heavy hydrocarbons in the formation, the potential content of C5+ hydrocarbons in the production gas changes and, accordingly, the composition of the production condensate «lightens». Thus, as the formation pressure drops during the development of productive deposits, a natural decrease in the content of C5+ hydrocarbons in the production gas (in terms of separation gas) was observed.

The efficiency of further gas transportation and compliance of the physico-chemical parameters of gas with the requirements of its consumer value in accordance with the needs of different categories of consumers depends on the level of preparation of natural gas in the industry.

Thus, in order to ensure the technical conditions of providing gas to the consumer, it is necessary to apply the technology of its drying. Natural gas transportation conditions do not require complete removal of moisture from it. It is only necessary to maintain the dew point temperature of moisture and hydrocarbons. When the temperature of the gas decreases, it should not transfer the gas from an unsaturated state to a saturated one, and the condensed phase may be released from the gas composition.

Under today's conditions of intensification of gas production, the ground infrastructure faces the challenge of local overloading of existing gas preparation systems. Such local overloads are temporary since methods of intensification of mining have a short-term effect.

To ensure quality indicators of the gas supplied to the network, it is proposed to adopt a block gas drying unit (GDU) as part of a low-temperature separation unit (LTS) and a freon-refrigerating unit (FRU). This technology is able to ensure high-quality gas preparation under low pressure conditions, can be unified for different gas productivity, and is characterized by relatively low capital and operating costs.

In order to quickly solve the problem of local overloads of existing gas preparation systems, it is proposed to develop technical solutions for the implementation of a model series of small-sized block gas preparation plants (block GPP) with a capacity of 100, 200, and 300 thousand m^3/day. A block GPP can be quickly mounted on an overloaded facility, and after the gas volume is reduced to the design capacities of a stationary GPP, the block GPP can be moved to another overloaded facility (Fig. 1).

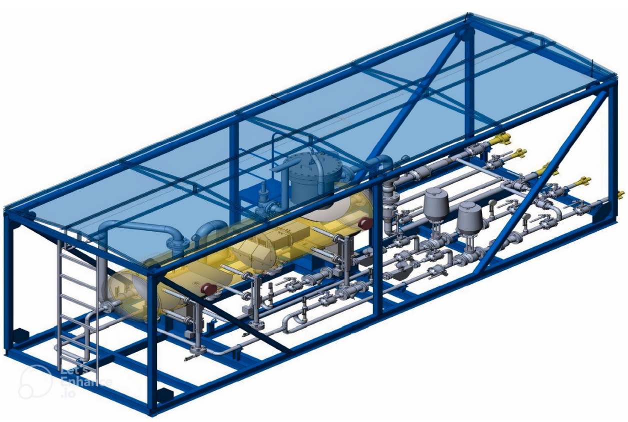

Fig. 1. Small-sized block rig for well exploration

It is proposed to prepare gas at the block GPP using the method of low-temperature separation using a source of artificial cold – a freon refrigeration unit. This technology will ensure the preparation of gas to meet the requirements of the GTS Code regarding the dew point temperature for water (DPTW) and for hydrocarbons (DPTH) and can be implemented in a small-sized block structure.

It is proposed to complete GPP with three blocks: a gas separation block, a gas cooling block, and an FRU block. These blocks will be mounted on existing CGPP and form an additional technological line for the preparation of additional volumes of gas. If necessary, the block GPP can be moved to another facility.

Unification of the location of connecting fittings and geometric dimensions of GPP blocks is expected, regardless of its performance, which will allow using a typical project of connecting GPP to the existing infrastructure with minimal changes. The sizes of GPP units should not exceed the dimensions of a standard 20- or 40-foot sea container to allow for rapid transportation. The small size and weight of the blocks will allow their installation on reinforced concrete slabs without building a foundation. Examples of GPP blocks are shown in Fig. 2.

Necessary conditions for the installation of a block GPP are the availability of free space at the facility, a reserve of electric power up to 100 kVA (or additional equipment of the GPP with a generator), a tank park for the shipment of liquids (or additional equipment of GPP with a block of containers), and a methanol farm (or additional equipment of GPP with a methanol supply unit).

Fig. 2. Practical solution for gas preparation plant units

In the process of preparing raw gas by the method of low-temperature separation, additional production of hydrocarbon condensate is expected. In the calculations of additional production of condensate at LTS, its degassing is assumed at atmospheric pressure and a temperature of 20 °C.

