

# Development of a device for the utilization of drilling rig heat

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**Abstract.** Drilling wells is an energy-intensive process. Due to the specifics of drilling operations, the distance from industrial centers and their power systems, and the mobility of equipment, energy supply experience does not always allow its application to other industries. When drilling, along with electricity, large quantities of thermal energy are also consumed. This article presents the results of practical research on improving the operation of internal combustion engines of drilling equipment and heat recovery systems of mobile diesel power plants, as well as increasing the efficiency of diesel power plants by improving their design and optimizing operating parameters.

## 1 Introduction

Drilling operations are mainly mobile in nature [1]. That is, since drilling operations are carried out over large areas, the power supply system for drilling equipment is sometimes connected to a centralized network, and sometimes to autonomous power systems in remote areas. In such cases, during cold weather, a number of difficulties arise related to heating drilling operations [1]. At the same time, a certain part of the power of diesel power plants, which are mainly used to generate electricity, is spent on heating systems, or special furnaces that burn wood, coal, peat or fuel oil are used to produce thermal energy [1-2].

These factors, in turn, create difficulties in organizing a comprehensive energy supply for drilling operations and lead to higher costs for drilling operations [1-2].

When using autonomous power supply systems, the use of electric heaters to supply drilling equipment with the necessary thermal energy is not considered appropriate, since they create additional loads on the diesel power plant, thereby increasing fuel-energy consumption. When drilling geological exploration wells for heat supply, in most cases, stoves running on coal, wood, fuel oil or other types of fuel are used [3].

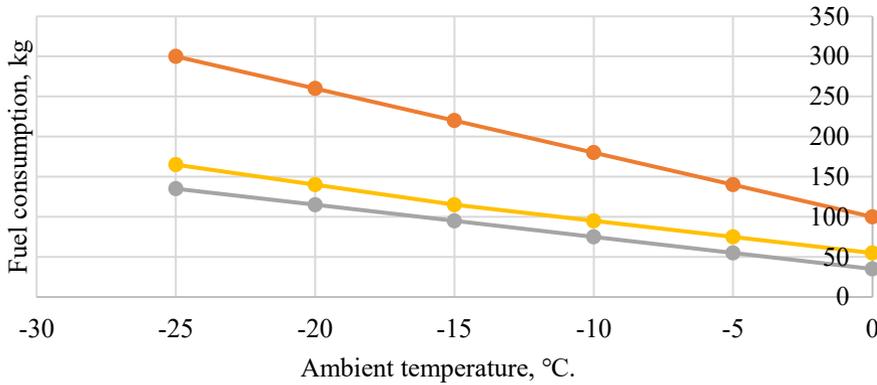
To maintain the temperature standard of drilling equipment, 250 kg of standard fuel is consumed per day. Figure 1 shows the dependence of fuel consumption on weather temperature by type of fuel used to heat drilling equipment [3-4].

Heating drilling equipment with fuel in the form of coal, fuel oil, peat or wood, taking into account the costs of supplying these types of fuel to the areas where drilling is carried out, their expenses will increase up to 2 times. This, in turn, leads to an increase in energy

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costs for drilling. This will also entail an increase in financial costs allocated for geological exploration work to 50% [5].



**Fig. 1.** Dependence of weather temperature consumption on the type of fuel used to heat drilling equipment.

In addition to the above, the use of this type of fuel causes a number of negative factors, such as a labor-intensive heating process, pollution of the building and the environment with combustion products, high fire hazard, and gas poisoning of personnel [5-6].

Today, due to the acceleration of geological exploration work in our country, exploration drilling is carried out in areas remote from infrastructure, about 60% of the total volume of drilling work is carried out using autonomous power systems. During winter drilling in hard-to-reach areas, the need for thermal energy increases, that is, thermal energy used to maintain the optimal temperature of the drilling fluid, heating the working area of drilling equipment, heating outbuildings and other technological needs [6-7].

