UDK 532.626.8.

OF THE CHANNEL WITH A CASCADE OF PUMPING STATIONS

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Based on the numerical solution of differential equations of Saint-Venant investigated the transition process in the pond canal with a cascade of pumping stations established that side of the pond water selection leads to a reduction of positive and negative waves increase.

The transition process in channels with a cascade of pumping stations, mathematical model, Saint-Venant equations. Calculation of transient channels in a cascade of pumping stations conducted using a mathematical model based on the solution of Saint-Venant equations. Found that side of the pond water selection leads to a reduction of positive and negative waves increase. If regulation cascade pumping stations on the channel can be applied regulatory scheme on the upper pond and "flowing volumes."

By this time built a significant number of large backbones with a cascade of pumping stations, Karshi, Amu-Bukhara, Sarativskyy, Irtysh-Karaganda, the Dnieper-Donets Basin, Dnieper-Krivoy Rog, combining zone Pivnichnokrymskoho channel and others. In these channels, in addition to wind waves, with starts and stops pumping units there are waves of displacement, a feature of which is the ability to move large volumes of water [3,4,8].

In case the pumping station in the canal that brings water formed positive backward wave thereof, and a channel that drains water - a direct negative wave - "wave discharge" (Fig. 1a).

When starting the pump station (Fig. 1b) in offtake positive wave - "filling wave" in scuba channel thus formed negative wave - "wave discharge". Discontinuous wave is characterized by steep, sometimes almost vertical front, causing quite a sharp change mark the water level in the canal.

Knowledge of the parameters in the design of waves moving channels with a cascade of pumping stations is important for the following reasons:

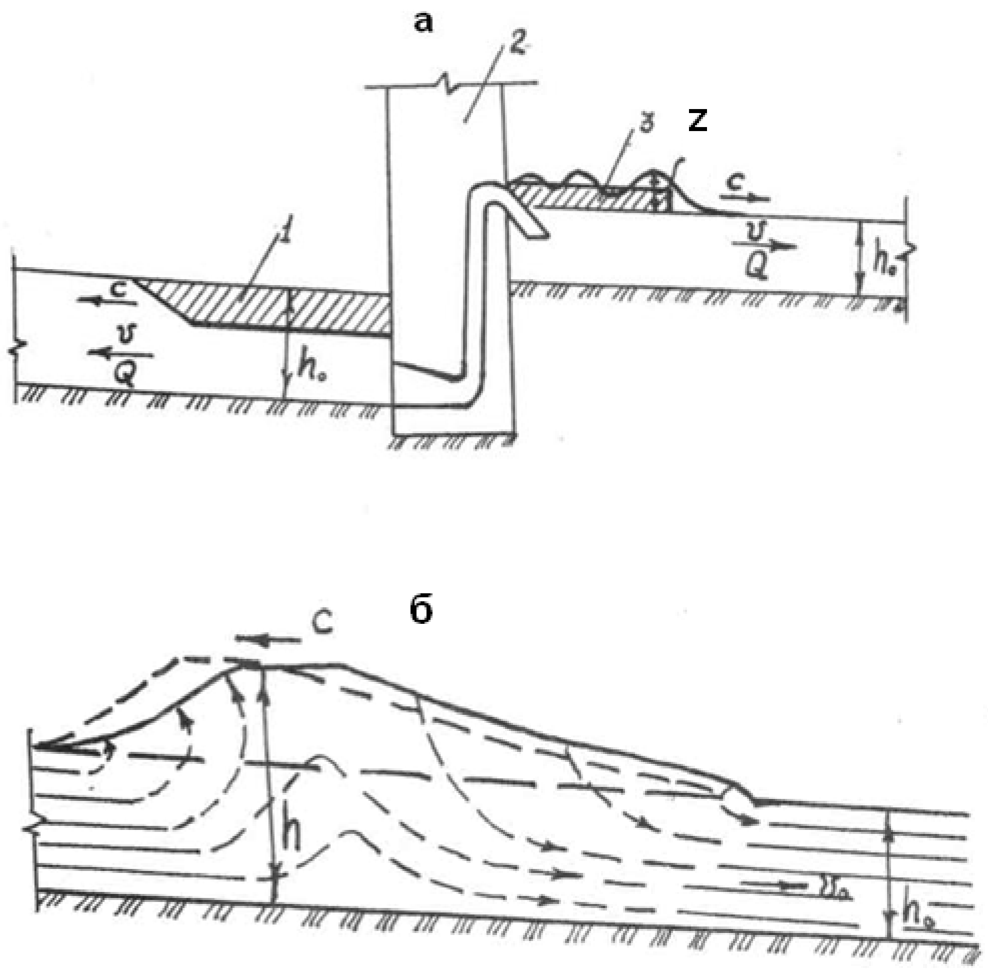


Fig. 1. The formation of waves moving at start pumping station: a - simple wave; 1 - reverse the negative wave discharge); 2 - pump station; 3 - positive direct discharge); 2 - pump station; 3 - direct positive wave (wave content); b - a complex wave. Firstly, should be taken into account wave height, together with the height surges, which can be determined by the formula Solovyov DS