The principle technological diagram of gas preparation on the project low-pressure line using LTS and FRU installations is shown in Fig. 3. Raw gas from wells with a pressure of 3.56 MPa is pre-cleaned from mechanical impurities and droplet liquid in the first-stage separator C-1-1 and is then fed to the recuperative heat exchanger T-1 for pre-cooling with a commercial gas flow. The cooled gas after the recuperative heat exchanger T-1 is supplied to the inlet of the separator C-2-1. The gas purified in C-2-1 is fed to the T-2 heat exchanger, where it is cooled by an intermediate coolant from the FRU to a temperature of –20 °C. Methanol with a concentration of 96 % by mass is used as a coolant. or propylene glycol. After T-2, the gas is fed to the low-temperature separator C-3-1 to remove the condensed liquid. The gas purified in C-3-1 passes through the T-1 heat exchanger for heat recovery and is supplied to the MG SHPC with a pressure of 2.20–3.42 MPa. To prevent hydrate formation, methanol is supplied to the gas flow before T-1.

The liquid from separators C-1-1, C-2-1, and C-3-1 is supplied to the existing liquid storage tank EB-1 (V=4.0 m^3, PN 2.0). Partially degassed condensate from EV-1 is fed to the existing BDK-1 condensate degassing unit (V=25.0 m^3), where it is additionally degassed at atmospheric pressure and sent to the existing container E-1 (V=10 m^3, PN 0.1) for storage or enters the inlet of the H-3 pump for feeding through the filling riser to the tank truck. The degassed water-methanol mixture from BDK-1 is sent to the existing container E-2 (V=10 m^3, PN 0.1) for storage.

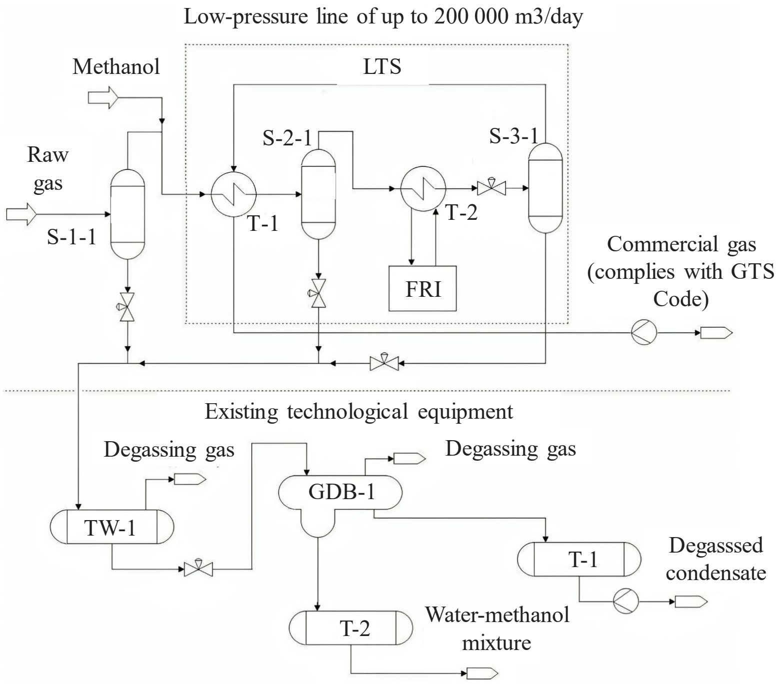

Fig. 3. Schematic diagram of a low-pressure line with low-temperature separation and freon refrigeration unit at a pilot plant for complex gas preparation

As can be seen from Fig. 3, the proposed improvement does not require a major reconstruction of the existing line.

5. Results of studying the effectiveness of the block drying unit

5. 1. Results of core material research and technological calculations

As a result of the industrial-geophysical research of wells and laboratory research of core material, the physico-lithological properties of the reservoir rocks of the productive layers and covers of the studied deposits were determined.

Fig. 4 shows the obtained diagram of a temperature change of LTS, necessary to bring DPTW (brought to a pressure of 3.92 MPa) to minus 10 °C, with an increase in the operating pressure.

The results of technological calculations are given in Table 2.

According to the results of technological calculations, it was determined that in order to achieve a DPTW of minus 10 °C at a working gas pressure of 0.2 MPa, it is necessary to reach a temperature of LTS of minus 37 °C (taking into account heat losses of 3 °C and a separation efficiency of 99 %).