The heat used to maintain the temperature conditions of drilling equipment buildings and other technological purposes leads to an increase in the overall energy costs of drilling operations. When carrying out thermal calculations of drilling equipment at an ambient temperature of -20 °C, to ensure a comfortable operating temperature of the drilling equipment at the work site, about 30 kW of heat is required, which in some cases exceeds the electricity consumption of process equipment [7].

Considering the above, it is possible to achieve a reduction in energy costs through the beneficial utilization of heat from internal combustion engines of technological equipment during drilling operations at decentralized sites in remote areas [7-10].

## 2 Development of technical solutions for the beneficial use of drilling equipment heat during drilling by cleaning wells with flushing fluids

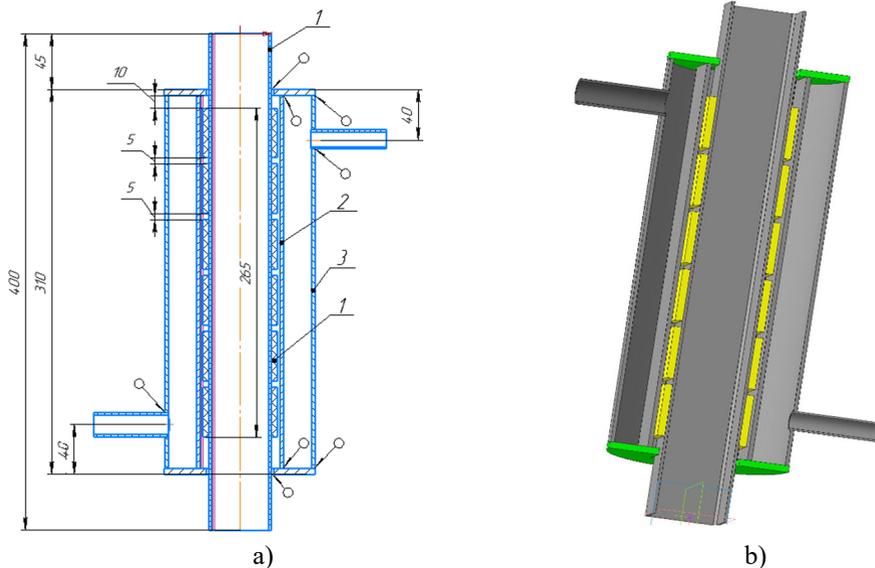
Today, at a time when the cost of energy resources is rising throughout the world, the exception is that secondary energy resources in the form of flue gases from internal combustion engines used in technological processes are emitted into the atmosphere without useful use [3]. Internal combustion engines that do not use secondary energy resources in the form of heat are economically ineffective and irrational machines, since the thermal energy released by internal combustion engines into the atmosphere can be usefully reused through a number of systems.

We have developed a device for useful recovery of heat from the internal combustion engine of drilling equipment.



batteries and others. The cold unit is cooled with water supplied by the pump, heated water as a result of the operation of the thermoelectric generator is used to prepare drilling fluid or to recharge the sump with drilling fluid. Exhaust gases leaving the thermoelectric generator block enter the vortex tube, where the temperature separation of the gas into cold and hot flows occurs. The cold flow is discharged to the water cooler in the form of an air-water heat exchanger installed between the pump and the thermoelectric generator unit for deeper cooling of the water. The hot stream is supplied to an air-water heat exchanger to produce hot water used for hot water supply or for heating domestic and technological premises. The hot flow leaving the air-water heat exchanger enters the air-air heat exchanger for additional heat extraction. The air flow created by the fan removes heat from the radiator of the internal combustion engine and enters the air-to-air heat exchanger for additional heating. The heated air flow, purified by an air filter, is used for heating domestic and technological premises.

