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EFFECT OF WATER LEVEL CHANGES IN THE FOREBAY ON THE ELECTRIC ENERGY CONSUMPTION OF PUMP UNITS

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Introduction. One of the technological parameters during the operation of pumping stations used for irrigating crop fields is the periodic change in the water level VpbV_{pb}Vpb at the lower weir of the intake structure (forebay) of the pumping station. The water level at the lower weir of the forebay largely depends on the water source, the hydrogeological regime of the inlet and outlet channels of the irrigation water supply systems, as well as the water consumption patterns of the irrigated agricultural fields.

The main hydraulic regimes during the operation of the forebay include maintaining a uniform water surface for the inflowing water, preventing water from spilling over the hydraulic structure due to waves or sudden forced shutdown of the pump units, and ensuring cavitation-free operation of the pump units. In particular, a sharp increase in the water flow being lifted by the pumping station should not lead to a drop in the inlet channel water level or cause cavitation processes.

Cavitation is the process of disruption of the water flow density, accompanied by the formation of bubbles filled with water, air, or gas vapor. Cavitation leads to additional energy losses and causes erosion of the impeller and pump casing surfaces.

Main Part. The operating mode of the pumping station with changes in the water level V_{pb} at the lower weir, as well as the performance characteristics of the pump unit and pressure pipeline, are analyzed based on graphical-analytical descriptions. In Figure 1, the head–flow (H–Q), power–flow (P–Q), and efficiency–flow (η–Q) characteristics of the 5000Д–32 type pump are shown, along with the pressure pipeline curve at static head H_{st} The intersection point A of the centrifugal pump characteristics with the pressure pipeline curve corresponds to the nominal operating mode of the “pump–pipeline” system, providing the water flow Q_A head H_{AH} power P_A and efficiency ηA .

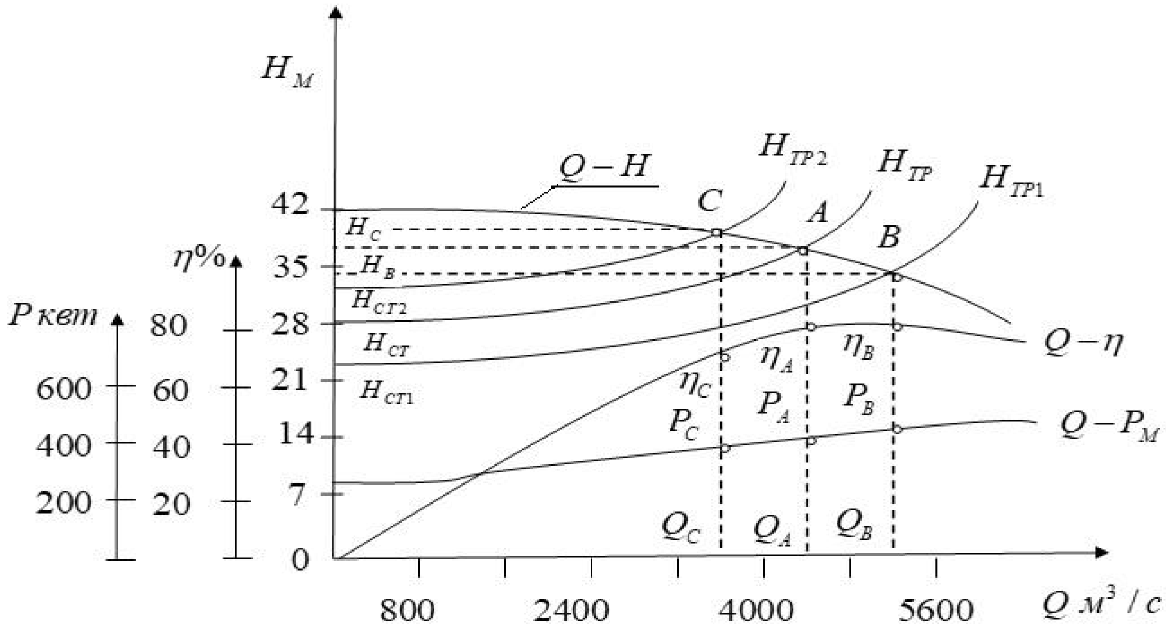

Figure 1. Effect of Water Level Changes at the Lower Weir of the Forebay on the Operating Mode of the Pump Unit

As can be seen from Figure 1**,** with an increase in the water level in the forebay, the static head decreases $H_{ст1}<H_{ст}$ In this case, the operating point of the “pump–pipeline” system shifts to point V, corresponding to the pump parameters Q_B, H_B, P_B, η_B An increase in the forebay water level leads to a higher water flow rate, which creates a discrepancy between the water consumption and water supply curves.

