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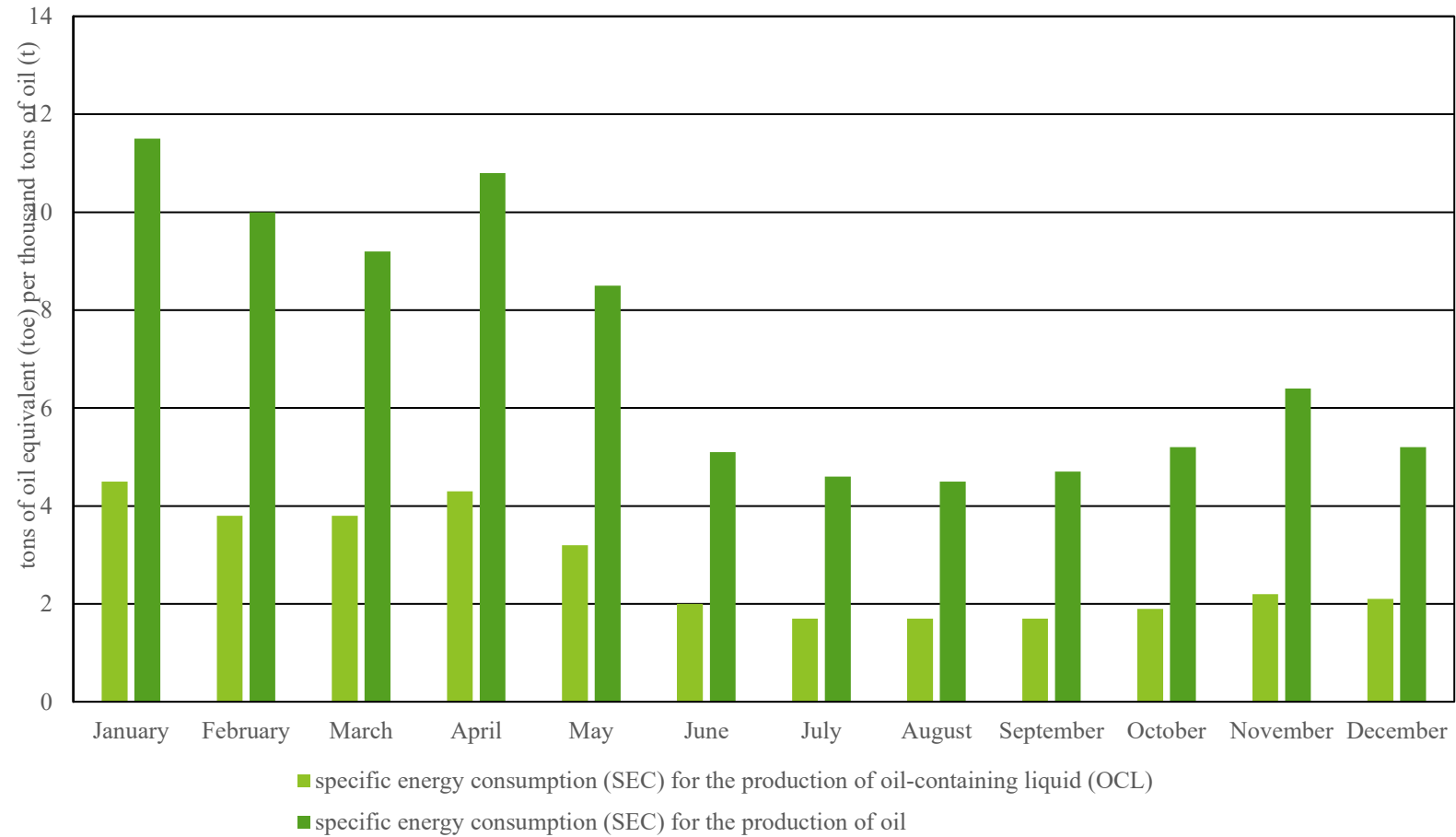
## **Energy-saving technologies in the operation of oil fields**

As is known, oil is one of the most important minerals ensuring the well-being of many countries including Russia. More than 500 million tons of oil is produced annually in our country. However, a significant number of oil fields are located in the Arctic zone, the border of which runs along the Arctic Circle north of  $66^{\circ}33'$  N. The development of such fields is complicated by climatic conditions, difficulties in cargo delivery and oil transportation, as well as distance from powerful energy systems.

