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# IMPLEMENTATION OF BLOCK ARTIFICIAL COOLING UNITS FOR GAS PREPARATION

*The object of research is the process of implementation and use of block artificial cooling units in the technology of natural gas preparation.*

*The research has confirmed the high efficiency of using artificial cooling units. Due to deep gas cooling, it is possible to achieve a significant increase in condensate production and improve gas quality. In addition, modern units are characterized by high energy efficiency and compactness.*

*A comprehensive analysis of existing gas preparation technologies and a comparative assessment using block artificial cooling units revealed a number of significant advantages of the proposed system, namely:*

*– block units provide deeper removal of heavy hydrocarbons, water and other impurities, which improves the quality of the final product;*

*– due to lower gas temperature, more intensive condensation of heavy hydrocarbons is achieved, which leads to additional extraction of valuable components;*

*– modern block units are equipped with energy-efficient equipment, which reduces energy costs;*

*– the units have a modular design, which facilitates their transportation, unit and maintenance;*

*– the use of block units allows to reduce emissions of harmful substances into the atmosphere;*

*– the ability to adapt to different operating conditions and product quality requirements.*

*The study found that existing natural gas preparation technologies have a number of disadvantages, such as:*

*– low efficiency of gas purification;*

*– high energy consumption;*

*– complexity of maintenance;*

*– large dimensions of the equipment.*

*Despite some drawbacks, the introduction of block artificial cooling units is a promising direction for the development of the gas industry. The results of the study indicate the high efficiency of this technology and its economic feasibility in the long term.*

**Keywords:** *block artificial cooling units, low-temperature separation, unit performance, gas recovery.*

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## 1. Introduction

Natural gas preparation is a complex technological process aimed at cleaning gas from impurities, water and other components that degrade its quality and can lead to equipment corrosion [1]. Increasing requirements [2] for the quality of natural gas, as well as the need to increase condensate production, stimulate the search for new, more efficient gas preparation technologies. One of such promising areas is the use of block units (BU) of artificial refrigeration [3].

The use of BU leads to a reduction in labor and material resources, a reduction in the duration of construction of ground facilities and costs during their operation [4].

When designing block units (BU) of artificial refrigeration, it is necessary to ensure:

– fulfillment of operational requirements (including issues of fire protection and occupational safety) [5];

– fulfillment of technical aesthetics and architecture requirements;

– maximum unification of technical solutions at all levels (from individual block devices to the master plan) [6];

– maximum increase in the compactness of individual block devices and the facility as a whole (based on the use of a high degree of factory readiness of technological equipment of the main and auxiliary purpose and the articulation of block boxes into a single block building) [7].

During design, one should strive to implement facilities in a block-complete design from a minimum number of block devices based on the creation of combined aggregate structures, large-sized block devices (superblocks), prefabricated structures and units of maximum unit mass [8–10].

Therefore, *the aim of research* is to increase the efficiency of gas preparation and increase condensate extraction by using block artificial cooling units. After all, they allow to achieve a deeper purification of gas from heavy hydrocarbons and water, which improves the quality of the final product.

## 2. Materials and Methods

To prepare gas to meet requirements of the GTS (gas transportation system) and GDS (gas distribution systems) Codes in terms of the dew point temperature of gas for moisture (DPTM) and for hydrocarbons (DPTH) at all facilities, it is planned to install a low-temperature gas separation (LGS) unit using a freon refrigeration unit (FRU). The use of gas preparation technology using the LGS unit provides DPTM below minus 8 °C and DPTH about minus 20 °C. The initial data for the calculation are given in Table 1.

**Table 1**

Input data for the calculation

| No. | Parameter | Indicators | | | | |
|---|---|---|---|---|---|---|
| 1 | Productivity of the gas preparation unit (max.), thousand $m^3$/day | 250 | 150 | 50 | 35 | 20 |
| 2 | Gas pressure at the unit inlet (adv.), MPa | 0.7÷1.2 | 0.7÷1.2 | 0.7÷1.2 | 0.7÷1.2 | 0.7÷1.2 |
| 3 | Gas pressure at the unit outlet (adv.), MPa | 0.6÷1.1 | 0.6÷1.1 | 0.6÷1.1 | 0.6÷1.1 | 0.6÷1.1 |
| 4 | Gas temperature at the unit inlet (max.), °C | 15 | 15 | 15 | 15 | 15 |
| 5 | DPTH of gas at the unit inlet is reduced to a pressure of 3.92 MPa, °C | 32 | 32 | 32 | 32 | 32 |
| 6 | DPTH of gas at the unit inlet, °C | 14 | 14 | 14 | 14 | 14 |

The component composition of the gas is taken in accordance with the typical one for gas condensate fields. The component composition of the gas and its physicochemical properties are given in Table 2.

