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ESTIMATION OF THERMODYNAMIC EFFICIENCY OF USING EXPANDER-GENERATOR UNIT

Introduction

Currently, considerable attention is paid to the development of measures to improve the energy efficiency of production.

These developments are associated, in particular, with the use of various types of energy that are lost in the main production process.

The work of modern industrial enterprises, equipment, as a rule, is accompanied by the release of a significant amount of heat. Its use is hampered by its low temperature potential. Work on the use of low-grade thermal energy is carried out in almost all developed countries of the world and, undoubtedly, are perceived as an urgent scientific and engeeniring problem.

The processes of transportation and distribution of natural gas are associated with the appearance of surplus heat and potential energy. Their utilization at gas distribution stations (GDS) can increase both the autonomy of the stations and the overall efficiency of the entire gas transporting system.

In the world practice, a sufficiently large experience has already been accumulated in research and development of scientific and technical solutions aimed at utilization the power potential of fuel gas at gas distribution stations and gas control points (GCP).

One of the energy efficiency technologies for power generation is the expander-generator technology. It is based on the using of expander-generator units (EGU) for technological reduction of the pressure of the transported gas.

An expander-generator set is a device in which the energy of the transported natural gas stream is converted first into mechanical energy in an expander and then into electrical energy in a generator. Cold, which is used to obtain liquefied gas, can be obtained simultaneously with the electrical energy.

In the gas supply system of Ukraine, the pressure of the transported gas is reduced by throttling and is usually carried out in two stages — at the gas distribution station and at gas control points.

Gas is supplied to industrial and urban gas supply systems through gas distribution stations from the main gas pipelines, the pressure in which is maintained by compressor gas pumping stations at the level of 5.5–12 MPa. The gas pressure in the gas pipelines is reduced to the required value at gas distribution stations. The gas pressure is reduced to the values required by the consumer at gas control points.

Depending on the consumer category, low pressure distribution gas pipelines are distinguished — for gas supply to residential buildings (0.003 MPa); medium and high pressure — for supplying gas to industrial enterprises (for consumers of category I, pressure, as a rule, is 1.2 MPa and for category II — 0.6 MPa).

Currently, the energy of reduced natural gas is considered as one of the most significant but not enough used reserves of secondary energy resources

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in the gas industry. One of the ways to save energy resources is the using of the natural gas reduction process in gas distribution stations and gas control points with partial return of the energy spent on natural gas compression for its transportation. The main way of its implementation is the replacement of throttling devices of gas distribution stations and gas control points with expander-generator units designed to generate electricity through the use of excess gas pressure in the gas pipelines of the gas supply system.

Replacing the throttling devices of gas distribution station and gas control points with expander-generator units designed for power generation allows the use of pressure drop.

Currently, diesel and gas turbine power plants operating on fossil fuel [1], as well as external sources of electricity, are used at compressor stations to generate electricity for their own needs. The use of EGU allows to reduce fuel costs for their operation and reduce the amount of purchased electricity. Expander-generator units can be used both in the gas industry at gas distribution stations and at compressor stations, in gas points of all industrial enterprises that are large consumers of gas.

Simultaneously with the generation of electricity, there is also the possibility of obtaining heat of various temperature levels (high temperature for heating and low temperature for creating refrigeration units and air conditioning systems), generated during the operation of the EGU.

The high energy efficiency of the expander-generator units is determined, first of all, by the fact that the expander is not a heat machine, for the operation of which it is necessary to give a part of the supplied heat to a cold source. In a EGA, almost all of the heat supplied to it (with the exception of mechanical losses) can be converted into electrical energy. When the EGU is operating, the gas in front of the expander must be heated to such a temperature that its temperature at the expander outlet is not lower than the dew point (–10...–15 °C). This is due to the provision of normal operating conditions for both the expander itself and the gas pipelines.

In foreign scientific and technical periodical literature, a high assessment of the effectiveness of EGU is given.

Analysis of recent research and publications

To ensure the gas transportation the costs of energy resources are required: natural gas, electricity and heat. Therefore, the problem of energy saving during gas transportation is urgent. A detailed analysis of the problem and the search for alternative solutions are given in [2; 3].

The relevance of the use of secondary energy resources is increasing every year. This is due to the current state of natural resource reserves and the ecological situation in the world. The work [4] estimates the use of secondary energy resources as a source of energy, leading to a decrease in the consumption of fossil fuel for energy generation and a decrease in emissions into the environment.