An analysis of energy consumption of one of the fields within the Nenets Autonomous District (NAD) of the Arkhangelsk Region shows that up to 95% of electric energy is used to provide process (oil production, formational pressure maintenance system, electrical heating of process pipelines and equipment of the oil pumping station) and household consumers.

Electricity generation is provided by diesel power plants (DPP). A significant amount of diesel fuel is also spent for thermal energy generation, taking into account the low temperature for heating calculation ( $-39\text{ }^{\circ}\text{C}$ ) and, accordingly, the duration of a heating period of 289 days.

# Dynamics of changes in specific discharge per month for the year

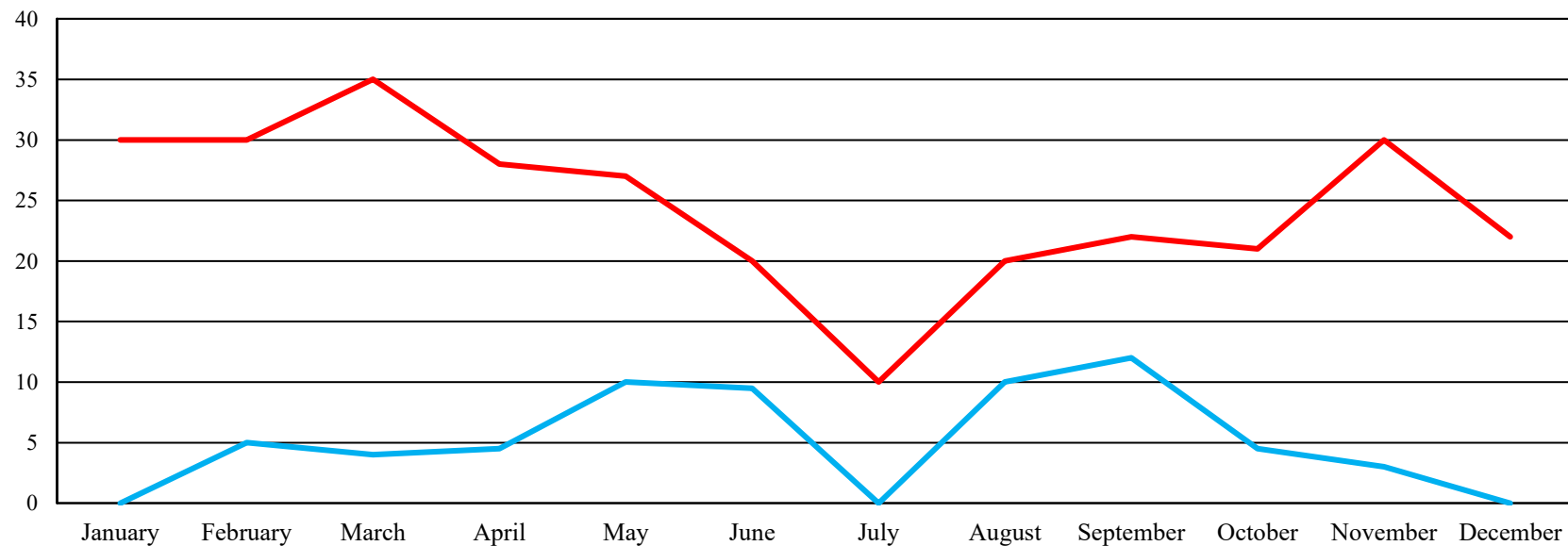


Difficulties in diesel fuel delivery, the state policy in the field of improving the energy efficiency of production processes, the need to solve environmental problems in oil fields specify the search for alternative methods of heat and electricity generation.

