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Features of planning and implementation of energy-saving measures at compressor stations of main gas pipelines

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<p>Received: 14 March 2021 Peer reviewed: 15 April 2021 Accepted: 13 May 2021</p>	<p>Abstract Currently, the National gas supply operator in Kazakhstan pays special attention to the rational use of natural gas for its own and technological needs, while maintaining the optimal management of the gas transportation system, taking into account the specific technical situation of the equipment. Energy efficient management of gas pipelines is one of the priority directions for optimizing gas costs. The use of innovative methods of energy-saving technologies during the operation of the gas transmission system, an increase in the efficiency of gas-pumping units, as well as the implementation of automated energy saving control systems, will significantly increase the efficiency of gas transportation.</p> <p>Keywords: Pipeline, natural gas, gas-pumping unit, operation, compressor stations.</p>
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Introduction

Comprimation of gas at compressor stations (COP) is the most energy-intensive thermal power process in the gas industry, therefore the problem of reducing energy costs will first of all be aimed at improving the efficiency of compressor stations as basic consumers of fuel and energy resources. This task is largely enhanced, if we take into account that the efficiency of gas turbine installations operated on gas pipelines (GTU), the total capacity of which is over 80% of the power of all other specified species

of the energy receipt, in some cases, is at the level of 20 -22%.

The energy efficient mode of operation of the compressor station is the mode in which the necessary technological indicators of the main gas pipeline is provided (performance, working pressure and temperature) at a minimum of electricity costs (for COP with electric parking lot gas-pumping units (GPU)) and minimum fuel gas costs (for COP with gas turbine Park GPU).

One of the priority activities of the Operator is to improve the efficiency of the use of fuel and

energy resources (FER) - natural gas, electricity and thermal energy.

Methods

In the conditions of using different types of equipment at compressor stations with individual characteristics, the task of developing methods for modeling the analytical dependencies of the equipment, taking into account the actual technical condition, is relevant. Optimization of the technological modes of natural gas transportation will increase the energy efficiency of the compressor stations of the main gas pipeline.

Research

To effectively manage, control, calculate and optimize the operation of gas pumping units (GPU) of a compressor station (COP), it is necessary to adapt mathematical models describing the

relationship between technological parameters, taking into account the technical condition [4, 7].

The GPU consists of a natural gas supercharger, a discharge drive, suction and exhaust devices (in the case of a gas turbine drive), automation systems, oil-systems, fuel-air and oil communications and auxiliary equipment.

GPU on the type of forcing distinguish between reciprocating gas compressors (gas engine compressors) and GPU with centrifugal superchargers; type of drive - GPU with a gas internal combustion engine (gas engines), with gas turbine drive and electric.

GPU with a gas turbine drive, in turn, are divided into units with a stationary gas turbine installation and a drive for aircraft and gas turbine engines [1, 2, 3].

A reciprocating gas engine compressor is a GPU consisting of a two - or four-stroke gas engine (or electric motor) and a horizontal reciprocating compressor connected directly to it. They are divided into low, medium and high pressure units.