The analysis of energy efficient technologies in gas pipelines was carried out in [5]. The author examines the options for the use of expander-generator units at gas distribution stations in order to convert and use the energy stored in the main gas pipelines. The use of the EGA technology in the gas supply system has received much attention in the works [6; 7]. The works are devoted to the issues of power supply of gas distribution stations with the use of EGU. In their studies, the authors came to the conclusion about the high prospects of this method of power supply to stations for technological reduction of the pressure of the transported gas. The work [8] substantiates the relevance of the use of energy-saving expander-generator technology, shows the fundamental thermodynamic advantages of EGU in comparison with the units traditionally used for the production of electricity.

The work [9] compares the efficiency of using a turbo expander at a gas distribution station in comparison with a throttling device. The minimum heat spent on gas heating is considered as a criterion for assessing energy efficiency.

In recent years, the topic related to the use of EGA not only for generating electricity, but also for generating heat and cold, has been developed [10].

The authors of all the articles mentioned are of the same opinion that the use of a generator for technological reduction of the pressure of the transported gas using the expander technology is thermodynamically effective enough, since it allows using the potential of the mechanical energy of the gas flow.

The aim of the study

The aim of the work is to compare the thermodynamic efficiency of the use of EGU and throttling devices at gas distribution stations and gas control points.

Initial data taken for the calculation

To determine the influence of the process parameters on the thermodynamic efficiency of using EGU instead of throttling devices, computational studies were carried out with various initial data (inlet and outlet pressures, gas temperatures at the inlet to the station for technological reduction of the pressure of transported natural gas).

The calculations were carried out under the following conditions:

- constant parameters:
- gas density ρ is equal to 0.72 kg/m^3;
- methane adiabatic index k is equal to 1.32;
- internal relative efficiency of the expander is equal to 0.85;
- efficiency of heat exchangers is 0.95, taking into account losses to the environment;
- variable parameters:
- P_1 — gas pressure at the inlet to the pressure reduction unit in the range of 0.6...1.2 MPa for gas control point and 4...11 MPa for gas distribution station;
- P_2 — gas pressure at the outlet of the pressure reduction unit in the range of 0.2 to 0.4 MPa for gas control point and 1.2 MPa for gas distribution station;
- t_1 — gas temperature at the inlet, it is in the range of –10 °C...+15 °C;
- t_2 — gas temperature after heating before the expander in the range of 20 °C...130 °C;
- $t_\text{н}$ — the temperature of the heat-transfer agent supplied for heating the gas before the expander in the range of 25 °C...135 °C;
- t_{1x} and t_{2x} — the temperature of the coolant coming from the consumer and to the consumer, respectively. Two cases were analyzed: 12 °C and 7 °C; minus 20 °C and minus 25 °C.

Calculation method

To perform the calculation, the thermodynamic properties of methane were taken from the reference data [11].

The calculation was carried out according to the method described in [12; 13; 14].

Heat Q, which must be supplied to heat the gas befor entering the turboexpander in order to ensure normal operation:

$$Q = G\Delta h = Gc_p\Delta T\ ,$$

where: G — the gas consumption for the EGU; $\Delta h = h_2 - h_1$; h_1, h_2 — enthalpy of a gas at the entrance to the heat exchanger and at the exit from it, respectively; ΔT is the drop in the gas temperature during expansion.

The energy potential of the energy carrier of excess pressure is determined by the work of isoentropic expansion l. For the case of adiabatic expansion of 1 kg of gas, the specific work will be:

$$l = \frac{k}{k-1}P_1 v_1\left[1-\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}\right],$$

or

$$l = z\frac{k}{k-1}RT_1\left[1-\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}\right],$$

wrere k — adiabatic exponent; P_1, T_1, v_1 — initial gas pressure, Pa, temperature, °C, gas specific volume, m^3/kg; P_2 — final gas pressure, Pa; z — compressibility factor; R — gas constant, J/kg K).

The specific total energy of the overpressure in the case of its useful using for getting electricity in the turboexpander is determined by the power N, W, i.e. the amount of work produced by the generator shaft per unit of time:

$$N = G\,l\,\eta_{\text{mech}}\eta_0\,\eta_{\text{gen}}\ ,$$

where G is the gas flow rate, kg/s; l — specific work of gas expansion in the turboexpander, kJ/kg; η_{mech} — mechanical efficiency of EGU (only for EGU with a mechanical reducer); η_0 — internal relative efficiency of the expander; η_{gen} — electromechanical efficiency of the generator.