One of the most appropriate solutions to reduce diesel consumption is the use of associated petroleum gas (APG), which inevitably accompanies the oil production process. Use of APG significantly reduces greenhouse gases emission into the atmosphere. In Russia the volume of greenhouse gas emissions due to APG flaring is about 35 billion m<sup>3</sup>/year, which is more than the total amount of the fields of Nigeria, Iraq and Iran.

In Russia, APG is used primarily for oil heating in special process furnaces at the stages of marketable product obtaining and during preparation for transportation. Such furnaces do not provide for a system for exhaust gases heat recovery, the temperature of which reaches 583 °C. The use of gas-water heat exchangers widely used at compressor stations would provide the rotational field camp and production facilities with thermal energy, thereby reducing diesel fuel costs. However, currently, for heating, its own hot-water boiler-house using diesel fuel is used, and electric heaters are used at distant sites.

# Actual diesel fuel consumption, t, for thermal energy generation and potentially possible using heat recovery system (HRS)



— for 2018

— potentially possible

The boiler house also is not provided the heat recovery system, while significant heat losses are associated with the above-ground laying of heating networks, poor insulation and non-compliance of burning characteristics of rotational field camps enclosing structures with the current energy saving requirements. As a result, excessive consumption of thermal energy also leads to an excessive consumption of diesel fuel. In addition, to reduce thermal energy consumption, it is possible to use modern automated heat points with weather control.