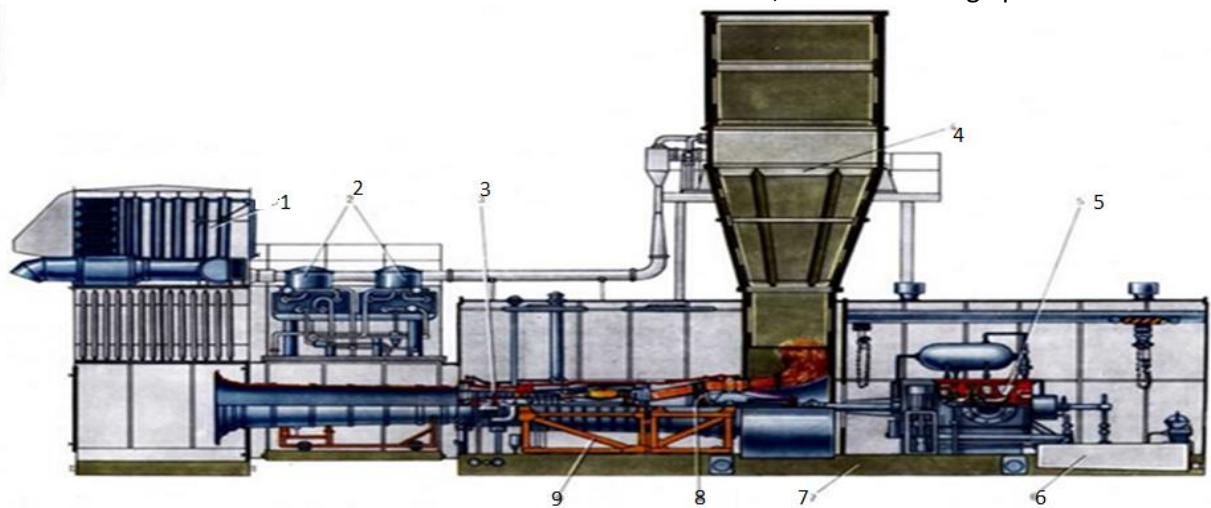


Figure 1 - Gas-pumping block-container unit GPU-C-16 with air drive: 1-inlet air purifier; 2-oil radiators; 3-aircraft drive NK-16 KT; 4-exhaust device with noise silencer; 5-natural gas supercharger; 6-oil tank of the unit; 7-base metal frame of the unit; 8-power turbine of the unit; 9-under-engine frame of the air drive

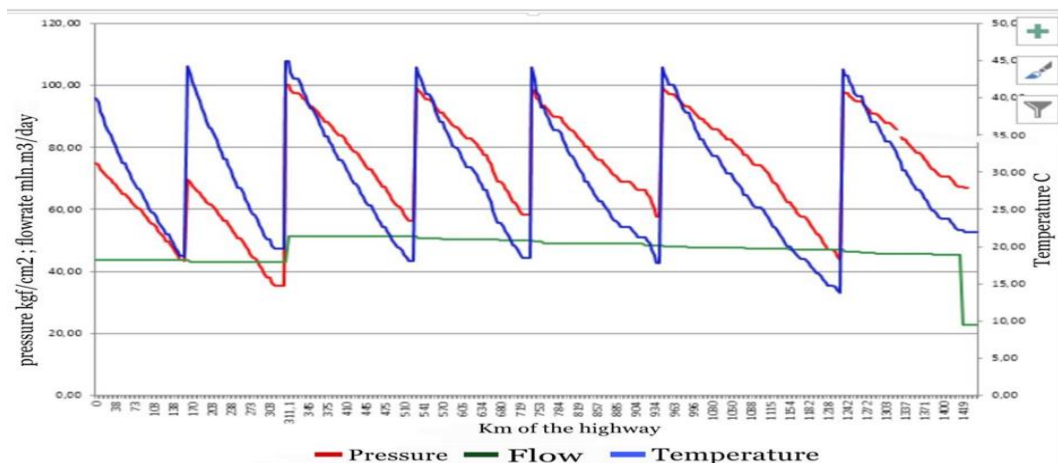


Figure 2 - Pressure and temperature changes along the MG Beineu-Akarys highway

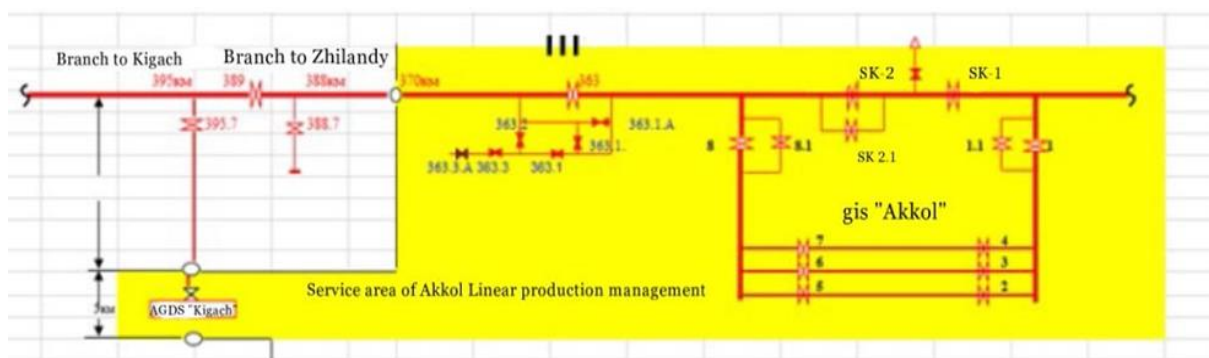


Figure 3- Technological scheme of the section of the MG "Makat-North Caucasus" with 362-370 km

Medium-pressure compressors (2-5 MPa) operate mainly at intermediate compressor stations to increase the throughput of gas pipelines. High-pressure units (9.8-12 MPa) are installed at compressor stations for pumping gas to underground storage facilities.