The effective use of thermoelectric generators in the device for useful heat recovery from the internal combustion engine of the proposed drilling equipment is associated with some technical difficulties, that is, it requires the development of new technical solutions for heating one side using secondary energy of the internal combustion engine and cooling the other side without additional energy. For this reason, the thermoelectric generator block design shown in Figure 3 was developed.



1-pipe, 2-thermoelectric generator sealing plate, 3-shell, 4-thermoelectric generator, 5 and 6 cooling water inlet and outlet pipes

**Fig. 3.** Structural device (a) and general view (b) of a thermoelectric generator installation.

The thermoelectric generator installation is designed as follows: there is a pipe (1) for the movement of flue gases, thermoelectric generators (4) are installed on the pipe and are closed on top with a round tubular plate (2) and the large diameter pipe is closed in the form of a shell (3) using bolts. An annular gap is left between the plate (2) and the shell (3) for water movement. Nozzles (5) and (6) are installed in the housing to ensure the movement of cooling water. This unit operates in the following order: when flue gases move through the pipe (1), it heats the thermoelectric generators installed on it, water for cooling is transferred from the pipe (5) into the space between the shells (3), and the plate (2) after cooling the thermoelectric

generators The heated water flows out through the pipe (6), through which cooling water continues to circulate continuously during operation.

A unique feature of the drilling equipment combustion engine heat recovery device shown in Figure 2 above is that the thermoelectric generators used in it require exposure to different temperatures on both sides to start, resulting in a large consumption of thermal energy, so their efficiency is considered low.

However, in our proposed device, the secondary energy of the internal combustion engine, i.e., the energy lost to the atmosphere, is used to heat the thermoelectric generator.

Also used for cooling is the water used to prepare and maintain the drilling fluid. This, in turn, makes it possible to save energy spent on cooling and obtain hot water for preparing and maintaining the temperature of the drilling fluid in the cold season.

Electrical energy generated in a thermoelectric generator can be used to illuminate drilling areas, provide energy for measurement and control devices, and store the generated energy. This, in turn, leads to a reduction in the energy intensity of drilling operations and an increase in operating efficiency.

### 3 Experimental studies of a device for useful heat recovery of an internal combustion engine of drilling equipment

Tests were carried out to determine the performance and efficiency of the developed heat recovery device for drilling equipment, as well as the magnitude of the electrical and heat flows generated in it.

The first stage of experiments was carried out during industrial production, in which it was carried out on a diesel power plant of the DES-100.1 brand with a nominal power of 100 kW.

During the experiments, it was established that the heat generated in the radiator of the cooling system of the internal combustion engine of a diesel power plant can be usefully used using a heat exchanger, that the heat generated in the radiator depends on the load applied to the engine and the magnitude of the heat flows

The air flow from the engine radiator, as well as the air flow entering and leaving the heat exchanger, was determined by knowing the pipe diameter and air flow, using the following expression 1.

$$G = v_x \cdot \frac{\pi d_x^2}{4} \cdot \rho_x, \text{ kg/s}, \quad (1)$$

here,  $v_x$  – air flow speed, m/s;  $d_x$  – pipe diameter, m;  $\rho_x$  – air density, kg/m<sup>3</sup>.

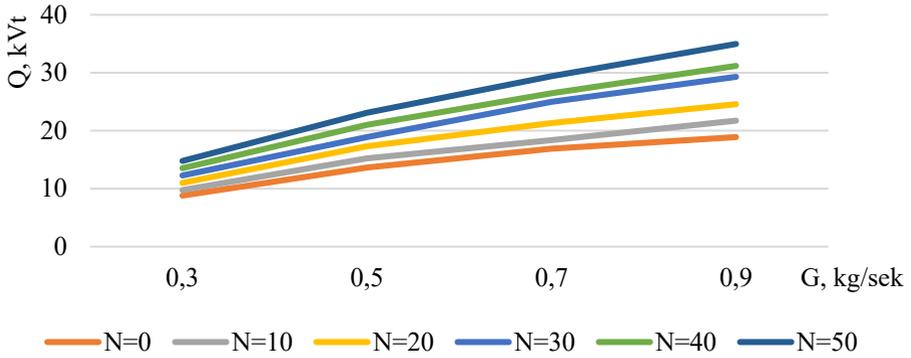
We determined the heat flow power using the following expression.