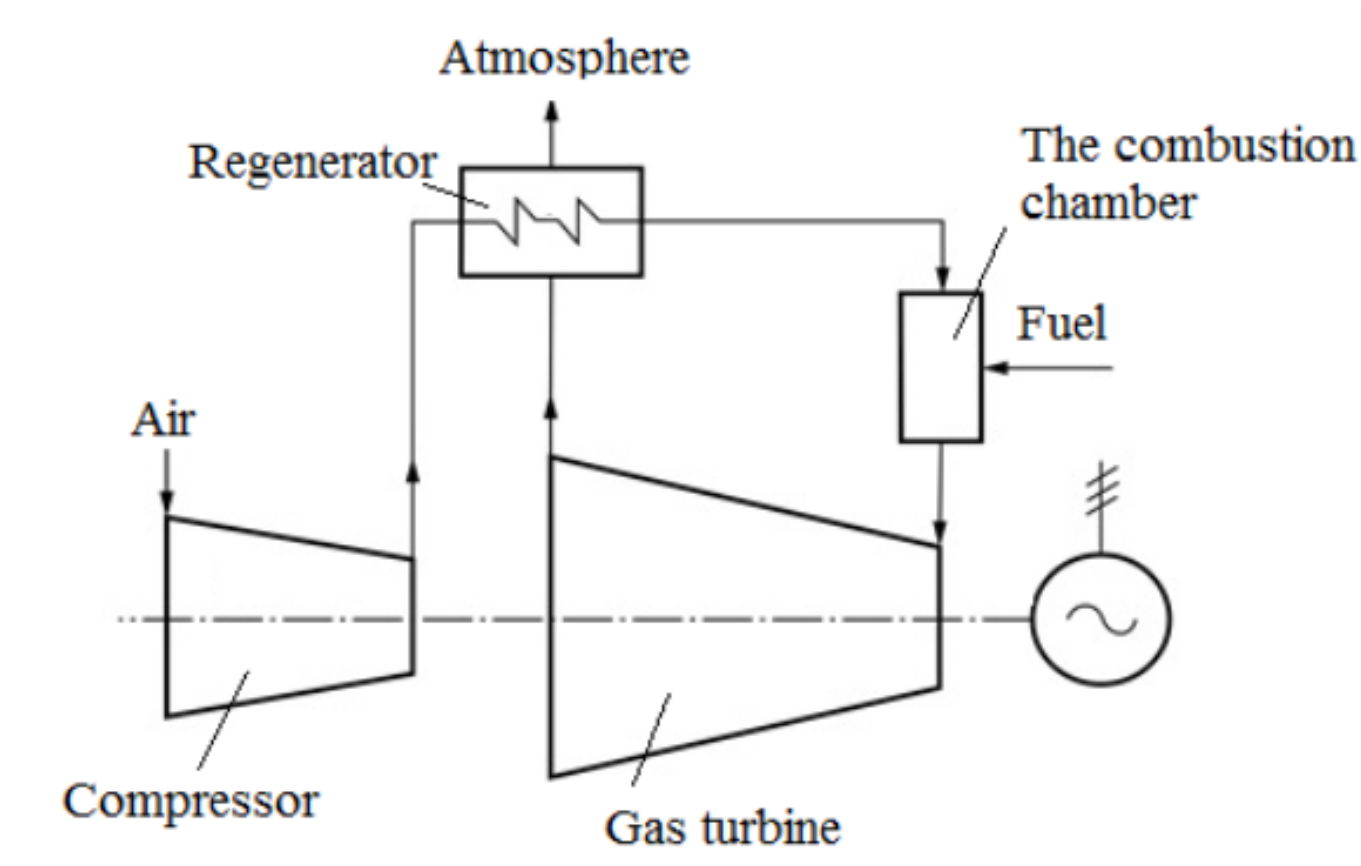


In addition to thermal energy generation for heating and hot water, diesel fuel is used in the following lines:

- power station (energy generation);
- motor transport.

Using gas power plants (GPP), currently the gas turbine exhaust gases with a temperature of about 500 °C are removed without recovery, increasing thermal pollution in the atmosphere. In addition, the non-regenerative cycle has a rather low efficiency (28-32%). In order to save energy, it is proposed to use a regenerative cycle to heat cyclic air, which is also widely used in gas turbine units for gas blower driving at compressor stations of gas mains.

The use of the regenerative cycle according to the analysis of will decrease the specific consumption of fuel gas by 0.01 kg/kW·h, which corresponds to an increase in efficiency up to 37%.



Another possible vector of energy saving in the development of energy resources in the oil field is the use of the combined cycle providing for reduction of exhaust gases temperature and increase in plant efficiency up to 60%.

There are also potential opportunities for energy conservation in the power supply system of the main production sites of the enterprise. Technical losses in electric networks are load losses (37%) and idle losses (62%) due to uneven energy consumption. The limit reactive power coefficient ( $\text{tg}\varphi$ ) for consumers connected to 6 kV voltage networks is 0.4.

To analyze the level of reactive power compensation in the networks of the enterprise under study,  $\text{tg}\varphi$  values for outgoing feeders were calculated based on the experimental data. An increase in reactive power level by 11 out of 63 studied 6 kV feeders shows an insufficient level of reactive power compensation. An increase in reactive power factor leads to an increase in electric energy losses in electric networks and an increase in electric energy cost.

To increase the energy efficiency of pumps operation responsible for formational pressure maintenance (RPM) systems, it is recommended to implement a variable frequency drive (VFD).

However, it should be noted that when installing the VFD on high-voltage electric motors (EM), the converters will be equipped with power transformers of about 1000 kVA (for EM - 630 kW). In this case, it is necessary to take into account the idle and short-circuit losses, which will be at least 2% of the power transformer capacity, and also the own costs of the VFD block modules at least 0.5% of the power, then the total potential reduction will be 2.5% for each unit.

Thus, the total estimated potential energy savings as a result of implementing the VFD system on the pumps of the RPM system will amount to 2924.2 thous. kW\*h/year.