$z = 0{,}07w,$

where - w - wind speed, z - wave height provided to prevent overflow of water through the dam channel; secondly, should be taken into account dynamic impact not only on the wave slopes, but the bottom bed of the channel. Discontinuous wave is characterized by steep, almost vertical front sometimes causing enough mark a sharp change in water level in the canal.

With the passage of the crest of the wave of pressure in the pores of the soil will increase, and the hollow - decrease. That will affect the soil volume, filtration forces directed toward the movement of water filtration, and lead to a decrease in resistance hruntudo erosion and suffusion of an external or seepage slopes vyporu on the channel.

In the case of negative waves pumps can work in cavitation mode canarise breakthrough air suction pipe to pump, leading to the breakdown in vacuum siphon water master facilities. Repeated charging siphons later passing waves lead to pressure fluctuations in the pressure pumping station tract and complications of pumping equipment.

Increase of control pumping stations on channels can be achieved by applying the principle of cascade control.

To calculate the movement of water in the channel [10] at the starting and stopping of pumps used method of mathematical modeling results are consistent with experimental data.

As an object of research was selected channel with three pumping stations operating in cascade. Pond between stations have different lengths, which makes it possible to identify the impact of long headrace on the size and shape of the wave movement.

The cross section of the channel - polygonal with a width at the bottom equal to b = 4,0m. Factor bookmarks accepted equal slopes m_1 = 4na height 2.5 m from the bottom and m_2 = 2 other altitudes. Bow channel i = 0,00008. Slopes channel coefficient m_2 = 2 reinforced gravel thickness of 20cm. This attachment is put on the slopes m_1 = 4 (0.5 m below the minimum water level in the canal). The lengths of the pond between pumping stations: I-4,46km; II - 21,67km.

Pumping stations are equipped with axial and centrifugal pumps with supply 9m^3/s. Feed each pump station Q = 36m^3/s.

The movement of water in the channel with no established mode described by Saint-Venant equations [1]:

$$\frac{\partial Q}{\partial t} + 2v\frac{\partial Q}{\partial x} + B\,(c^2 + v^2)\,\frac{\partial h}{\partial x} = g\omega\varphi \qquad (1);$$

$$b\frac{\partial h}{\partial t} + \frac{\partial Q}{\partial x} = q; \qquad (2);$$

where $\varphi = i - \frac{Q^2}{K^2}$; $c^2 = \frac{v^2}{i\,R}$; $Q = v\omega$; $K^2 = \frac{\omega}{h^2}R^{7/5}$; $R = \frac{\omega}{\chi}$; i = bow to the bottom of the channel; b - width of the free surface flow; χ - wetted perimeter section; h - depth of flow in the section in question; v - the average flow rate in the same section; R - hydraulic radius; ω - sectional area of the living; Q - flow; q - lateral inflow (outflow); x - longitudinal coordinate; t = time.

Solution of equations (1) and (2) made using implicit difference scheme. For the solution of the problem of nonlinear equations (1) and (2) were presented finite-difference form of a dimensionless form. For the method of solving matrix developed in the Institute of Hydrodynamics of the Academy of Sciences [1,9].

In case of violation of continuity of the flow channel carried breakdown investigated on parts that were calculated in such a way that the interior points are not breached conditions of models under consideration. These points appeared Places of water from the canal. The calculations were performed on a computer.

Input data have been calculated geometric and hydraulic characteristics of the channel modes pumping stations and water level in the canal.

Disable all pumps at pumping stations cascade (emergencies) provided the channel depth 4,5m showed that the share of the channel between the pumping stations is a damped oscillation process (Fig. 2). In the pumping station №2 deviation level is Δh_1 = - 0,38m, and the initial alignment (pumping station №1) Δh_1 = 0,41m. In the second compartment Δhn = - 0,91m and end alignment Δh_k = 1,0m in the third alignment Δh_k = 0,62m, Δh_n = 0,64m.