$$Q = c_x \cdot G(t_1 - t_2), \text{ kWt}, \quad (2)$$

here,  $c_x$  – is the heat capacity of air, J/kg·°C;  $G$  – air flow, kg/s;  $t_2$  – temperature of heated air, °C;  $c_x$  – heat capacity of air, J/kg·°C;  $t_1$  – temperature of air entering the heat exchanger, °C.

As a result of the analysis of the experimental work, the dependence of the power of the heat flow leaving the heat exchanger ( $Q$ ) on the air flow ( $G$ ) at various loads ( $N$ ) supplied to the engine was established; this dependence is presented graphically in Figure 4.

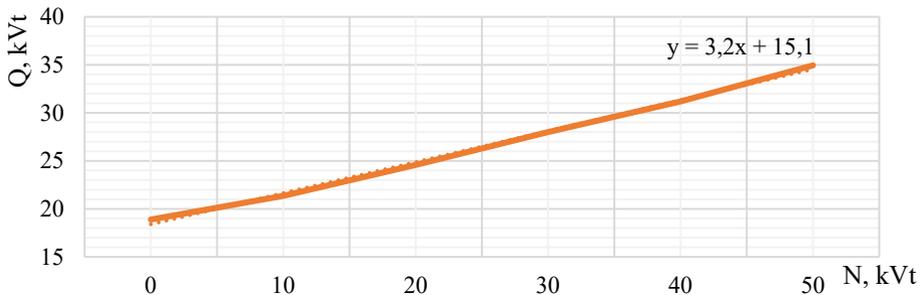
Analysis of the results of experimental work shows that when an internal combustion engine operates in a cold state, the heat release from the radiator of its cooling system is less, that is, when the flow of hot air from the radiator is directed to the heat exchanger, with a secondary coolant air flow rate of 0,3 kg/sec, it is placed in the heat exchanger The heat flow power was 8,82 kW, with an increase in the flow rate of secondary coolant air to 0,9 kg/sec, it amounted to 19 kW. By increasing the flow rate of secondary heat-carrying air, it is possible to increase the power of the utilized heat flow.



**Fig. 4.** Graph of the dependence of the heat flow power ( $Q$ ) on the heat exchanger on the secondary coolant air flow rate ( $G$ ) at various loads.

As a result of increasing the loads applied to the engine, the heat flow from the heat exchanger can be increased.

With an engine load of 50 kW, the secondary coolant air flow rate was 0,3 kg/sec, the power of the heat flow used in the heat exchanger was 14,8 kW, and with the secondary coolant air flow rate increased to 0,9 kg/sec, it was 35 kW. Figure 5 below shows a graph of the heat flow power in the heat exchanger depending on the loads applied to the engine at  $G=0,9$  kg/sec.



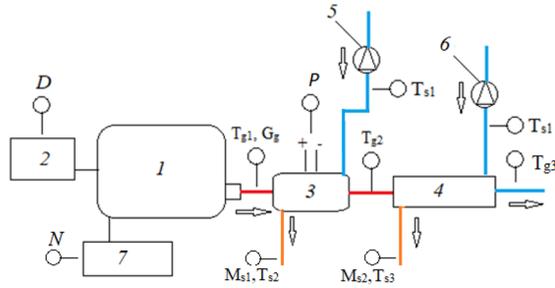
**Fig. 5.** Graph of the dependence of the heat flow power in the heat exchanger ( $Q$ ) on the load applied to the engine ( $G=0,9$  kg/sec).