Gas motor compressors are highly efficient in conditions of variable capacities and compression ratios above 1.3. The main advantages of these GPU are: reliability in operation; long service life; the ability to operate in a wide range of pressures; the ability to regulate performance by changing the speed of the units, as well as the ability to create high pressures in them. The efficiency of modern gas engine compressors is up to 45%.1.

Table 1 - Pipe and gas parameters of Makat-North Caucasus gas Station

<i>Pipe and gas parameters</i>		
<i>Outer diameter</i>	<i>mm</i>	1067
<i>Wall thickness</i>	<i>mm</i>	12,1
<i>The inner diameter of the pipe</i>	<i>mm</i>	1042,8
<i>Pipe roughness coefficient-t</i>	<i>mm</i>	0,03
<i>Gas density</i>	<i>kg/m³</i>	
<i>Air density at 293 K and 0.1013 MPa</i>	<i>kg/m³</i>	1,205
<i>Density by air</i>		0,586
<i>Coefficient of unevenness</i>		0,941
<i>Dynamic viscosity</i>	<i>kg power sec/m²</i>	0,0000012 706
<i>Efficiency coefficient</i>		0.95

There are single-stage (incomplete-pressure) centrifugal superchargers with a compression ratio of 1.23-1.25 and two-stage (full-pressure) - 1.45-1.7. Centrifugal superchargers are characterized by a

significantly higher capacity than that of reciprocating compressors (12-40 million m³ / day).

The disadvantage of partial pressure centrifugal blowers is that to achieve a gas compression ratio of 1.45-1.5, it is necessary to start 2 series-connected units. This leads to an increase in fuel consumption in the GPU. The efficiency of units with centrifugal fans is up to 29%, thermoregulators - up to 35%. The GPU is controlled by a gas turbine unit or an electric motor [4, 5, 6].

Gas turbine units of aircraft and ship types (stationary) are characterized by small dimensions and weight, which allows them to be modified on the production site and delivered to the compressor stations in a ready-made form. Gas-pumping units controlled by aircraft units are made in the form of block containers. It is delivered to compressor stations with fire and explosion protection systems. In the GPU, asynchronous motors with a capacity of 4500 kW and synchronous motors from 4000 to 12,500 kW are used as electric drives. The maximum efficiency of the gas pumping unit with an electric drive is achieved when the compressor stations are located at a distance of 300 km from the power line.

Automation systems have been created for all types of GPU, providing automatic start-up and operation of the unit, protection in emergency modes, fault signaling and protective actions, and monitoring of volume indicators. fan, automatic maintenance of the set temperature and oil pressure in case of emergency shutdown of the unit, etc.

Each type of compressor has its own design and functional characteristics. Therefore, when choosing a compressor or accelerator for your graphics processor, it is important to fully consider its operating conditions and performance requirements [5]. The following parameters are considered important:

- the volume of the pumped gas and the pressure and temperature of the gas inlet/outlet;

- chemical composition and humidity of the injected gas;

Characteristics of the GPU installation site (maximum and minimum air temperature, altitude above sea level); type of disk used;

- annual working time;
- performance class (explosion, earthquake, etc.);
- permissible amount of oil in the exhaust gas;
- type of automation (electric or pneumatic).

Certain types of compressors are best used in the following conditions:

Piston compressor - high degrees of pressure increase and high absolute pressures, variable modes, relatively small flows and capacities (up to 6 MW).

Screw compressor - high degrees of pressure increase at low absolute pressures and small pressure drops, variable modes, relatively small flows and capacities (up to 2000 kW) [1, 2, 7].