**Table 2**

Component composition of the gas and its physicochemical properties

| Component name | Component content, % vol. |
|---|---|
| Methane | 88.3500 |
| Ethane | 5.6145 |
| Propane | 1.2761 |
| Iso-Butane | 0.2430 |
| n-Butane | 0.2840 |
| neo-Pentane | 0.0000 |
| Iso-Pentane | 0.0600 |
| n-Pentane | 0.0470 |
| n-Hexane | 0.0450 |
| n-Heptane | 0.0375 |
| n-Octane | 0.0300 |
| n-Nonane+higher | 0.0375 |
| Nitrogen | 1.9872 |
| Carbon dioxide | 1.9882 |
| Physicochemical properties of gas at 20 °C and a pressure of 760 mm·Hg | |
| Chromatographic density, kg/$m^3$ | 0.767 |
| Relative density | 0.636 |
| Lower calorific value, kcal/$m^3$ | 8354.3 |

For technological calculations, the average annual volume of gas supply to the consumer is calculated as the average between the maximum and minimum volume of gas consumption by the local consumer. The minimum volume of gas consumption is taken at 10 % of the maximum. The maximum productivity of gas preparation units corresponds to the maximum volume of gas consumption by the local consumer. The annual volumes of gas consumption are taken as constant for the calculation period.

Technical characteristics and cost of the FRU are taken in accordance with the commercial offer [11, Appendix D].

The calculations assume the following expected terms of commissioning of technological equipment: LGS unit with the use of FRU – January 2024 [11].

## 3. Results and Discussion

The basic technological scheme of gas preparation is shown in Fig. 1. Raw gas undergoes preliminary purification from mechanical impurities and droplet liquid in the existing first-stage separator C-1 and is fed to the recuperative heat exchanger T-1 of the LGS unit. The cooled gas after the recuperative heat exchanger T-1 is fed to the inlet of the heat exchanger T-2, where it is cooled by an intermediate coolant from the FRU. After T-2, the gas with a temperature of minus 29 °C is fed to the existing second-stage separator C-2 to remove condensed liquid. The gas purified in C-2 passes through the heat exchanger T-1 for heat recovery and is fed to the consumer. To prevent hydrate formation, methanol is fed into the gas stream after C-1 in an amount of 2.66 kg/1000 $m^3$ of gas.

Liquid from separators C-1 and C-2 is fed to the three-phase separator P-1. Partially degassed condensate from P-1 is throttled to atmospheric pressure and fed to the tank E-1.

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 condensate production at the LGS, its degassing at atmospheric pressure and a temperature of 20 °C was assumed.

The results of technological calculations of gas preparation and additional condensate extraction volumes are given in Table 3.

The data in Table 3 allow to assess the efficiency of the unit, production and consumption volumes, as well as the dynamics of these indicators over time. As it is possible to see, most of the indicators remain unchanged throughout the period, which may indicate stable operation of the unit and the absence of significant changes in the technological process.

Capital investments in equipping facilities with additional technological equipment are given in Table 4.

As can be seen from Table 4, the cost of the unit is directly proportional to its productivity. The higher the productivity, the more expensive the equipment. This is explained by the fact that for processing larger volumes of gas, more powerful equipment and a larger number of materials are required.

The operational characteristics of additional technological equipment are given in Table 5.

As the unit productivity increases, electricity consumption also increases. This is logical, since more energy is required to process a larger volume of fluid.