As a result of an increase in the load on the engine, the heat transfer of the heat exchanger increases, while the flow of the secondary coolant remains unchanged (0,9 kg/sec), the heat flow ( $Q$ ) is 18.9 kW. when the engine was running alone and the load ( $N$ ) was 10 kW and 21.3 kW, when the load increased to 50 kW, the heat flow was 35 kW. As the load increased, an increase in heat capacity was observed.

The second stage of experimental work was carried out to study the performance of a thermoelectric generating unit when used in the exhaust pipe of an engine, the electric current that can be obtained from a thermoelectric generating unit, and the possibility of obtaining hot water, which can be used for technological and domestic needs in a heat transfer device.

When performing the experimental work, the following tools and equipment were used: internal combustion engine (2 kW), lamp unit (2 kW), thermoelectric generators 36 pcs., heat exchanger, water pump, thermometer (UNI-T), anemometer and scales.

A schematic view of the experimental setup is shown in Figure 6.



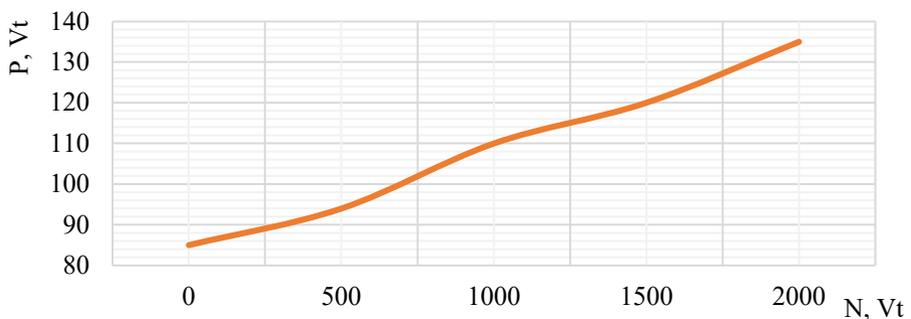
1-internal combustion engine, 2-fuel tank, 3-thermoelectric generator unit, 4-heat exchanger, 5-6-pump, 7-lighting unit to create a load on the engine,  $T_{g1}$ - temperature of the flue gases at the engine outlet,  $T_{g2}$ - temperature of the flue gases supplied to the heat exchanger,  $G_g$ - flue gas consumption,

$T_{s1}$ - water temperature at the pump outlet,  $T_{s2}$ ,  $T_{s3}$ - water temperature at the outlet of the thermoelectric generator and heat exchanger,  $M_{s1}$ ,  $M_{s2}$ - water flow at the outlet of the thermoelectric generator and heat exchanger, P- thermoelectric generator output power measurement point, D- fuel consumption measuring point, N-engine load

**Fig. 6.** Schematic view of the experimental device.

Experimental tests of a heat recovery device for an internal combustion engine determined the temperature of the water at the outlet of the heat exchanger ( $T_{s3}$ ), that is, the dependence of the secondary coolant on the engine load ( $N$ ) at  $T_{s1}=\text{const}$  and the electric current power ( $R$ ) from the thermoelectric generator on the engine load ( $N$ ) made it possible to establish a dependency.

The output power ( $R$ ) of the electric current from the thermoelectric generator unit used in the useful heat recovery device of the internal combustion engine of the drilling equipment depends on the temperature and flow of the flue gases. The temperature and consumption of engine exhaust gases, in turn, directly depend on the loads applied to it. Therefore, we studied the dependence of the power ( $R$ ) of the electric current from the thermoelectric generator on the load ( $N$ ) applied to the engine, and the result of the study is presented as a graph in Figure 7.

