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ANALYSIS OF THE STATE OF ENERGY SUPPLY AND OPERATING MODES OF PUMPING STATIONS

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ABSTRACT
The article presents the level of electrical energy supply of pumping stations, their energy supply, operating modes of pumping units, economic costs and other information.

It is known that pumping stations are among the leading energy consumers in agriculture, industry, and municipal services, which are important sectors of any country's economy. For example, in the Russian Federation, more than 300 billion kWh of electricity is consumed annually for pumping stations, which is more than 20% of the country's consumption [1]. According to the Ministry of Water Resources of Uzbekistan, more than 55% of the irrigated areas in our Republic, i.e. 2.4 million hectares of arable land, are irrigated by pumping stations, and 7.4 billion kWh (10.84% of the country's energy consumption) were consumed for this in 2020 [2]. In addition, a large amount of electricity is consumed by pumping stations in the municipal system, according to the data presented in [3], this amount in Russia per year is 120...130 billion kWh, that is, 7.0...8.0% of total energy consumption. In the energy sector, the amount of energy consumed by pumping stations for technical water supply at thermal power plants (TPPs) is also quite large, for example, a 4000 MW TPP requires 135 m^3/s of technical water [4], taking into account the head value of 30...40 meters for technical water supply, 10.0...15.0 kW of pumping power is consumed for each 1 MW of power. If we calculate these figures based on the current indicators of thermal power plants of the Republic of Uzbekistan, then 3.0...4.0% of the total energy consumption is spent on technical water supply pumping stations per year. Therefore, it is not an exaggeration to say that all pumping stations operating in the above-mentioned economic sectors of our Republic consume at least 16...18% of the total electricity produced, which is 3.0...3.2 trillion soums at the current electricity tariff.

The above figures show that pumping stations are large energy-intensive facilities, and any measures aimed at reducing energy costs are very important.

Due to high energy costs, the cost of water supplied to land areas using pumping stations is more than 2 times the average cost of water in the Republic [5]. This situation in the use of pumping stations requires paying sufficient attention to energy efficiency and operational efficiency of equipment. Along with replacing outdated equipment in pumping stations with new, more economical equipment, one of the most important issues in the use of pumping stations is the use of advanced, modern systems.

The work [5] emphasizes the need to improve energy efficiency and operational efficiency in pumping stations in the following areas.

- replacing outdated, low-efficiency equipment with new equipment with better performance;
- increasing the operational performance of equipment based on the reconstruction of the pumping station;
- application of advanced, modern methods of technological process control at pumping stations;
- application of highly effective technical solutions and methods to reduce electricity costs at pumping stations.

To meet the demand for water, pumps of various brands are used. For irrigation of crops, industrial, municipal and economic needs, mainly dynamic, vane-centrifugal and displacement pumps are used. The range of application of displacement pumps is limited to only 27 meters and since they cannot be sucked from water levels below, centrifugal pumps are mainly used in the above-mentioned areas. The water delivery capacity of these pumps ranges from 1.5 l/s to 3600 l/s for horizontal-axis pumps and up to 25000 l/s for vertical-axis, spiral chamber pumps. The displacement values allow pumping water up to a height of 110 meters [6] .

The operating mode of pumps varies depending on the flow rate and pressure of the pumped water. Usually, the operating modes of pumps are evaluated by their operating characteristics. An example of the operating characteristics of centrifugal pumps is shown in Figure 1.