Influence of gas heating on the reduction process in the expander-generator units

When consedering the possibility of generated electricity by using the excess pressure of natural gas in turbo expanders, it should be remembered that the efficiency and capacity of a turbo expander is determined not only by the pressure, but also by the initial absolute temperature of natural gas in front of a turbo expander. Natural gas supplied to consumers has a fairly low temperature, which is usually 10 °C in summer and about 0 °C in winter. The calculation shows [6] that when natural gas is heated at the turboexpander inlet to 50 °C and 100 °C, its capacity increases only by 18.3 % and 36.6 %, respectively, compared with the case when the temperature is 0 °C. It can be seen that the power of the turboexpander increases disproportionately to the thermal energy spent on natural gas heating. To use a turboexpander, heat sources are required to heat the natural gas at the inlet to the turboexpander. The scientific literature describes various options for the possibilities and schemes for the implementation of natural gas heating. Gas distribution stations located near enterprises with a source of secondary heat resources have a particular advantage.

There is a known method of operation of a turboexpander unit, which makes it possible to ensure the operation of an EGU without burning fuel. The essence of the proposed method lies in the fact that before the expander, the gas is heated using part of the energy generated by the electric generator of EGU. In this case, low-grade energy is used to heat the gas. The heat of the environment or secondary energy resources of enterprises can be used as a source of this energy. This technology requires a significant complication of the GDS equipment and is not economically feasible yet [15].

Consider how much the temperature drops in the process of throttling and reduction in the expander at an initial gas temperature of 10 ºC. Using the tables of thermodynamic properties of methane and the main thermodynamic dependences of the expanding and throttling processes, we calculated the gas temperature at the end of the expansion processes.

Fig. 1 and Fig. 2 show the processes of gas throttling and expansion in EGU.

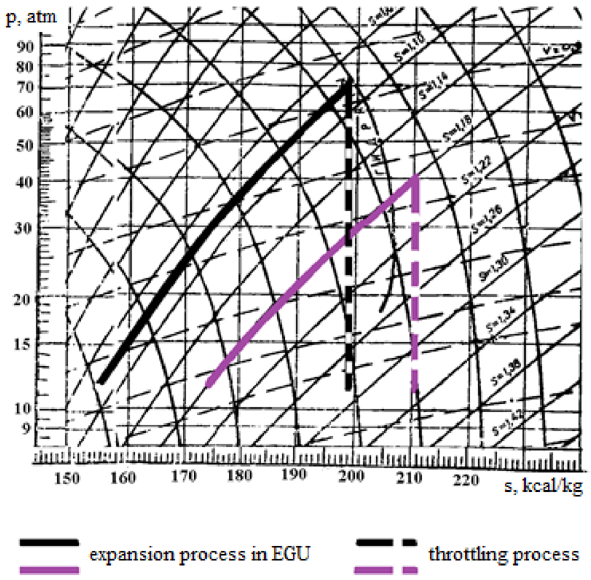

Fig. 1. Diagram of throttling and reduction processes in the expander with pressure drops of 7.5/1.2 MPa and 4.0/1.2 MPa

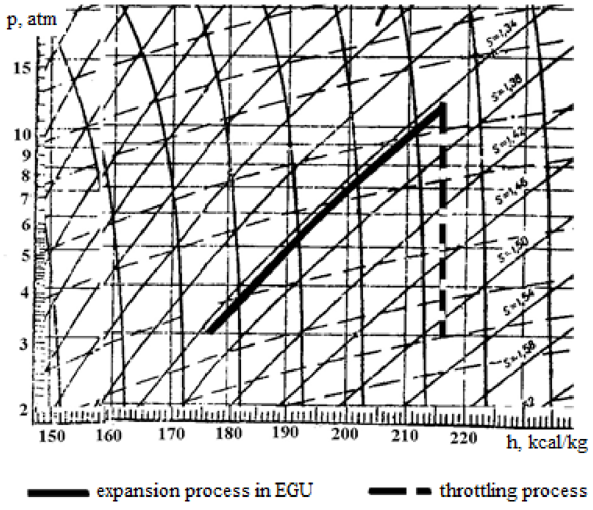

Fig. 2. Diagram of throttling and reduction processes in the expander with pressure drops 1,2/0,3 MPa

In GDS, the initial gas temperature is 10 ºC, after throttling the outlet temperature at different pressures is: –22 ºC with a pressure drop of 7.5/1.2 MPa, –15 ºC with a pressure drop of 4 /1.2 MPa, 8 ºC with a drop pressure 1.2/0.6 MPa, 5 ºC with a pressure drop of 1.2/0.3 MPa.