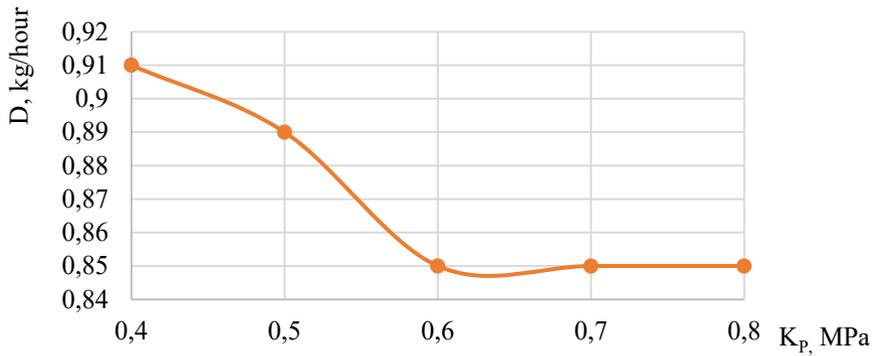


**Fig. 7.** Graph of the dependence of the electric current power ( $R$ ) from the thermoelectric generator on the load ( $N$ ) applied to the engine.

From the graph of engine fuel consumption ( $D$ ) versus engine load ( $N$ ), it can be seen that fuel consumption increases uniformly with increasing load. Fuel consumption has a linear characteristic and is displayed on the diagram

$$D = D_s + b \cdot N, \text{ kg/hour}, \quad (3)$$

here  $D$  is the fuel consumption of the engine, kg/h;  $D_s$  – fuel consumption when the engine is running;  $b$  – increase in fuel consumption due to increased load, kg/kWh;  $N$  – engine load, kW.



**Fig. 8.** Graph of the dependence of fuel consumption ( $D$ ) on air pressure ( $K_p$ ) supplied to the ejector nozzle at engine load  $N = 1500$  W.

In order to determine the efficiency of the heat recovery device of the internal combustion engine of the drilling equipment being developed, a comparison was made of the efficiency of the equipment with and without the use of a heat recovery device.

The efficiency of a diesel power plant of drilling equipment is determined as follows.

$$\eta = \frac{N}{Q}; \quad (4)$$

here  $N$  is the generator load, kW;  $Q$  is the heat flux released as a result of fuel combustion, kW.

The heat flow released as a result of fuel combustion depends on the fuel consumption and its heat of combustion.

$$Q = \frac{Q_p^H D}{3600}; \quad (5)$$

here  $Q_p^H$  – lower heating value of fuel ( $Q_p^H = 44500$  kJ/kg for gasoline).

When using a device for useful heat recovery from the internal combustion engine of the drilling equipment being developed, the efficiency coefficient was determined

$$\eta = \frac{N+P+Q_{ut}}{Q}; \quad (6)$$

here  $Q_{ut}$  – used heat flow, kW;  $P$  – power of electric current generated in a thermoelectric generator, kW.

The heat flow of engine exhaust gases in the heat exchanger is determined as follows.

$$Q_{ut} = G_g \cdot C_g (T_{g2} - T_{g3}), \text{ kWt}; \quad (7)$$

here  $C_g$  – heat capacity of flue gases, kJ/kg $\cdot$ °C.

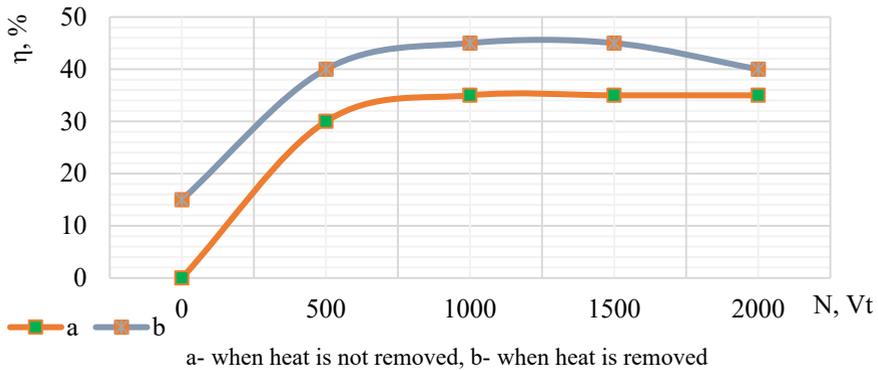
The efficiency of diesel power plants is determined by what part of the thermal energy generated in their engines is converted into useful mechanical energy and then into electrical energy.