Centrifugal compressor - large flows and capacities, preferably small degrees of pressure increase and low absolute pressures, constant modes.

It can be noted that the issue of energy saving should be solved using an integrated approach and considered from the point of view of the operation of the entire gas transmission system as a whole. When calculating the operating modes of the Gas transmission system, the actual gas-dynamic characteristics of the COP equipment, obtained on the basis of the passport characteristics of the equipment, should be used.

In accordance with the Concept of Energy Saving, one of the directions of implementing the energy saving and energy efficiency policy is to improve the efficiency of energy saving management, including improving its organizational structure, monitoring the level of energy saving and energy efficiency, and developing the regulatory framework for energy saving. Currently, energy

saving in the industry is implemented in accordance with regulatory documents.

To plan and implement energy-saving measures in gas transmission Companies, energy-saving programs are drawn up for a certain period of time.

In the energy saving program, they form:

- energy saving targets;
- energy efficiency targets;
- integral results of the assessment of the economic efficiency of the implementation of energy-saving results and projects based on the implementation of the best achieved technologies;
- a set of organizational and technical measures to improve energy efficiency in the field of energy saving, including measures based on the results of energy surveys of technological facilities for all types of activities;
- the speed of rotation of the rotor of centrifugal superchargers.

The efficiency of gas transport depends on both operating modes and on the technical condition of the equipment of compressor stations. The efficiency of the COP is determined by the type and state of the GPU. Currently, a significant part of the GPU on the COP has operational efficiency, significantly lower than the passport value, which leads to a significant overcurrent of fuel gas to the pump. This is due to two factors - a decrease in the technical condition of the GPU (which, ultimately, leads to the need to replace them) and their underload, which requires solving the problem of optimizing the operation of the COP. Periodic update of the GPU on the COP is the necessary and legitimate way to improve gas transport indicators in general and reduce energy consumption for its implementation. The main transport of natural gas has the greatest potential for saving, there are known typical energy-saving measures used in the main transport of gas.

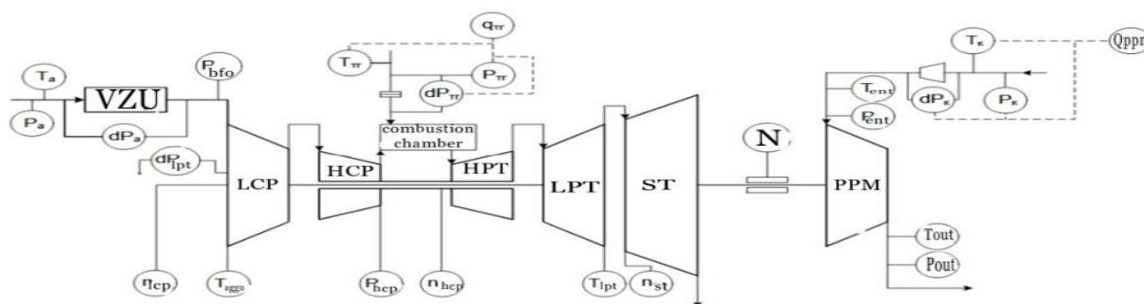


Figure 4 - Schematic diagram of the measurement of technological parameters by standard means using Sauer

Innovative energy-saving technologies for the reconstruction and modernization of the gas transmission system include:

- increasing the capacity of the GPU, taking into account the planned volumes of transported natural gas and the prospects for loading the pipeline;
- the use of axial compressors on gas turbine and electric GPU with an efficiency of up to 85%, providing a reduction in fuel gas consumption of up to 7%;
- improving the efficiency of low-pressure modes of gas transport on unloaded gas pipelines or on individual sections of gas transmission systems (the effect in saving fuel gas can be up to 8%);
- coordination of gas-dynamic characteristics of gas turbine units and gas pipelines due to the introduction of new high-efficiency flow parts in gas turbine and electric compressor shops (COP) and the transfer of shops to more economical full-pressure compression with re-linking of units (the effect of saving fuel gas and electricity can reach 9%);

Innovative energy-saving technologies in the operation of the gas transmission system:

- optimization of GTS operating modes based on software optimization systems (the effect of fuel economy can reach 3%);
- optimization of the operating modes of gas cooling devices based on the use of modern electric drives (the effect in saving electrical energy can reach 15%);
- introduction of turbo-expander units at GTS facilities for electric power generation;
- the use of gas-piston power plants of a new generation with high efficiency, which allows you to get the effect of saving gas consumption for your own needs up to 25%;
- increasing the hydraulic efficiency of the linear part and compressor considering streaming download pipelines based on sets of cameras launching and receiving treatment devices in the linear part, allowing for the cleaning of pipelines timely diagnosis and repairs to keep the hydraulic efficiency of the linear part at the normative level (the effect in saving of fuel gas consumption GPU in compression reaches 2%);
- improvement of methods and systems for waste heat recovery of the exhaust gas at compressor stations;
- equipment of technological equipment with modern means of measuring the production and consumption of energy resources.

During operation of gas delivery systems to ensure energy efficiency objectives to cs gas

pipelines it is necessary to assess the basic technological performance GPU: gas Turbine power plant, fuel consumption, effective efficiency, the coefficients of the technical condition and the flowing parts of gas turbines and centrifugal compressors.

On COP equipped with automatic control systems of the GPU, these indicators should be determined in real time. However, at the COP, even when equipped at the shop level with microprocessor-based control and control systems, the GPU is not determined with the necessary accuracy. In this regard, the operating personnel do not have the important information necessary to ensure the energy-efficient operation of the GPU at the compressor stations.

The reason is the lack of simple, but at the same time quite accurate methods and algorithms for determining the technical indicators of GTP. The methods should also be universal with the possibility of adaptation for any type of GTP.

Energy-saving issues should not be solved periodically, but constantly. Of particular importance in this case is the dispatching control of the main gas transport.

If multiple modes of operation of technological equipment, the CS decided a complex set of tasks: information software and dispatching services; organization of accounting of a consumption of gas on their own and technological needs of the COP; operational cooperation dispatch service with the production and dispatch service operator in providing technology compression at the transport of gas.

In the information software of dispatching tasks, diagrams of the given characteristics of the GPU are usually used for the calculation. These diagrams have a number of drawbacks: the given characteristics are not constant (they undergo deformation with the operating time of the aggregates), in addition, they are obtained according to a number of assumptions.

In this regard, an alternative analytical method is used to calculate the operational characteristics of the GPU of compressor stations, develop a system of initial and converted values of fuel and energy indicators of the GPU, solve the problem of the influence of the adiabatic efficiency of the axial compressor and turbine, the efficiency of the combustion chamber on the output indicators of the GTP-effective power and efficiency, fuel gas consumption and commercial performance of the GPU.

The deterioration of the efficiency of the main elements to varying degrees affects the deterioration of the main characteristics of the GPU. So, while reducing the adiabatic efficiency of the axial compressor 5-10% effective capacity and commercial performance decrease by 15-32%, respectively, and decreasing the adiabatic efficiency of the gas turbine at 5 and 10% capacity and performance reduced by 20% and 39%. Commercial performance depends more on the adiabatic efficiency of the axial compressor and turbine than on the polytropic efficiency of the centrifugal supercharger, for example, if the latter is reduced by 5%, commercial performance also decreases by 5%.

Increase the efficiency of gas turbines, a new generation can be achieved by increasing the gas temperature before the turbine and the pressure ratio of an axial compressor, but the implementation of such indicators is complicated by the degradation of gas turbines and ensuring the assigned resource GTP becomes difficult without the use of new design solutions and material with high heat resistance.

On the example of regulating the operating modes of the three-shaft installation of the GPU -10 "Wave", the characteristics of the control panel = f (tvx, N) are used in graphical form (Fig. 5).

The paper considers a method of modernization of a gas turbine plant for energy saving purposes. This goal is achieved by the system of injection of prepared water into the combustion chamber in an amount that allows you to completely replace the main purpose of secondary air in the heat balance of the GTP.

The Gorenje water, entering the annular space between the casing (housing) and the combustion chamber heat pipe, instantly evaporates due to the high temperature of the walls

of the heat pipe under the action of the combustion zone inside the heat pipe; the flame temperature reaches 1800-2200 °C. The vapor formed during evaporation with a temperature of 250-350 °C plays the role of secondary air.