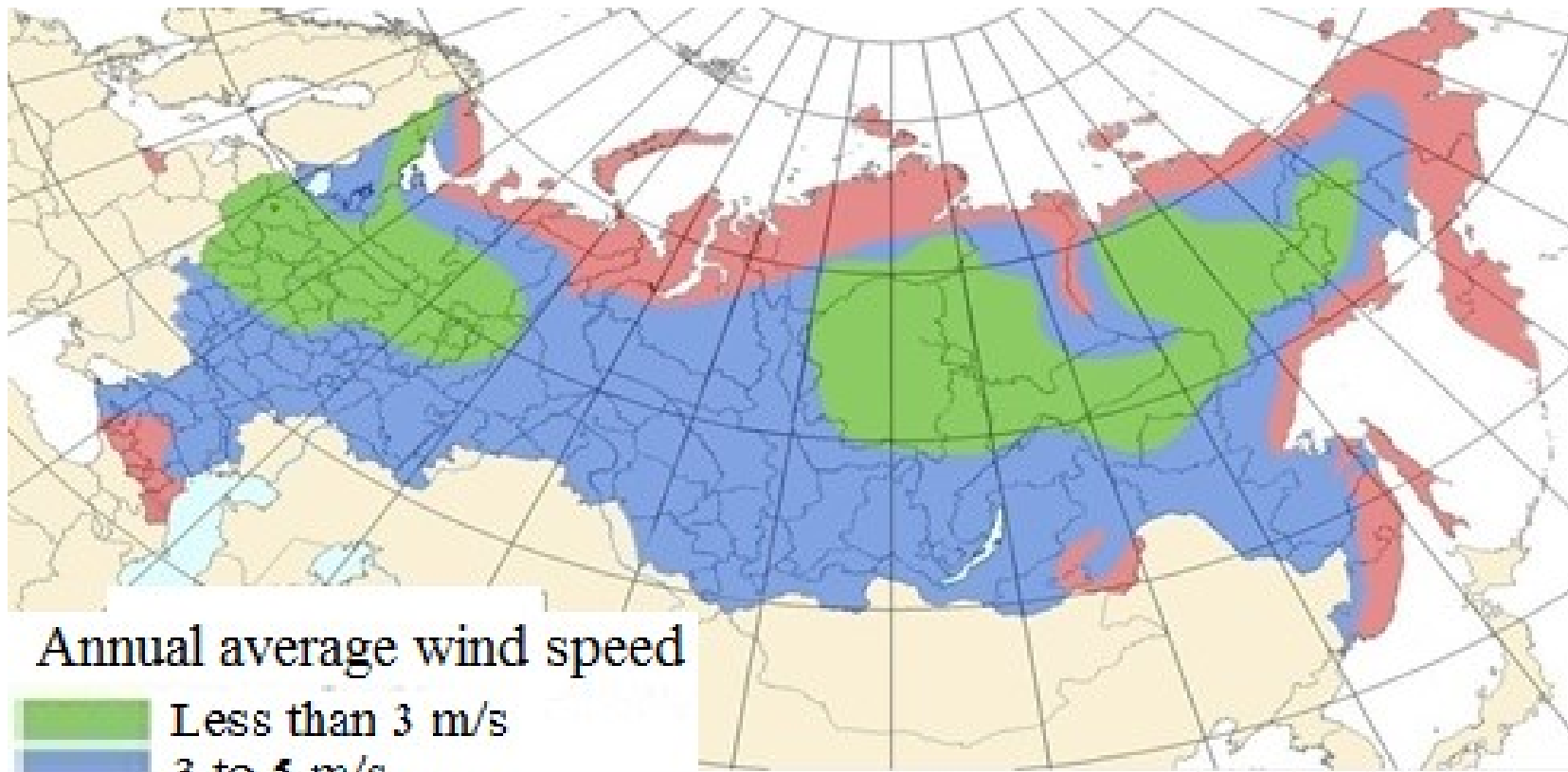
While studying the operation mode of pumps for commercial oil transferring from the central oil collection point (CCP), it was found that the pumps operate with a variable load, which is due to the performance control through throttling. In this system, the VFD is also the most economic control mode that contributes to energy saving in the amount of 6250.2 thous. kW\*h/year by reducing power consumption and process automation.

A modern energy-efficient automated induction-resistive system, which allows maintaining the necessary temperature conditions for transportation of oil (40 ... 45 °C) and water (+ 10 °C) is implemented at the enterprise for electric heating of the main pipelines.