For example, with a 1000 W engine load during testing, the fuel consumption was 0.72 kg/h, the heat flow from the engine was 30.24 MJ/kg, and only 35% of this heat was removed to generate electricity. through the generator, and the rest is released into the atmosphere.

When using a heat recovery device connected to the engine, at a load of 1000 W, the fuel consumption was 0.78 kg/h (the increase in fuel consumption is explained by the resistance

in the chimney pipe), and the heat flow divided from the engine is 32,76 MJ/kg, 45% the generated heat is usefully recovered.

In Figure 9 shows the dependence of the efficiency ( $\eta$ ) of a diesel power plant of drilling equipment on the load (N) applied to the engine.



**Fig. 9.** Graph of the dependence of the efficiency coefficient ( $\eta$ ) of a diesel power plant of drilling equipment on the load (N) attached to the engine.

## 4 Conclusion

Analysis of the research results shows that the efficiency of the internal combustion engine of a diesel power plant of drilling equipment is actually 30-35%. It has been established that when using the proposed heat recovery device, this figure can be expected to be up to 45%.

The useful efficiency of the engine is increased by recovering secondary energy resources in the form of heat released into the atmosphere.

In the graph presented in Figure 9, line b shows the change in engine efficiency when using a heat recovery device, as can be seen from the graph, load efficiency (N) increases from 0 to 1000 Watts. , we can observe a decrease at loads of 1500 and a maximum of 2000 Watts. This is explained by the fact that at high loads the flow and consumption of flue gases increases, but the heat exchange process in the heat exchanger does not have time to completely utilize this heat, which leads to energy losses. In addition, the reason is also the low efficiency of thermoelectric generators used in the proposed device.

Thus, it has been established that our proposed device for useful heat recovery from a diesel power plant of drilling equipment will have high efficiency when using an engine with loads in the range of 50-75%.

## References

1. M.V. Merkulov, Mining informational and analytical bulletin **8**, 1-8 (2008)
2. P. Aird, *Deepwater Drilling: Well Planning, Design, Engineering, Operations, and Technology Application* (Gulf Professional Publishing, London, 2019)
3. M.V. Merkulov, R.U. Djuraev, O.B. Leontyeva, G.Y. Makarova, Y.B. Tarasova, International Journal of Emerging Trends in Engineering Research **8**, 4383-4389 (2020)
4. V.A. Kosyanov, G.V. Cherezov, S.V. Golovin, Prospect and protection of mineral resources **3**, 47-53 (2016)

5. M. Ramsey, *Practical Wellbore Hydraulics and Hole Cleaning: Unlock Faster, more Efficient, and Trouble-Free Drilling Operations* (Gulf Professional Publishing, London, 2019)
6. B. Aadnoy, R. Looyeh, *Petroleum Rock Mechanics: Drilling Operations and Well Design* (Gulf Professional Publishing, London, 2019)
7. V.V. Neskromnih, M.S. Popova, L. Baochang, *Destruction of rocks when drilling wells with diamond drilling tools* (Krasnoyarsk, 2020)
8. U. Sharafutdinov, I. Razhabboev, Z. Kadirova, A. Koldarov, M. Atamuratova, E3S Web of Conferences, **414**, 02020 (2023)
9. G. Eshonova, I. Razhabboev, Z. Kadirova, M. Atamuratova, U. Sharafutdinov, E3S Web of Conferences, **414**, 02019 (2023)
10. B. Kholmurodov, M. Dzhuraeva, U. Sharafutdinov, E. Kuznecov, E3S Web of Conferences, **278**, 01025 (2021)