In order to increase the efficiency of the GPU, we consider the option of mixing natural gas with hydrogen, which has a higher flame propagation speed, wider ignition limits, while reducing the fuel gas consumption.

The technical condition of the GPU, determined by the quality of its manufacture, installation on the COP and repairs carried out, significantly affects the consumption of energy resources. The coefficient of technical condition for the power of a gas turbine driven GPU is usually at the level of 0.85 - 0.90 and even lower, and the efficiency of the operated units is significantly lower than the design level, which can not but affect the reduction in the indicators of natural gas transport. Calculations show that the fuel gas consumption on the gas turbine drive can be reduced by 5 - 6% only by improving the quality of the repairs carried out by the gas turbine engine.

To assess the possibility of calculation, simulation and synchronization of modes of operation of gas turbines and mill in the composition of the GPU method of power balance proizvedeniakh the technical condition for power turbines and mill on the basis of the data industry performance measurements. The reference values of power consumption for a turbine of the supercharger (next – T) system "GTP- mill" is defined capacity values for each industrial measurement on the basis of gas-dynamic parameters of the flow of gas through the mill by the method of "enthalpy" [17, 18]:

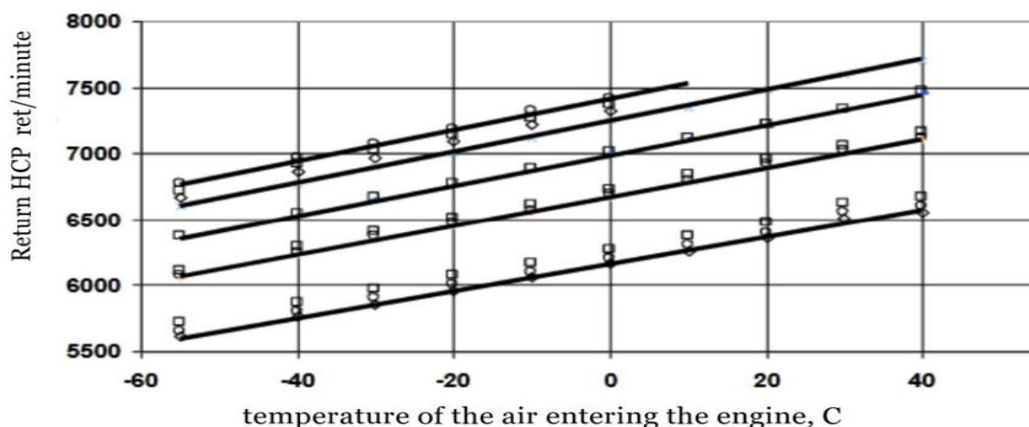


Figure 5 - The dependence of the speed of the high-pressure stage on the air temperature at the engine inlet

$$NE=N_i+\Delta NM+NT, \quad (1)$$

where N_i is the internal power of the pulp and paper mill, kW;

ΔNM -mechanical losses in the pulp and paper mill, kW;

NT – heat loss of the CBN to the environment, kW.

$$N_i=H_i \cdot G_H \quad (2)$$

where H_i is the internal specific work of the pulp and paper mill, kJ/kg;

G_H – mass flow rate of gas through the flow part of the pulp and paper mill, kg/ s.

$$H_i=l_{2H}-l_{1H} \quad (3)$$

where l_{2H} and l_{1H} are the enthalpy of the pumped natural gas in the sections of the inlet and outlet pipes of the pulp and paper mill, kJ/kg.

$$N_T=\alpha_T \cdot F \cdot (T_H-T_A) \cdot 10^{-3} \quad (4)$$

where α_T is the coefficient of heat transfer to the environment, according to [17, 18], for performing estimated calculations, it is allowed to take [4, 5, 10]

$$\alpha_T=14 \frac{B_T}{m^2K};$$

F the surface area of pulp and paper mill (passport size, also can be determined using the procedure of laser surface scan PPM), m^2 ;

T_H, T_A the average temperatures of the pulp mill housing (can be determined by thermal imaging of the surface of the pulp mill housing or overhead temperature sensors) and the ambient air.