Moreover, the shaft power of the pump unit increases, which in turn can lead to overloading of its electric motor, and in some cases, the motor temperature may exceed the permissible limit. An increase in the pump shaft power results in a decrease in the pump unit’s efficiency (η\etaη) and the energy efficiency of the pumping station, ultimately causing a rise in the specific electricity consumption.

Conversely, with a decrease in the water level in the forebay, the static head increases $H_{ст2}>H_{ст}$ In this case, the operating mode of the “pump–pipeline” system is characterized by another operating point C, with coordinates Q_C, H_C, P_C, η_C

A decrease in the forebay water level increases the head generated by the centrifugal pump while reducing the flow rate. As a result, the pump shaft power and pump efficiency (η\η) decrease. A reduction in the flow rate may cause the pumping station to fail in meeting the water supply curve requirements, which can negatively affect agricultural crop irrigation. Insufficient irrigation of crops can lead to severe economic losses.

Table 1. Main operating parameters of the 5000Д-32 centrifugal pump along the full length of the pressure pipelines

№ т/с	Difference in Weir Levels $H_{СТ}$, м	HA Water Supply Q*, m3/s	HA Head H^*, м	HA FIK η^*	HA quvvati P^*, кВт	HA solishtirma elektr sarfi $\Delta Э^*$, кВт*соат/млн.м^3
1.	22,5	0,776	0,797	0,972	0,742	0,9836
2.	23	0,804	0,781	0,975	0,748	0,9768
3.	23,5	0,832	0,766	0,976	0,755	0,9742
4.	24	0,860	0,750	0,977	0,762	0,9711
5.	24,5	0,889	0,734	0,976	0,769	0,9729
6.	25	0,917	0,719	0,975	0,776	0,9765
7.	25,5	0,946	0,705	0,972	0,783	0,9837

Analysis of Energy-Efficient Operating Modes of Pump Units under Forebay Water Level Variations

To analyze the energy-efficient operating modes of the pump unit under changes in the forebay water levels, the “Ramadan” pumping station in Tashkent region was taken as an example. The real technical characteristics of the hydromechanical and electromechanical equipment were considered. The centrifugal pump of type 5000Д-32, along with the geometrical dimensions of the pressure pipelines along their entire length—including suction, communication, and main pressure pipeline characteristics—were taken into account. Additionally, the model considered pressure losses due to local resistances (throttle valves, check valves, smooth bends, gradual expansions or contractions, etc.). Using a developed mathematical model and methodology, the main operating parameters of the pump unit were calculated, and these values are presented in Table 1.

Conclusion. Table 1 shows the relative values of flow rate, head, pump efficiency (η), shaft power, and specific electricity consumption of the pump unit under different forebay water levels. These values are expressed in dimensionless form as follows:

($Q^*=Q/Q_Н$, $H^*=H/H_Н$, $\eta^*=\eta/\eta_{НАС_Н}*\eta_{ДВ_Н}$, $P^*=P/P_Н$, $\Delta Э^*=\Delta Э/\Delta Э_Т$), $\Delta Э_Т$– is the theoretical specific electricity consumption of the pump unit for the delivered water. This normalization allows identification of the most efficient operating modes of the forebay water level.