Whereas in the case of gas expansion in the EGU with similar initial parameters, the outlet temperature is: minus 90 °C at the differential pressure of 7.5/1.2 MPa, minus 58 °C at the differential pressure of 4/1.2 MPa, minus 28 °C at the differential pressure of 1.2/0.6 MPa, minus 73 °C at the differential pressure of 1.2/0.3 MPa.

Numerical calculations show that a more significant decrease in temperature during the reduction in the expander is observed over the entire range of differential pressures.

The operation of the EGU and gas pipelines at such temperatures at the outlet of the EGU is not permissible. Based on this, it can be concluded that in all cases of using EGU at the gas distribution stations, it is necessary to heat the gas if there is no need to obtain cold. Gas heating can be carried out before or after the EGU.

One of the tasks in the organization of heating is to determine the gas temperature at the outlets, depending on the temperature at the inlet of the expander-generator unit.

Table 1 shows the calculated values of the temperature at the outlet of the unit depending on the temperature at the inlet for various values of pressure drop.

Table 1

The dependence of the temperature at the outlet of the expander on the inlet temperature

$P_1/P_2\backslash T_1$°C	10	35	60	95	120
7,5/1,2=6,25	–151	–126	–96	–57	–19
1.2/0,3=4	–102	–77	–50	–13	+9
4,0/1,2=3,33	–88	–65	–37	–4	+19
1,2/0,6=2	–38	–16	+3	+40	+63

Graphically, this dependence for different pressure drops is presented in Fig. 3.

According to Fig. 3, to ensure the normalized temperature at the outlet from the gas distribution station at a pressure drop of 7.5/1.2 MPa, the gas should be heated to a temperature in the range from 140 ºC...150 ºC, at pressure drops (1.2/0.3 MPa and 4.0/1.2 MPa), the gas before the expander must be heated to a temperature of 100 ºC...110 ºC, with a lower pressure drop (1.2/0.6 MPa) — to a temperature of 40 ºC...60 ºC.

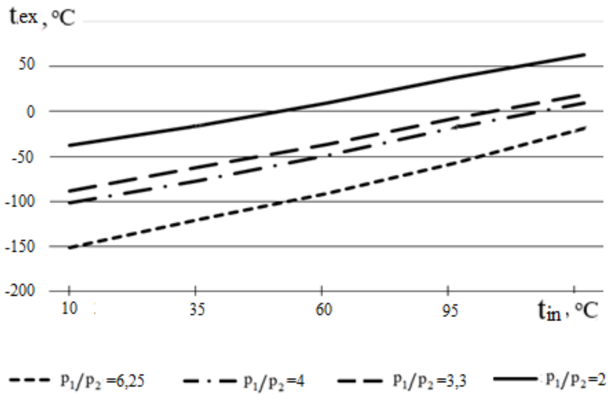

Fig. 3. Dependence of the gas temperature at the outlet on the inlet temperature in the turboexpander

For example, to ensure the temperature of the gas at the outlet of the GCP at 10 ºC, the gas in front of the expander must be heated to:

- 140 ºC at a pressure drop of 7.5/1.2 MPa;
- 107 ºC at a pressure drop of 1.2/0.3 MPa;
- 115 ºC at a pressure drop of 4/1.2 MPa;
- 55 ºC at a pressure drop of 1.2/0.6 MPa.

When operating equipment within low temperatures with multistage reduction of gas, in order to save energy resources, multistage gas heating is required.

The temperature before the second stage of reduction is assumed to be equal to the temperature before the first stage of reduction.

The optimum pressure of the intermediate heating in this case [16]:

$$P_{np}^{opt} = \sqrt{P_1 \cdot P_2} .$$

When the pressure changes from 7.5 MPa to 1.2 MPa, the pressure drop is more than 4.5 times.

For a multistage pressure reduction with intermediate gas heating, the intermediate pressure is 3 MPa at a pressure drop of 7.5/1.2 MPa.

The change in temperature after the EGU versus the temperature before the EGU in schemes with intermediate heating is shown in Fig. 4.

In the calculations, it was assumed that heating in the first and second stages occurs to the same level.

The pressure drop in the first stage is 7.5/3.0 MPa, in the second — 3.0/1.2 MPa.

It can be seen from Fig. 4 that the schemes with stage pressure actuation and with intermediate heating make it possible to obtain a similar power of the EGU at lower temperatures at the inlet to the turboexpander.