According to [15, 16, 17] the mechanical losses of GPU ΔNm do not exceed 1.0-1.5% of the power consumption. The most reliable assessment of mechanical losses can be made with the use of torque meters installed on the shaft of the supercharger turbine (power turbine) or special tests in the factory. More detailed thermal and gasdynamic calculations using the "enthalpy" method (as well as the "Schultz" method) are described in the methodology [14, 13].

In the design, construction and reconstruction of compressor stations, it is necessary that the main equipment and auxiliary equipment comply with the following aspects:

- If the requirements of the design capacity at the plant are met with the design volume of gas

transportation, the installed gas turbine units must provide highly efficient transportation of the required volumes of gas over long distances;

- The units must provide convenience during operation and repair work;

-For the convenience of operation, maintenance and maintenance, it is necessary to use gas pumping units of the same model at the station. Gas pumping units must work effectively under the climatic conditions of this station.

- Based on the experience of using the units, as well as taking into account the needs and parameters of this gas pipeline, the GPU should be able to repair in the conditions of the COP;

- The compressors must meet the relevant operating requirements in accordance with the volumes of gas transportation over the years, taking into account the possibility of adapting to changing (adapt to changes) volumes of gas transportation. The efficiency of the compressors at the design volume of gas transportation should be maximum, the compressors should work highly efficiently in all possible operating modes.

The use of centrifugal compressors with an electric drive, equipped with an appropriate system of power supply, distribution, and energy supply, can fully meet the needs of working with various changes in the situation on the pipeline. Usually, the presence of several sources of cheap electricity in the construction area of the COP can serve as a basis for making a decision to use an electric drive.

The following technical and economic criteria should be applied to solve the tasks of selecting a GPU and constructing a COP:

- minimum input capacity (GPU);

- maximum reliability of the COP operation at a given performance;

- minimum capital expenditures for equipment and operating costs for the CS.

Guided by the generally accepted design standards in the oil and gas industry, the recommended number of GPU, their unit capacity, and technological characteristics should be determined by the results of appropriate calculations and comparative analyses.

The number of units should be calculated based on the estimated capacity for the COP as a whole, taking into account the available capacity of one GPU. The available power of the GPU depends on the operating conditions (ambient temperature, high-altitude location of the GPU), as well as the characteristics of the GPU itself, provided by the manufacturer.

For the long-distance transportation of natural gas through a pipeline, a centrifugal compressor is mainly used.

The centrifugal type compressor refers to high-speed units, the effective operation of which is possible only in conditions of high rotational speeds. The selected drive can be a gas turbine unit, or an electric motor. To transport large volumes of gas over long distances, gas turbine units are mainly used as the drive of the GPU centrifugal compressor.

The main advantage of the centrifugal compressor is a large pumping volume, large capacity of a single unit, small relative weight, simple design, small footprint, high operating efficiency, stable gas flow volume, low noise, convenient operation, long service life, low maintenance costs, while the compressed gas does not come into contact with the lubricating oil of the compressor mechanisms, so high quality gas transportation is ensured.

Modern centrifugal compressors have a wide range of performance, being machines with minimal maintenance costs with a long service life, have an efficient dry gas sealing system (DGS), do not require reducing the number of revolutions or can be connected to the drive shaft through a coupling. [10]

Introduction of automated energy-saving management systems, hereinafter referred to as the Automated Power Supply Management System, is intended for monitoring and accounting of COP power supply facilities.

The COP management system is built as distributed with the decentralization of individual management functions. The goals of creating an integrated automated process control system and ES are:

- improving the efficiency and quality of decision-making on the management of energy supply and gas supply system;

- improving the reliability of gas and power supply, rapid elimination of pre-emergency and emergency modes, with subsequent analysis of emergency situations;

- technical and commercial accounting of gas and electricity consumption; introduction of equipment operation diagnostics.

The COP APSMS are designed for automated control and real-time control of the compressor station power supply, as well as for transmitting the necessary information to the CS APSMS. [9, 11-16]

The objectives of the establishment of the APSMS are:

- improving the efficiency of energy supply quality management;

- improving the reliability of power supply;
- improvement of the system of accounting for the quantity and quality of electricity received;
- accounting and control of electricity consumption;
- timely submission of reliable information to operational personnel on the progress of the technological process, the state of equipment and controls; reduction of unproductive costs and energy losses;
- improvement of primary equipment diagnostics and reduction of equipment repair costs; provision of personnel with retrospective technological information;
- the possibility of including the APSMS in automated systems of the highest level.