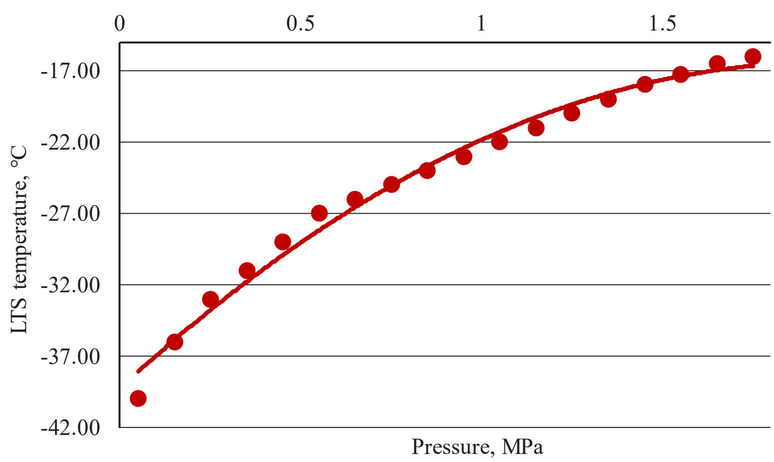

Fig. 4. Dependence of low-temperature separation temperature on pressure

Table 2

Results of technological calculations of gas preparation according to the basic option

Year of develop-ment	Gas output from the second CGPP, million m^3/year	Gas dew point temperature at the outlet of the first CGPP for hydrocarbons, °C	Gas dew point temperature at the outlet of the second CGPP by moisture (reduced to a pressure of 3.92 MPa), °C
2019	14.300	19.1	20.8
2020	95.208	19.1	20.8
2021	80.812	19.1	20.8
2022	70.425	19.1	20.8
2023	62.467	19.1	20.8
2024	56.087	19.1	20.8
2025	50.742	19.1	20.8
2026	46.291	19.1	20.8
2027	42.305	19.1	20.8
2028	38.996	19.1	20.8

5. 2. Recommendations for improving the technological line

According to the results of our calculations (Table 3) and taking into account the fact that the minimum gas pressure at the facilities is 0.2 MPa, it is recommended to use the LTS and FRU installations at the temperature of LTS down to –37 °C to prepare the gas to meet the requirements of the GTS Code.

According to the basic version, to ensure gas supply to the gas pipeline with a pressure of 3.42 MPa, the gas pressure at the mouth of the wells of the first experimental GPP is constantly maintained at the level of 3.60 MPa. Gas preparation at the second experimental CGPP is carried out according to the existing two-stage technological scheme of separation. New construction, reconstruction, or technical re-equipment of the existing gas preparation system is not envisaged. The economic calculations take into account the additional fee to the operator of the gas transmission system for non-compliance of gas quality indicators with the requirements of the Code of Gas Transmission System on the temperature of the dew point of gas by moisture reduced to a pressure of 3.92 MPa (DPTW) and the temperature of the dew point of gas by hydrocarbons (DPTH).

To ensure compliance of gas quality indicators with the requirements of the GTS Code on DPTW and DPTH, technical re-equipment of the second experimental CGPP is planned. It is achieved by installing the design low-pressure line of LTS with the use of FRU for gas preparation of the first experimental GPP and well No. 2 of the second experimental GPP and the high-pressure line of LTS. The Joule-Thomson effect is used to prepare the gas of well No. 54 of the same GGP.

Table 3

Summarized results of technological calculations of gas preparation at the high-pressure line of LTS and the low-pressure line of LTS with FRU according to the proposed option

Year	Gas production, mln m^3/year			Commercial gas output, mln m^3/year	Methanol consumption 96 % by weight on LTS, thousand tons/year
	Low-pressure line (LTS+FRU)	High-pressure line (LTS)	Total		
2020	30.148	65.060	95.208	94.816	0.108
2021	27.804	53.008	80.812	80.485	0.091
2022	25.859	44.566	70.425	70.143	0.079
2023	24.174	38.293	62.467	62.219	0.070
2024	22.647	33.440	56.087	55.867	0.062
2025	21.179	29.563	50.742	50.607	0.050
2026	19.783	26.408	46.191	46.069	0.045
2027	18.520	23.785	42.305	42.193	0.041
2028	17.426	21.570	38.996	38.892	0.038

As technological calculations show, as a result of the use of a modular gas drying unit, the output of commercial gas has increased.