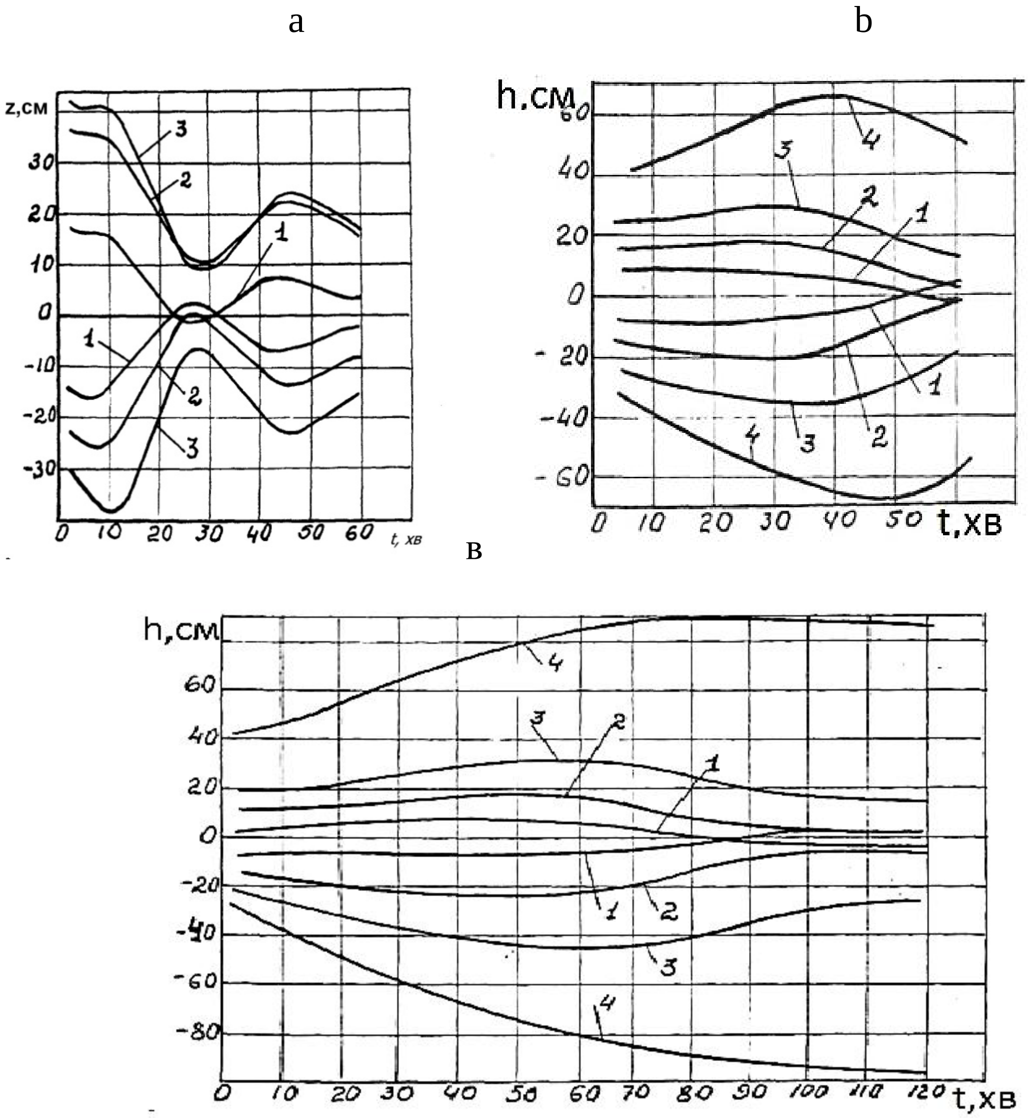


Fig. 2. Dynamics of fluctuations in rivnivvody b'fah at vid¬klyuchenninasosnyh stations: and - b'ef I; 2 - b'ef 2; in - b'ef 3; Q, m^3/s: 1-9; 2 - 13; 3 - 27; 4 - 36.

As shown in Figure 2 for the deviation levels the potential impact of long headrace, the longer the pond, the more level fluctuations. Identical pattern of oscillations is observed at a deviation of three, two and one pump. Changing only the deviation level.

This shows thatmost dangerous are positive displacement waves that occur when you stop pumping stations (emergency situation). In this case, the maximum wave height and movement in this case must be checked dry stock channel stability and fixing its slopes.

Analysis of wave motion in the case of stop pumping stations showed that the shape of the wave depends on the length of the channel between the pumping stations. The smaller length headrace, the more stysnutoyustaye initial wave. With increasing length of headrace initial wave formed more spread. Length of headrace influences on time damping fluctuations of the water level in the pond. Time attenuation level fluctuations in the first pond is 120 ... 140 min., At the same time as the other two pond chasbilshe this several times.