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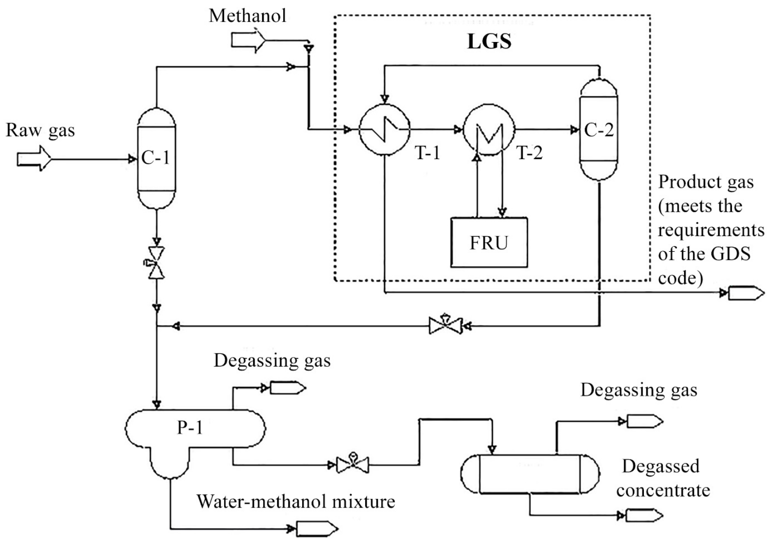


**Fig. 1.** Schematic technological scheme of gas preparation

**Table 3**

Results of technological calculations for gas preparation

| Year | Maximum unit capacity, thousand m³/day | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 250 | | | | 150 | | | | 50 | |
| | Average annual gas supply to the consumer*, million m³/year | Output of commercial gas, million m³/year | Output of degassed condensate from the LGS, t/year | Consumption of methanol 96 % by weight on the LGS, t/year | Average annual gas supply to the consumer*, million m³/year | Output of commercial gas, million m³/year | Output of degassed condensate from the LGS, t/year | Consumption of methanol 96 % by weight on the LGS, t/year | Average annual gas supply to the consumer*, million m³/year | Output of commercial gas, million m³/year |
| 2024 | 50.188 | 49.966 | 292.791 | 133.499 | 30.113 | 29.979 | 175.675 | 80.099 | 10.038 | 9.993 |
| 2025 | 50.188 | 49.966 | 292.791 | 133.499 | 30.113 | 29.979 | 175.675 | 80.099 | 10.038 | 9.993 |
| 2026 | 50.188 | 49.966 | 292.791 | 133.499 | 30.113 | 29.979 | 175.675 | 80.099 | 10.038 | 9.993 |
| 2028 | 50.188 | 49.966 | 292.791 | 133.499 | 30.113 | 29.979 | 175.675 | 80.099 | 10.038 | 9.993 |
| 2029 | 50.188 | 49.966 | 292.791 | 133.499 | 30.113 | 29.979 | 175.675 | 80.099 | 10.038 | 9.993 |
| 2030 | 50.188 | 49.966 | 292.791 | 133.499 | 30.113 | 29.979 | 175.675 | 80.099 | 10.038 | 9.993 |
| 2031 | 50.188 | 49.966 | 292.791 | 133.499 | 30.113 | 29.979 | 175.675 | 80.099 | 10.038 | 9.993 |
| 2032 | 50.188 | 49.966 | 292.791 | 133.499 | 30.113 | 29.979 | 175.675 | 80.099 | 10.038 | 9.993 |
| 2033 | 50.188 | 49.966 | 292.791 | 133.499 | 30.113 | 29.979 | 175.675 | 80.099 | 10.038 | 9.993 |
| 2034 | 50.188 | 49.966 | 292.791 | 133.499 | 30.113 | 29.979 | 175.675 | 80.099 | 10.038 | 9.993 |