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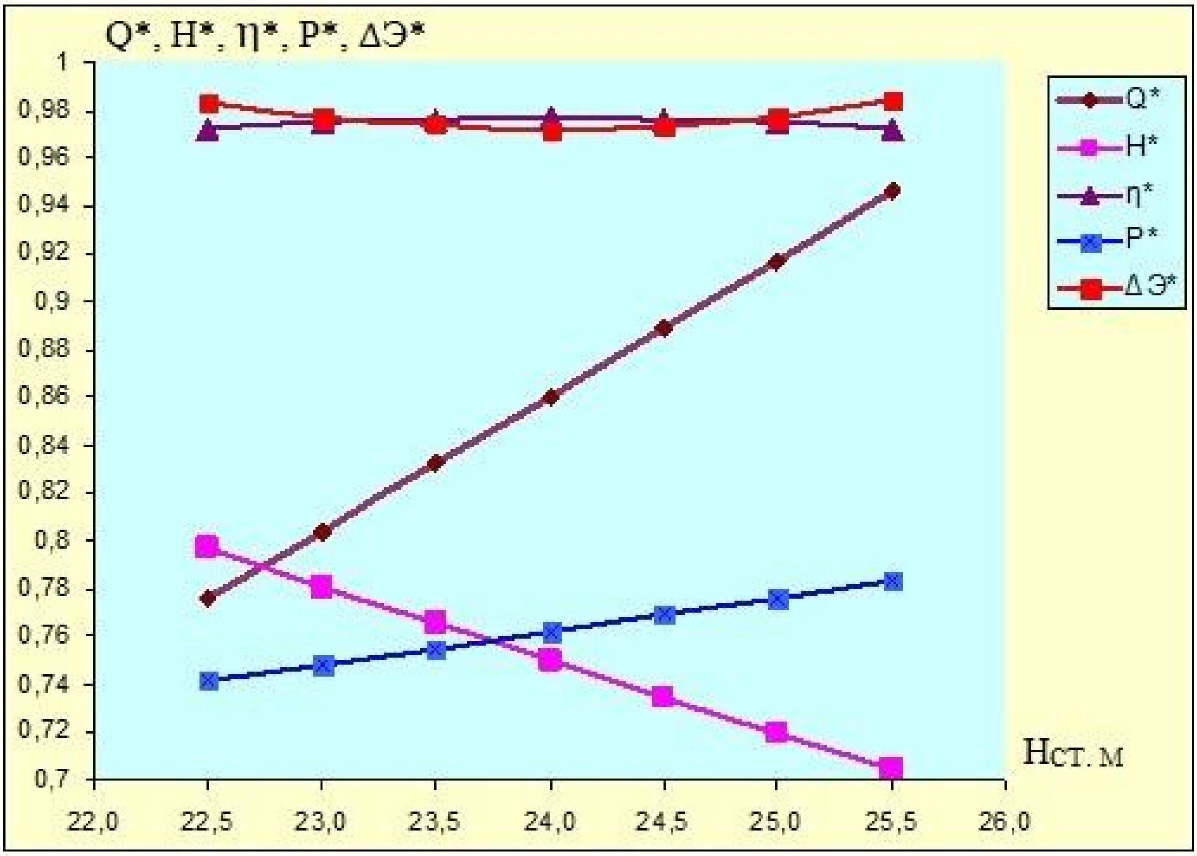

Figure 2. Effect of Lower Weir Water Level Changes on the Main Parameters of the Pump Unit at the Ramadan Pumping Station

In the graph of **Figure 2**, the pump unit parameters of the “Ramadan” pumping station are shown for the static head in the pressure pipeline ranging from 22.5 to 25.5 m. The most efficient operating mode occurs at H_{CT} = 24 m, where the pump units operate with the minimum specific electricity consumption. To maintain this mode, it is necessary to keep the water level in the forebay stable and steady.

Conclusion. Taking this into account, based on the actual operational and technical characteristics of the hydromechanical and electromechanical equipment, it is necessary to determine the optimal and minimum permissible fluctuation range of the lower weir water level for each pumping station in order to ensure energy-efficient operating modes of the pump units. Efficient operation of the pump unit and achieving the required parameters of the hydromechanical equipment can be ensured by stabilizing the lower weir water level and maintaining it within the minimum permissible fluctuation range (H_{st} control). Additionally, the flow rate of the pump unit and the water consumption curve can be optimally matched by proper regulation to maximize performance.

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