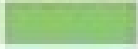


However, in order to avoid inefficient energy consumption, the system requires modernization, which consists in installation of additional temperature sensors on each parallel pipeline upstream of a common collector.

In terms of using alternative energy sources at the fields under question, wind generators can be used to generate electric energy, since the facilities are located in the way of the Bolshezemelskaya Tundra with a flat relief.

The average wind speed is 4-8 m/s, which determines the feasibility of wind generators application. The calculation for one production site presents that the energy saving potential will be 2102.4 thous. kW·h/year when installing wind generators with a total capacity of 396 kW.



**Annual average wind speed**

-  Less than 3 m/s
-  3 to 5 m/s
-  More than 5 m/s

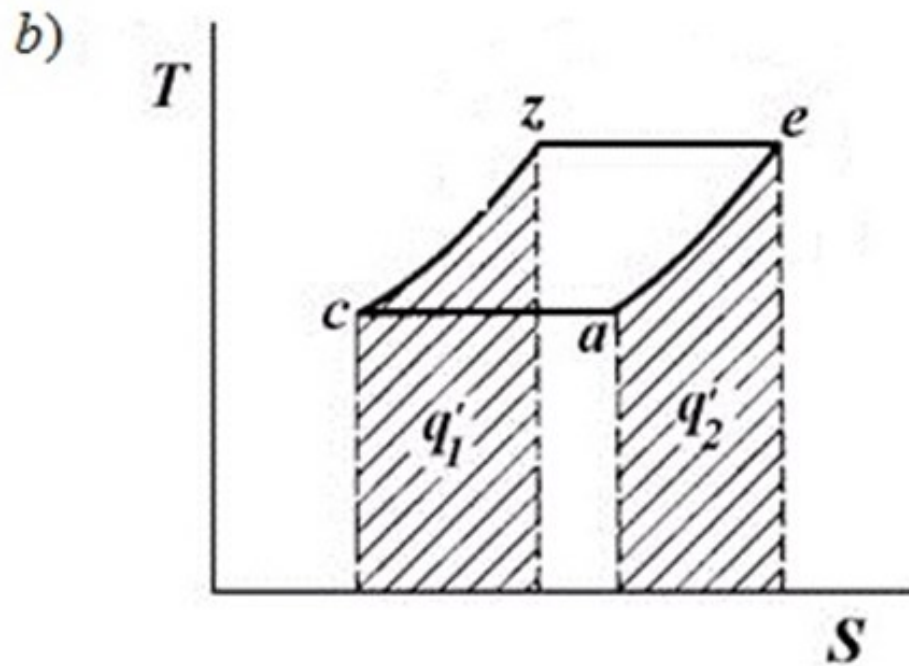
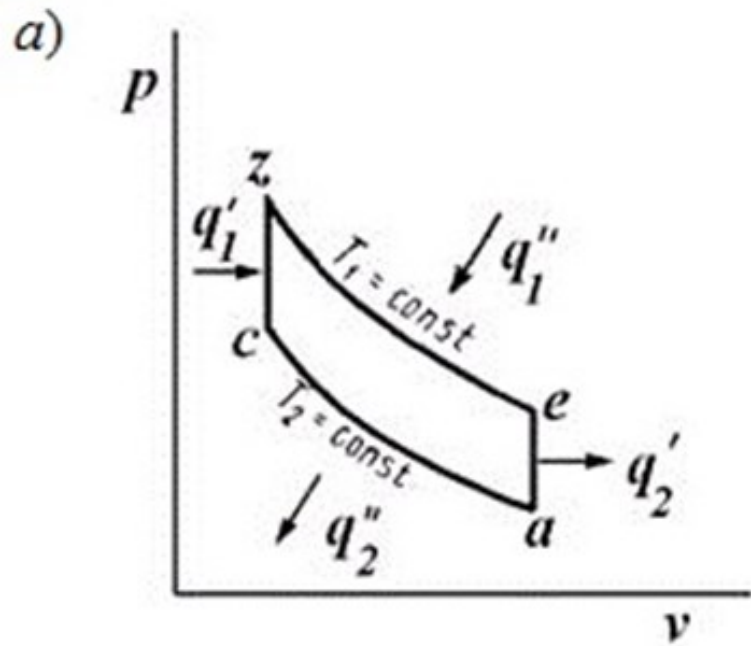