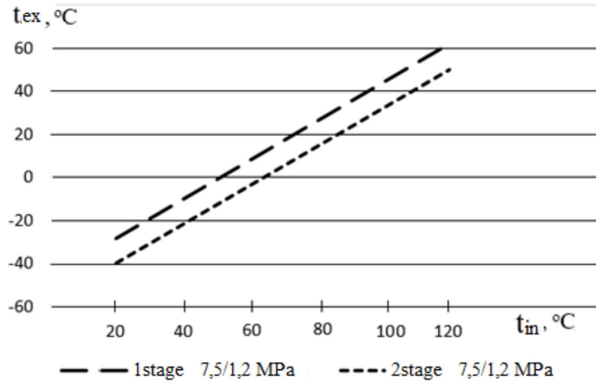

Fig. 4. The gas outlet temperature versus the temperature at the inlet to the turboexpander with two-stage heating and a total pressure drop of 7.5/1.2 MPa

So, if in a one-stage scheme with a pressure drop of 7.5/1.2 MPa the gas must be heated at the inlet within the range from 110 °C to 120 °C to ensure an outlet temperature of 10 °C, then in a two-stage scheme it must be heated to temperatures ranging from 50 °C to 65 °C.

Estimation of energy potential of excess gas pressure in the process of reduction

The energy potential of overpressure is directly proportional to the energy potential of the energy carrier, which is determined by the technical work of the adiabatic expansion of 1 kg of gas and is presented in Table 2.

Table 2

Specific useful work of the turboexpander

Pressure drop, P_1/P_2, MPa	Temperature at the inlet, T_1, °C	Specific work, kJ/kg
1,2/0,6 = 2	10	91
4/1,2 = 3,3	10	135
1,2/0,3 = 4	10	166
7,5/1,2 = 6,25	10	223
1,2/0,6 = 2	35	99
4/1,2 = 3,3	35	152
1,2/0,3 = 4	35	184
7,5/1,2 = 6,25	35	238
1,2/0,6 = 2	60	107
4/1,2 = 3,3	60	172
1,2/0,3 = 4	60	200
7,5/1,2 = 6,25	60	254
1,2/0,6 = 2	95	119
4/1,2 = 3,3	95	192
1,2/0,3 = 4	95	221
7,5/1,2 = 6,25	95	275
1,2/0,6 = 2	130	129
4/1,2 = 3,3	130	209
1,2/0,3 = 4	130	244
7,5/1,2 = 6,25	130	295

First of all, the work directly depends on the temperature at the inlet to the expander and the pressure drop in it.

Fig. 5 shows the dependence of the specific work of the adiabatic gas expansion on the gas heating temperature before the EGU for one-stage schemes with different pressure drops.

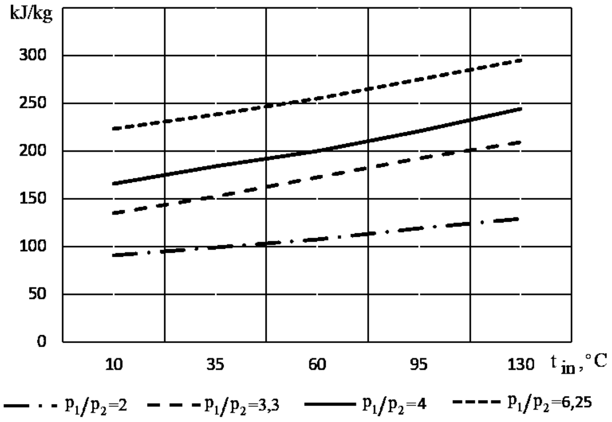

Fig. 5. Dependence of the specific work of the turboexpander on the inlet gas temperature

Fig. 5 shows that with an increase in the heating temperature, the specific work of adiabatic expansion increases. The temperature in front of the EGU should be taken on the basis of technical and economic indicators, depending on the unit scheme and the required temperature of the gas supplied to consumers.

When determining the dependence of work of the EGU on the temperature at the inlet, pressure drops were considered that are close to those that can occur at the GDS or GCP.

The results of calculations of the specific work of the EGU for different temperatures at the inlet to the expander depending on the pressure ratio are shown in Fig. 6.