5. 3. Determination of the economic feasibility of the proposed solutions

Thus, in order to determine the approximate capital investments for the technical re-equipment of the 2nd experimental CGPP, it is first of all appropriate to summarize the characteristics of the technological equipment for gas preparation according to the proposed option (Table 4).

Table 4

Characteristics of the project's basic technological equipment for gas preparation at the 2nd experimental CGPP according to the proposed option

No.	Name and characteristics of the equipment	Quantity	Weight, t	
			unit	total
1	Recuperative heat exchanger (T-1) 400 TNG-6.3-M1-N/20G-4-1-U-I	2	2.020	4.040
2	Cooler heat exchanger (T-2) 400 TNG-6,3-M1-N/20G-6-1-U-I	2	2.280	4.560
3	Recuperative heat exchanger (T-1v) 400 TNG-8,0-M1-N/20G-6-1-U-I	2	2.820	5.640
4	Separator (C-1-1) DN 600, PN 6.3	1	2.060	2.060
5	Separator (C-2-1) DN 600, PN 6.3	1	2.060	2.060
6	Separator (C-3-1) DN 600, PN 6.3	1	2.060	2.060
7	Three-phase separator (P-2) DN 2000, PN 1.6, VN 10.0	1	3.600	3.600
8	Freon refrigeration unit (FRU), cooling medium –25 °C, heat load up to 82.0 kW	1	–	–

Considering the data in Tables 3, 4, estimated capital investments for the technical re-equipment of the 2nd experimental CGPP according to the proposed option can be displayed as follows (Table 5).

Table 5

Approximate capital investments for the technical re-equipment of the 2nd experimental CGPP according to the proposed option

No. of entry	Name and characteristics of the equipment	Quantity	Approximate cost (including VAT), thousand y.o.	
			unit	total
1	Recuperative heat exchanger (T-1) 400 TNG-6.3-M1-N/20G-4-1-U-I TU 3612-024-00220302	2	11.56	23.11
2	Cooler heat exchanger (T-2) 400 TNG-6.3-M1-N/20G-6-1-U-I TU 3612-024-00220302	2	13.04	26.09
3	Recuperative heat exchanger (T-1v) 400 TNG-8.0-M1-N/20G-6-1-U-I TU 3612-024-00220302	2	16.13	32.26
4	Separator (C-1-1) DN 600, PN 6.3	1	11.78	11.78
5	Separator (C-2-1) DN 600, PN 6.3	1	11.78	11.78
6	Separator (C-3-1) DN 600, PN 6.3	1	11.78	11.78
7	Three-phase separator (P-2) DN 2000, PN 1.6, VN 10.0	1	20.59	20.59
8	Freon refrigeration unit (FRU), cooling medium –25 °C, heat load up to 82.0 kW	1	58.46	58.46
The main equipment of the low-pressure line with LTS and FRU and the high-pressure line together				195.87
Unaccounted equipment, 10 % of the cost of main equipment				19.59
Pipelines, fittings, metal structures, 25 % of the cost of basic equipment				48.97
Design and estimate documentation, 20 % of the cost of the main equipment				39.17
Construction and installation works, 50 % of the cost of the main equipment				97.93
Cost of main equipment and works together				401.52
Unaccounted costs, 25 % of the cost of main equipment and works				100.38
Total				501.91

According to the results of our calculations, the basic version of the technical re-equipment of the 2nd experimental CGPP is characterized by a negative value of the accumulated discounted cash flow (NPV), the payback of project capital investments for the considered period is not expected.

The summarized technical and economic indicators of the considered options for the reconstruction of the 2nd experimental CGPP are given in Table 6.

Table 6

Summarized technical and economic indicators of the considered options for the reconstruction of the experimental CGPP

Indicator	Basic option	Proposed variant
Additional gas production, mln m^3	1.1	–0.2
Commercial gas, mln m^3	–0.3	–0.2
Additional condensate production, thosand tons	0.5	3.7
Capital investments (excluding VAT), thousand y.o.	876.51	418.26
Operating costs, thousand y.o.	1180	1417.74
incl. depreciation	876.51	418.26
Free cash flow of expenses, thousand y.o.	–597.76	1882.97
Accumulated net cash flow (NPV), thousand y.o.	–640.33	842.52
Payback period, years	does not come	3
Rate of return, %	–16.60	87.3

The proposed variant of the technical re-equipment of the 2nd experimental CGPP is characterized by a positive value of accumulated reduced free cash flow (NPV), the payback period of project capital investments reaches 3 years.