| Year | Maximum unit capacity, thousand m³/day | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | | 35 | | | | 20 | | | |
| | Output of degassed condensate from the LGS, t/year | Consumption of methanol 96 % by weight on the LGS, t/year | Average annual gas supply to the consumer*, million m³/year | Output of commercial gas, million m³/year | Output of degassed condensate from the LGS, t/year | Consumption of methanol 96 % by weight on the LGS, t/year | Average annual gas supply to the consumer*, million m³/year | Output of commercial gas, million m³/year | Output of degassed condensate from the LGS, t/year | Consumption of methanol 96 % by weight on the LGS, t/year |
| 2024 | 58.558 | 26.700 | 7.026 | 6.995 | 40.991 | 18.690 | 4.015 | 3.997 | 23.423 | 10.680 |
| 2025 | 58.558 | 26.700 | 7.026 | 6.995 | 40.991 | 18.690 | 4.015 | 3.997 | 23.423 | 10.680 |
| 2026 | 58.558 | 26.700 | 7.026 | 6.995 | 40.991 | 18.690 | 4.015 | 3.997 | 23.423 | 10.680 |
| 2028 | 58.558 | 26.700 | 7.026 | 6.995 | 40.991 | 18.690 | 4.015 | 3.997 | 23.423 | 10.680 |
| 2029 | 58.558 | 26.700 | 7.026 | 6.995 | 40.991 | 18.690 | 4.015 | 3.997 | 23.423 | 10.680 |
| 2030 | 58.558 | 26.700 | 7.026 | 6.995 | 40.991 | 18.690 | 4.015 | 3.997 | 23.423 | 10.680 |
| 2031 | 58.558 | 26.700 | 7.026 | 6.995 | 40.991 | 18.690 | 4.015 | 3.997 | 23.423 | 10.680 |
| 2032 | 58.558 | 26.700 | 7.026 | 6.995 | 40.991 | 18.690 | 4.015 | 3.997 | 23.423 | 10.680 |
| 2033 | 58.558 | 26.700 | 7.026 | 6.995 | 40.991 | 18.690 | 4.015 | 3.997 | 23.423 | 10.680 |
| 2034 | 58.558 | 26.700 | 7.026 | 6.995 | 40.991 | 18.690 | 4.015 | 3.997 | 23.423 | 10.680 |

**Note:** * calculated as the average between the maximum and minimum volume of gas consumption by a local consumer (the minimum volume of gas consumption is taken at 10 % of the maximum)

**Table 4**

Capital investments in equipping facilities with additional technological equipment for the corresponding maximum productivity

| No. | Equipment name | Estimated cost of equipment (including VAT), UAH (USD) | | | | |
|---|---|---|---|---|---|---|
| | | 250 thousand $m^3$/day | 150 thousand $m^3$/day | 50 thousand $m^3$/day | 35 thousand $m^3$/day | 20 thousand $m^3$/day |
| 1 | Recuperative heat exchanger (T-1) | 1725936 (41629) | 1725936 (41629) | 151283 (3649) | 90770 (219) | 64460 (1555) |
| 2 | Cooler heat exchanger (T-2) | 668274 (16118) | 376233 (9075) | 181539 (4379) | 128919 (3109) | 128919 (3109) |
| Main equipment of the LGS unit together | | 2394210 (54747) | 2102169 (50704) | 332822 (8028) | 219689 (5299) | 193379 (4664) |
| Pipelines, fittings, metal structures, 25 % of the cost of the main equipment | | 598553 (14437) | 525542 (12676) | 83205 (2007) | 54922 (1325) | 48345 (1166) |
| Engineering, 20 % of the cost of the main equipment | | 478842 (11550) | 420434 (10140) | 66564 (1605) | 43938 (1060) | 38676 (933) |
| Assembly and construction work, 50 % of the cost of the main equipment | | 1197105 (28873) | 1051085 (25352) | 166411 (4014) | 109844 (2650) | 96689 (2332) |
| Total cost of the LGS unit | | 4668710 (112607) | 4099230 (98872) | 649002 (15654) | 428393 (10333) | 377088 (9095) |
| Unaccounted costs, 25 % of the total cost of the LGS unit | | 1167177 (28152) | 1024807 (24718) | 162250 (3914) | 107098 (2583) | 94272 (2274) |
| Freon refrigeration unit (FRU) | | 2198496 (53027) | 1467876 (35405) | 648227 (15635) | 504072 (12158) | 302694 (7300) |
| TOTAL | | 8034383 (193786) | 6591913 (158995) | 1459480 (35202) | 1039563 (25074) | 774054 (18670) |

**Table 5**

Operational characteristics of additional technological equipment

| No. | Name | 250 thousand $m^3$/day | 150 thousand $m^3$/day | 50 thousand $m^3$/day | 35 thousand $m^3$/day | 20 thousand $m^3$/day |
|---|---|---|---|---|---|---|
| 1 | Average FRU electricity consumption, kW/hour | 67.0 | 36.0 | 22.5 | 18.5 | 9.0 |
| 2 | Unit operating time, hours/day | 24 | 24 | 24 | 24 | 24 |

As a result, a linear relationship between productivity and energy consumption was obtained, that is, if productivity increases by two times, energy consumption will also increase by about two times.

This technology is of great *practical importance*, because it allows to accurately calculate the required electricity power for the unit to operate in different modes, helps determine the optimal mode of operation of the unit in terms of energy consumption.