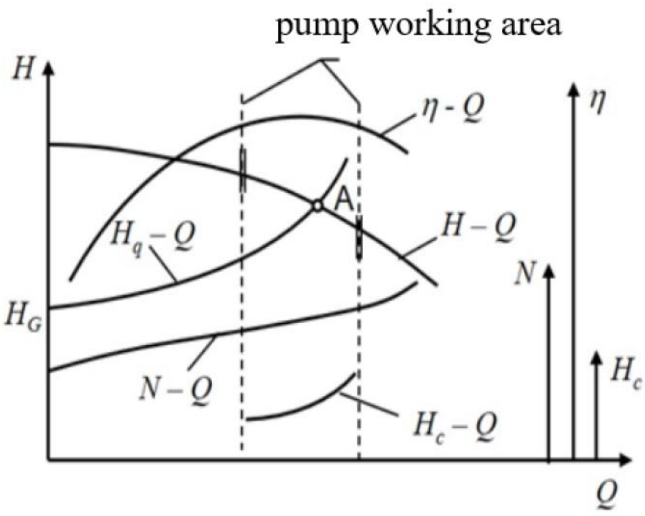

Figure 1. Operating characteristics of a centrifugal pump

This characteristic consists of curved graphs representing the dependence of the main parameters of the pump - head H , power N , useful coefficient of performance (FIC) $\eta$and suction head H_{c} - on the values of the pump efficiency Q. With the help of the characteristics, it is possible to predict how the other parameters of the pump will change at all values of its water delivery efficiency, which allows you to plan the pump operating mode. The selection of pumps based on the requirements is also carried out on the basis of their characteristics.

The above operating characteristic is obtained at constant values of the pump impeller and shaft rotation speed. If these values change, all the graphs in the characteristic will also change.

the pump pressure characteristic $H - Q$ *intersects* the piping system characteristic $H_q - Q$ is called the operating point of the pump (Figure 1).

Pipeline system characteristic $H_q - Q H_q = H_G + \sum\Delta h_q$ is built on the basis of connection. Therefore, according to this formula, the sum of the pressure loss values in the piping system at all available values of pump efficiency is $\sum\Delta h_q$ must be calculated and added to the constant value of the pump geometric pressure (water pumping height) H_G. But since this work has a large volume, $\sum\Delta h_q$ It is more convenient to determine the values of $\sum\Delta h_q = k \cdot Q^2$ using the formula [7]. Where k is the constant resistance coefficient of the pipeline system. As can be seen from the formula, *the* $H_q - Q$ graph is an increasing graph, since as the values of Q increase, $\sum\Delta h_q$ values also increase.

The optimal operating point of the pump is $\eta$the highest peak on the ηQ *graph, i.e.* corresponds to the maximum point of .

There are several ways to analytically express the pump pressure characteristic $H - Q$ *, for example, in [8]* $H=H_0 - K \cdot Q^2$ or it is proposed to express $H = A + B\cdot Q + C\cdot Q^2$ by the equations H= $H_0 - K_1 \cdot Q - K_2 \cdot Q^2$ [7]. In this case , the coefficients K, K_1, K_2, A, B, C *in the equations* are constant and are determined as a result of the analysis of the graphs of the pressure characteristics.

of the pump head based on the quadratic parabolic equation $H = H_F - C_F \cdot Q^2$ was proposed in [1]. Here, C_F is the imaginary hydraulic resistance of the pump, determined as follows.

$$S_F = \frac{H_1 - H_2}{Q_2^2 - Q_1^2} \qquad (1)$$

H_F – the pump's output when water consumption is zero or minimal is determined by the following formula

$$H_F = H_1 + S_F \cdot Q_1^2 \qquad (2)$$

S_F *The value is calculated based on the values of* H_1, H_2 and the corresponding values of Q_1, Q_2 obtained in the operating zone of the pump pressure characteristic .

However, the main drawback of these methods is the high level of error due to the fact that the constant coefficients are often determined based on graphs of pressure characteristics, which in most cases do not have a high level of accuracy.

Another analytical expression for the pump head is given in the form of the equation [9] $H = A\cdot n^2 + B\cdot n\cdot Q - C\cdot Q^2$, *where* n is the number of pump shaft revolutions, and the coefficients A, B, C are determined by the system of flow velocities at the outlet of the impeller and based on the coefficients of hydraulic resistance, which is much more accurate. However, the use of this equation is quite difficult due to the fact that it is quite difficult to determine the coefficients of hydraulic resistance in the impeller of the pump and does not give accurate results.

A new equation for determining the pressure value based on the geometric dimensions and the number of shaft revolutions at the outlet of the pump impeller was proposed in [10] in the form $H = A \cdot Q \cdot n - B \cdot Q^2$. This equation is free from the above-mentioned shortcomings, and a comparison of the results of the calculations performed with the measurement results shows that it gives results with high accuracy.

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