6. Discussion of results of the application of a modular drying plant

Our results of calculations of the technical and economic parameters of the reconstruction of the gas preparation line can be effectively used at gas preparation facilities, where the production of field wells at the late stage of operation is processed. Therefore, in view of the increasing number of such deposits, our research will eventually have a wider scope than, for example [3, 6, 7]. In cases where the existing technological lines do not have the capacity to ensure the supply of conditioned gas to the distribution network, the use of block installations for drying turns out to be economically more expedient than capital conversion of technological facilities. In contrast to [5], the method of calculating the efficiency of capital investments used here is accurate and is based on industrial data. The potential effect of the proposed measures will be to ensure gas quality at lower capital costs on the one hand and save on fines, on the other.

The results of technological calculations and research of the core material (Tables 1, 2; Fig. 5) are explained by the phenomena of low reservoir pressures of the developed field and the patterns of phase transitions of the well products. Recommendations for the re-equipment of the technological line are based on the existing equipment of CGPP, which is selected for the current geological model at the time of the development of the field. In turn, the geological model remains unchanged, as it is impractical to conduct exploratory drilling under the described conditions. In the current situation, a mobile drying unit is objectively the simplest solution to ensure compliance with the conditions of the GTS code at the experimental field.

In the gas industry, the main part of the costs is directed annually to the preliminary treatment of gas before its entry into the transport pipeline. To ensure the supply of conditioned gas to the system of main gas pipelines, the construction of gas preparation units is required, primarily for its drying. It is mainly carried out in three ways: low-temperature separation, absorption drying using glycols, and adsorption drying. The economic feasibility of the proposed solution is explained by the fact that the ground infrastructure has local overloads of the existing gas preparation systems. Such local overloads are temporary since methods of intensification of mining have a short-term effect. Accordingly, the need for a block drying unit is temporary at various deposits. This opens up the possibility of using a small number of installations that are quickly moved from object to object to ensure the operation of problematic CGPP. Instead of the capital conversion of lines or the purchase of an installation for each CGPP, which creates an organizational, financial, and logistical burden on the gas industry management, the proposed option reduces the costs of both labor and funds for conversion.

Despite the decrease in the indicator of additional gas production (Table 7), the proposed option of installing FRU at the 2nd experimental CGPP will have a positive effect due to:

– additional production of condensate;
– relatively small capital investments;
– payback period;
– rates of return.

Limitations for the application of the results and recommendations of this study are the expediency of their use in deposits that have entered the late stage of exploitation. In particular, where measures are being taken to intensify hydrocarbon production. These measures cause a temporary effect, which means the same temporary need for the application of a block drying unit. The effectiveness of the latter in deposits with consistently high reservoir pressures requires additional justification.

A certain degree of ozone depletion from operation is noted as a disadvantage of a freon refrigeration unit. A relevant area of improving the operation of this unit is to transfer its mode of operation to power from alternative sources of fuel, such as solar energy.

7. Conclusions

1. Analysis of core samples and samples of well products make it possible to identify the experimental object as a deposit at a late stage of development. There is also the problem of retrograde condensation, which makes it difficult for the gas to reach the conditioned parameters. Our calculations established the necessity of using low-temperature separation at –20 °C and gas drying technology.

2. Based on the existing solution of the technological line, it is proposed to improve it with a block gas drying unit with a freon refrigeration unit. This improvement technically provides low-temperature separation conditions. Also, the installation is mobile and makes it possible to quickly respond to temporary overloads in the line. This property of its operation meets the conditions of depleted deposits, where

active measures of mining intensification with temporary effects are carried out. In this way, capital re-equipment of a number of objects of the gas transportation system can be replaced by several block installations, which, according to the schedule, temporarily work at each of the objects.

3. Economic calculations were carried out, which established the cost of technical re-equipment of one object at about 507 thousand y.o. Using the method of calculating the accumulated discounted cash flow, it was determined that the proposed re-equipment has a payback project with a term of 3 years. On the other hand, the capital re-equipment of gas preparation plants does not pay off at all. In this way, the advantages of the block gas drying unit are shown, which allows extending the term of supply of conditioned gas to the network from fields at the late stage of operation.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

All data are available in the main text of the manuscript.

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