Despite its value, *there are certain limitations*, because Actual consumption may vary depending on factors such as raw material quality, ambient temperature, equipment wear. Electricity losses in networks and transformers are also not taken into account.

*Martial law* also had an impact on the results of the study, because the difficulty lies in importing the necessary equipment and reagents.

*In the future*, it is desirable to compare the energy efficiency of this unit with similar units at other enterprises and conduct a study of the impact of seasonal factors on energy consumption.

## 4. Conclusions

The conducted studies confirm the effectiveness of the low-temperature separation technology for gas preparation. The results obtained can be used for further development and improvement of technological processes in the oil and gas industry:

– it was established that the technological process of gas preparation is stable and ensures effective condensate extraction at the maximum productivity of the unit of 250 thousand $m^3$/day it will be 292.791 t/year;

– the calculations made it possible to assess the economic efficiency of the project and determine the optimal operating modes of the unit;

– the obtained data can be used to optimize the technological process in order to reduce costs and increase production efficiency.

## Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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The research was performed 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 current work.

### References

1. Maliarenko, V. A., Senetskyi, O. V. (2021). *Teplomasoobmin v obiektakh alternatyvnoi enerhetyky*. Kharkiv: KhNUMH im. O. M. Beketova, 311.
2. *Pro zatverdzhennia Kodeksu hazorozpodilnykh system* (2015). Postanova Natsionalnoi komisii, shcho zdiisniuie derzhavne

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rehuliuvannia u sferakh enerhetyky ta komunalnykh posluh No. 2494. 30.09.2015. Available at: https://zakon.rada.gov.ua/laws/show/z1379-15#Text

3. Asadullah, M. (2014). Biomass gasification gas cleaning for downstream applications: A comparative critical review. *Renewable and Sustainable Energy Reviews, 40,* 118–132. https://doi.org/10.1016/j.rser.2014.07.132
4. Koyuncu, I., Yilmaz, C., Alcin, M., Tuna, M. (2020). Design and implementation of hydrogen economy using artificial neural network on field programmable gate array. *International Journal of Hydrogen Energy, 45 (41),* 20709–20720. https://doi.org/10.1016/j.ijhydene.2020.05.181
5. Kopyscinski, J., Schildhauer, T. J., Biollaz, S. M. A. (2010). Production of synthetic natural gas (SNG) from coal and dry biomass – A technology review from 1950 to 2009. *Fuel, 89 (8),* 1763–1783. https://doi.org/10.1016/j.fuel.2010.01.027
6. Akolaş, H. İ., Kaleli, A., Bakirci, K. (2020). Design and implementation of an autonomous EGR cooling system using deep neural network prediction to reduce NOx emission and fuel consumption of diesel engine. *Neural Computing and Applications, 33 (5),* 1655–1670. https://doi.org/10.1007/s00521-020-05104-1
7. Shao, G., Hanaor, D. A. H., Shen, X., Gurlo, A. (2020). Freeze Casting: From Low-Dimensional Building Blocks to Aligned Porous Structures – A Review of Novel Materials, Methods, and Applications. *Advanced Materials, 32 (17).* https://doi.org/10.1002/adma.201907176
8. Petruniak, M., Rubel, V., Chevhanova, V., Kulakova, S. (2021). Application of grout slurries with the defecate addition for effective well cementing. *Mining of Mineral Deposits, 15 (1),* 59–65. https://doi.org/10.33271/mining15.01.059
9. Wan, K., Barnaud, C., Vervisch, L., Domingo, P. (2020). Chemistry reduction using machine learning trained from non-premixed micro-mixing modeling: Application to DNS of a syngas turbulent oxy-flame with side-wall effects. *Combustion and Flame, 220,* 119–129. https://doi.org/10.1016/j.combustflame.2020.06.008
10. Hadian, M., Saryazdi, S. M. E., Mohammadzadeh, A., Babaei, M. (2021). Application of artificial intelligence in modeling, control, and fault diagnosis. *Applications of Artificial Intelligence in Process Systems Engineering.* Elsevier, 255–323. https://doi.org/10.1016/b978-0-12-821092-5.00006-1
11. Shevchuk, L. V. (2020). *Quality management of business processes in the supply chain of refrigeration equipment.* Natsionalnyi Aviatsiinyi Universytet. Available at: https://er.nau.edu.ua/handle/NAU/45524

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