Save energy. The gas industry annually consumes tens of billions of kilowatt-hours of electricity, so the economical use of this energy is an urgent task. The main sources of its savings are the introduction of rational technological regimes based on the achievements of science and technology, the rationalization of power supply schemes, the improvement of the operation of energy and technological equipment, the introduction of new technology and progressive electricity consumption standards.

It is important to properly account for and analyze the specific energy consumption per unit of production. This is one of the main indicators that characterize the technical and economic level of production in general and the degree of rational management of the electric economy. The norms of specific electricity consumption allow you to control the state of production by comparing the actual consumption with the recommended or normalized one obtained over a long period of operation at a similar production or a separate production process [6, 14, 15].

Conclusions

The application of the approaches discussed in the design and reconstruction of compressor stations will improve the energy efficiency indicators of the COP, reduce the power consumption of compressor stations and reduce the cost of fuel gas. The calculation and selection of the main electric power equipment should be carried out taking into account the maximum savings and reduction of electricity losses due to the selection of optimal technical characteristics, possible operating modes of the equipment.

The use of electrical equipment that meets the modern requirements of international standards should be provided.

For example, measures to heat and increase the temperature of the fuel gas at the inlet of gas-piston power plants provide less gas consumption for electricity generation. A modern control system for parallel operation of generators will ensure an even distribution of the load between the installations, save the equipment from premature wear, and increase the inter-repair periods.

Also, the utilization of the heat of the exhaust gases for heating the air supplied for mixing with the fuel gas can serve to increase the efficiency of using gas-piston power plants. Rational loading of generators when the CS is not running at full capacity allows you to save fuel gas, extend the life of the equipment.

Conflict of interest. On behalf of all authors, the corresponding author declares that there is no conflict of interest.

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Магистральдық газ құбырларының компрессорлық станцияларында энергия үнемдеу шараларын жоспарлау және іске асыру ерекшеліктері

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ТҮЙІНДЕМЕ	
<p>Алынған: 14 наурыз 2021 Сараптама жасалды: 15 сәуір 2021 Қабылданған: 13 мамыр 2021</p>	<p>Қазіргі уақытта Қазақстандағы Ұлттық газбен жабдықтау операторы жабдықтың нақты техникалық жағдайын ескеріп және газ тасымалдау жүйесін оңтайлы басқаруды сақтай отырып, табиғи газды өз қажеттілігі және технологиялық қажеттіліктер үшін ұтымды пайдалануға ерекше назар аударады. Газ құбырларын энергиялық жағынан тиімді басқару - бұл газ шығынын оңтайландырудың басым бағыттарының бірі. Газ тасымалдау жүйесінің жұмысында энергия үнемдейтін технологиялардың инновациялық әдістерін қолдану, газ айдайтын қондырғылардың жұмысының тиімділігін арттыру, сондай-ақ автоматтандырылған энергия үнемдеу жүйесін енгізу газ тасымалдау тиімділігін едәуір арттыруға мүмкіндік береді. Түйін сөздер: Құбыр, табиғи газ, газ айдау қондырғысы, пайдалану, компрессорлық станциялар.</p>
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Особенности планирования и реализации энергосберегающих мероприятий на компрессорных станциях магистральных газопроводов

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Поступила: 14 марта 2021 Рецензирование: 15 апреля 2021 Принята в печать: 13 мая 2021	АННОТАЦИЯ В настоящее время Национальный оператор газоснабжения в Казахстане уделяет особое внимание рациональному использованию природного газа для собственных и технологических нужд при сохранении оптимального управления газотранспортной системой с учетом конкретной технической ситуации оборудования. Энергоэффективное управление газопроводами - одно из приоритетных направлений оптимизации затрат на газ. Использование инновационных методов энергосберегающих технологий при эксплуатации газотранспортной системы, повышение КПД газоперекачивающих агрегатов, а также внедрение автоматизированных систем управления энергосбережением позволит значительно повысить эффективность транспортировки газа. Ключевые слова: Трубопровод, природный газ, газоперекачивающих агрегат, эксплуатация, компрессорные станции.
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