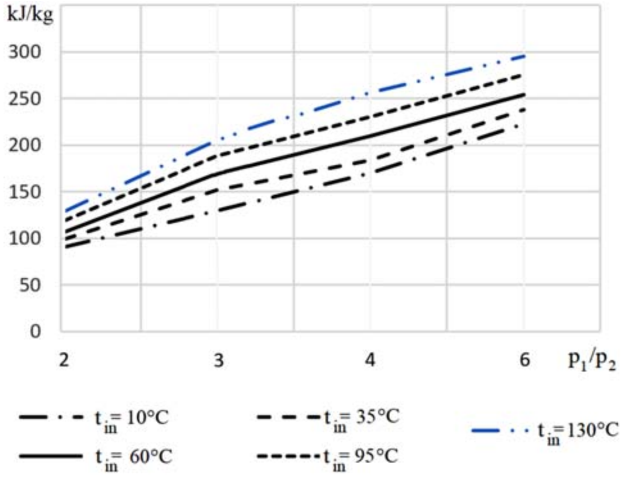

Fig. 6. The dependence of the specific work of the turboexpander on the pressure drop

Fig. 6 shows that with an increase in the pressure ratio before and after the EGU, the specific work of the expander increases.

So, for example, with a decrease in the gas pressure drop at the inlet and outlet from 6 to 3 (2 times at a constant pressure at the outlet of the expander), the power of the unit is reduced by 1.5 times.

This dependence shows that when operating at modes different from the calculated ones, it is the rezult of a decrease in pressure in gas pipelines or due to seasonal fluctuations in gas consumption, electricity generation will change.

Specific work is a function of the pressure drop ratio, on the other hand, it directly depends on the temperature at the expander inlet.

Fig. 6 shows that at different temperatures at the inlet, the graphs of work changes are similar to each other.

Let us determine the overpressure potential (EGU capacity) and the annual electricity generation for the given gas flow rates at the GDS 10000 m^3/h, 30000 m^3/h, 50000 m^3/h and pressure drops of 7.5/1.2 MPa and 4.0/1.2 MPa. The calculation results are shown in Table 3 and Table 4.

Table 3

Power of the expander and annual electricity generation of EGU at a pressure drop of 7.5/1.2 MPa

Gas mass flow rate, *G*, kg/s	Gas temperature at the expander inlet, T_1,°C	Specific work, *l*, kJ/kg	Power, *N*, kW	Annual power generatiokW·h
2	10	223	379	3154
6	10	223	1137	9462
10	10	223	1896	15788
2	35	238	405	3024
6	35	238	1214	10103
10	35	238	2023	16835
2	60	254	432	3595
6	60	254	1295	10777
10	60	254	2159	18266
2	95	275	468	3894
6	95	275	1403	11676
10	95	275	2338	19457
2	120	295	502	4178
6	120	295	1505	12525
10	120	295	2508	20872

Table 4

Expander capacity and annual power generation of the EGU by pressure drop 4.0/1.2 MPa

Gas mass flow rate, G, kg/s	Gas temperature at the expander inlet, T_1,°C	Specific work, l, kJ/kg	Power, N, kW	Annual power generatio kW·h
2	10	135	230	1914
6	10	135	689	5737
10	10	135	1178	9553
2	35	152	258	2147
6	35	152	775	6246
10	35	152	1292	10752
2	60	172	292	2430
6	60	172	877	7298
10	60	172	1462	12166
2	95	192	326	2712
6	95	192	979	8122
10	95	192	1632	13582
2	120	209	385	2954
6	120	209	1066	8871
10	120	209	1777	14788

According to the calculations, we see that the power of the EGU grows with an increase in the pressure drop and an increase in temperature.

The greatest potential of the overpressure energy is possessed by the GDS with a large pressure drop and a significant flow rate of gas passing through the GDS. An increase in electrical power can also be achieved with an increase in the gas temperature before the EGU, but this requires a separate feasibility study.

Graphical dependences of the EGU power on the gas flow rate at various temperatures at the inlet to the turboexpander are shown in Fig. 7 for a pressure drop of 7.5/1.2 MPa and in Fig. 8 for a pressure drop of 4.0/1.2 MPa. Power increases significantly with increasing gas flow rate.