One of the latest trends in energy saving, in particular in the European Union, is the use of energy cogeneration. Thus, as of 2020, the contribution of cogeneration is planned in the field of energy saving of about 15% and as for reduction of greenhouse gases - 24%. In this case, the share of cogeneration using equivalent energy sources is growing. The feasibility of distributed energy application is based on the conventional selection of equipment for peak conditions, while the structure of energy consumption is uneven. The use of distributed energy based on gas engine generator plants (GEGP) with gas-diesel engines and waste modules is a particularly rational solution for experiencing power shortages of oil fields development.

Starting from the production drilling stage, this solution will allow stopping usage of boiler houses. The modular technology will provide for the possibility of a gradual increase in generators and energy consumers, and will make it possible to replace the electrical heating of pipelines with heat using antifreeze.

However, distributed power generation does not currently exclude the need for the delivery of diesel fuel, preparation for the respective generators of fuel gas energy (APG), “crude” oil or its highly viscous derivative products. To solve this problem, it is proposed to use the well-known Stirling heat engine, which does not require special fuel preparation and uses any source of heat, such as solar energy, associated petroleum gas.

# Stirling ideal cycle diagrams



The process a–c is isothermal compression with intense heat removal,  $q_2'$  in this case,  $T_a = T_c = T_2$ .

The c–z process is isochoric,  $v_c = v_z$ , the temperature of the working fluid increases from  $T_c = T_2$  to  $T_z = T_1$  with heat  $q_1'$  supply.

The process z–e isothermal expansion ( $T_z = T_e = T_1$ ), heat  $q_1'$  is supplied to the working fluid.

The e–a process is isochoric,  $v_e = v_a = \text{const}$ , with heat  $q_2'$  removal.

External heat supply is carried out through a heat-conducting wall. The working fluid is in an enclosed space during operation.

The work in the Stirling cycle is a difference between the operation obtained in the process of isothermal expansion (heat supply  $Q_1$ ) and the work spent in the process of isothermal compression with heat removal ( $Q_2$ ). The cycle thermal efficiency is determined according to the formula:

$$\eta_{\text{St}} = 1 - \frac{\tau - 1 + (k - 1) \ln \varepsilon}{\tau [1 + (k - 1) \ln \varepsilon] - 1},$$

where  $\varepsilon = v_a / v_c$  – compression index;  $\tau = T_1 / T_2$  – extent of heating;

$k = c_p / c_v$  – adiabatic index.

Among the advantages of Stirling engines the simple design, economical operation, environmental friendliness can be noted. However, bulkiness and material consumption, inertia when changing the heat flux, the need to create high pressures introduce limitations in the use of Stirling engines.

The energy-saving technologies associated with the need for temperature stabilization of rocks in permafrost conditions to avoid deformation of production wells and potential emergencies have the special place in the development of oil fields.

Permafrost rocks in the Bolshezemelskaya Tundra of the Nenets Autonomous Area occupy almost the entire central and northeastern parts of the district - 95%. The thickness of permafrost rocks reaches 500 meters, the temperature ranges from  $-5\text{ }^{\circ}\text{C}$  to  $-2\text{ }^{\circ}\text{C}$ .

Currently, the following technical solutions are used to prevent permafrost thawing: strapping and suspension of casing strings, thermal insulation of casing strings and construction of seasonal cooling devices (heat pipes). A more reliable method to prevent soil from thawing is to use geothermal heat pumps, while heat can be used for heating and hot water supply facilities.

CONCLUSIONS: The use of the proposed energy-saving technologies in the operation of oil fields will allow reducing costs for fuel, amount of hazardous emissions and heat pollution of the atmosphere.

THANK YOU FOR ATTENTION!