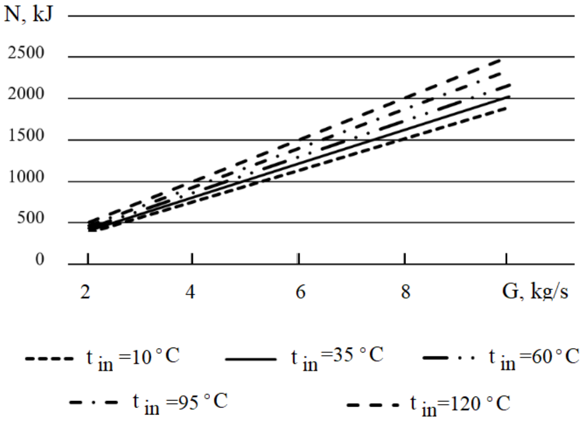

Fig. 7. Dependence of the power of the turboexpander on the gas flow rate at differential pressure 7.5/1.2 MPa

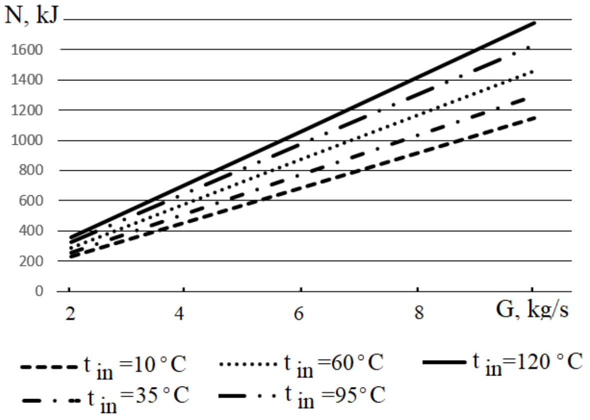

Fig. 8. Dependence of the turboexpander power on the gas flow rate by pressure drop 4.0/1.2 MPa

So, for example, for a pressure drop of 7.5/1.2 MPa at a gas flow rate of 2 kg/s and a temperature at the inlet to the turboexpander of 10 °C, the power is 379 kW, and at the same temperature and gas flow rate of 10 kg/s — 1896 kW. Power also increases with increasing temperature.

For a pressure drop of 4.0/1.2 MPa and a gas flow rate of 2 kg/s at an the inlet temperature of 10 °C, the power is 230 kW, and at a gas flow rate of 10 kg/s the power is 1178 kW.

Power also increases with increasing temperature. Thus, an increase in the temperature at the inlet to the turboexpander from 10 °C to 120 °C (at a gas flow rate of 10 kg/s) leads to an increase in power from 230 kW to 385 kW.

The annual electricity generation of the EGU at various temperatures and gas flow rates for a pressure drop of 7.5/1.2 is shown in Fig. 9. Obviously, a change in gas flow rate causes a significantly larger change in annual output than a change in temperature in these ranges of values of gas flow rate and temperature.

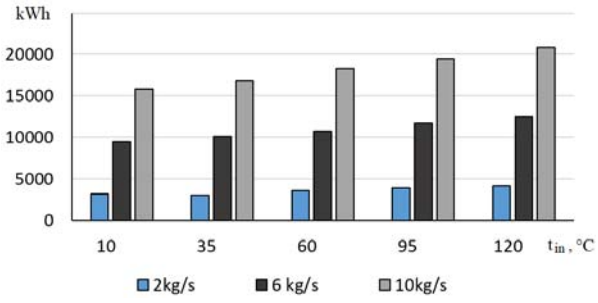

Fig. 9. Annual electricity generation by the EGU at various gas flow rates and gas temperatures for a pressure drop of 7.5/1.2 MPa

The heat consumption for heating the gas before the turboexpander is determined as:

$$Q = G\Delta h = Gc_p\Delta T \text{ , kW.}$$

The calculation is performed on the following conditions. The gas temperature in the inlet gas pipeline is 10 °C. Gas reduction is one-stage. The gas temperature at the outlet of the turboexpander is 10 °C. Under these conditions and depending on the pressure drop, the temperature to which the gas should be heated can be found from the graph (see Fig. 4). The calculation results are shown in Table 5.

Table 5

Heat consumption for gas heating

The gas temperature at the end of heating, $T_к$,°C	Gas mass flow rate, G, kg/s	Heat consumption for heating gas, Q, kW
60	2	244
60	6	732
60	10	1222
107	2	473
107	6	1416
107	10	2360
120	2	561
120	6	1680
120	10	2800
140	2	634
140	6	1902
140	10	3107

Conclusion

Comparing the results of calculating the heat consumption with the potential power of the turboexpander (see Fig. 7, 8), it can be concluded that one-stage gas heating in front of the turboexpander is possible under the condition of a heating temperature of 60 °C for all considered gas flow rates.

From a thermodynamic point of view, gas reduction in a EGU with a single-stage heating before the turboexpander to temperatures of 107 °C, 120 °C, 140 °C by a pressure drop of 4.0/1.2 MPa is unprofitable. The use of gas reduction with the help of expanders at such gas distribution stations can be recommended in the presence of significant sources of excess heat (for example, heat station, gas exhaust gas from gas turbines, etc.) and (or) a cold consumer.

For GDS with a pressure drop of 7.5/1.2 MPa and gas flow rates considered in the work, a two-stage reduction with intermediate heating can be proposed. According to Fig. 4, to ensure the temperature at the outlet of the turboexpander of 10 °C, the gas must be heated at the inlet to 65 °C.

Note that the study considered only thermodynamic conditions for energy conversion and did not take into account operating conditions, which also affects energy consumption and energy balance.

Thus, the efficiency of gas reduction using expanders in gas transportation systems depends on specific conditions (GDS throughput, available gas pressure drop, GDS location near waste energy sources, etc.). Therefore, for specific conditions, the question of the possibility of using the EGU must be resolved, and in the future, the appropriate EGU scheme is selected (or developed).

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Волянська Л. Г., Нікітіна Г. М., Береговий І. О.

ОЦІНКА ТЕРМОДИНАМІЧНОЇ ЕФЕКТИВНОСТІ ВИКОРИСТАННЯ ДЕТАНДЕР-ГЕНЕРАТОРНОЇ УСТАНОВКИ

У статті розглянуто можливість утилізації енергії надлишкового тиску природного газу, що підводиться по газопроводах до газорозподільних станцій і газорегуляторних пунктах промислових споживачів газу. Процеси транспортування і розподілу природного газу пов'язані з появами надлишків теплової і потенційної енергії. Їх утилізація на газорозподільних станціях може підвищити як автономність самих станцій, так і загальну ефективність роботи всієї газотранспортної системи. Розглядається застосування турбодетандерних установок з метою перетворення і використання енергії потоку стисненого природного газу як вторинної енергоресурсу надлишкового тиску. Проведено оцінку термодинамічної ефективності детандер генераторного агрегату порівняно з дросельними пристроями при їх використанні на газорозподільних станцій і газорегуляторних пунктах. Газорозподільни станціи і газорегуляторни пункти розглядаються як об'єкти, у яких при дроселюванні відбувається лише зміна енергії потоку газу, що транспортується, а при використанні детандер генераторного агрегату — зміна енергії потоку газу і генерація електроенергії. У статті представлені результати аналізу досліджень для різних рівнів технологічних перепадів тиску транспортованого природного газу. Проаналізовано вплив підігріву газу перед детандер-генераторним агрегатом або проміжного підігріву на ефективність застосування турбодетандерної технології зниження тиску природного на газорозподільній станції. Проведено оцінку термодинамічної ефективності детандер генераторного агрегату порівняно з дросельними пристроями при їх використанні на газорозподільній станції і газорозподільному пункті. Виявлено перспективи використання потенційної енергії тиску магістральних газопроводів і поновлюваних джерел енергії для отримання додаткової енергії.

Ключові слова: газорозподільна станція; турбодетандер; перепад тиску; утилізація; вторинні енергопотоки; природний газ.

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ESTIMATION OF THERMODYNAMIC EFFICIENCY OF USING EXPANDER-GENERATOR UNIT

The article considers the possibility of utilizing the energy of excess pressure of natural gas supplied through gas pipelines to gas distribution stations and gas control points of industrial gas consumers. The processes of transportation and distribution of natural gas are associated with the appearance of surplus heat and potential energy. Their utilization at gas distribution stations can increase both the autonomy of the stations themselves and the overall efficiency of the entire gas transmission system.

The use of turboexpander units for the purpose of converting and using the energy of a compressed natural gas stream as a secondary energy resource of excess pressure is considered. An assessment of the thermodynamic efficiency of an expander generating unit is carried out in comparison with throttling devices when used in gas distribution stations and gas control points. Gas distribution stations and gas control points are considered as objects in which, during throttling, there is only a change in the energy of the flow of the transported gas, and when using expander-generator units - a change in the energy of the gas flow and generation of electricity. The article presents the results of the analysis of studies for various levels of technological pressure drops of transported natural gas. The influence of gas heating before the expander-generator unit or intermediate heating on the efficiency of using the turbo-expander technology to reduce the natural pressure at the gas distribution station is analyzed. The assessment of the thermodynamic efficiency of the expander of the generator unit is carried out in comparison with the throttling devices when they are used at the gas distribution station and gas control point. The prospects of using the potential pressure energy of main gas pipelines and renewable energy sources for obtaining additional energy have been identified.

Keywords: gas distribution station; turboexpander; pressure drop; utilization; waste energy; natural gas.

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