When the pumps at each station cascade (water depth in the channel 4,5m) moving waves are formed differently than when disconnecting the pump stations (Fig. 3).

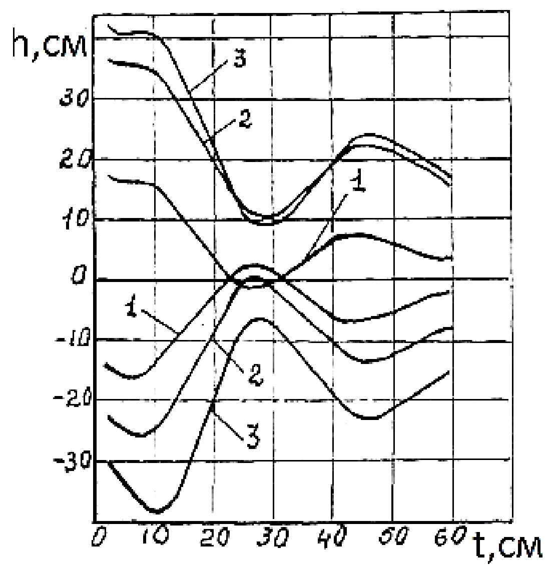


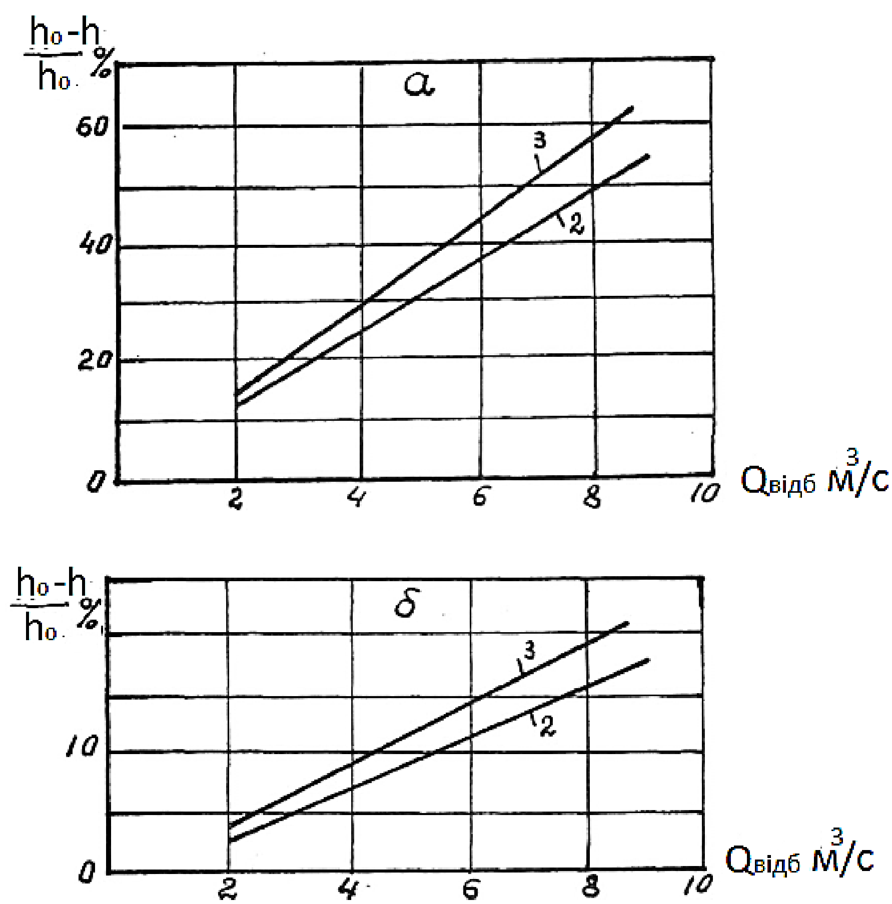
Fig.3. Dynamics of fluctuations in water levels in the pond at on/of pumping stations one pump. Water flow in the channel to include the pump is 18 m/s 1 - b'yef1; 2 - 2 pond; 3 - 3 pond:

As can be seen from the figure, the maximum wave in the first pond formed after 6 ... 8 minutes. after turning on the pump, and the second and third pond 45 ... 50 min. And 20 ... 25 minutes. respectively. The research results showed that the height of the wave depends on the initial flow in the channel. The higher the score, the higher the initial wave.

Applying the results of the calculation can analyze the course of the water level in the pond when disconnecting the previous and the next work station, and develop measures to exclude the possibility of a sharp reduction or overflow of water through the dam [3,4].

Consistent inclusion stations pumping units 10 and then 20 minutes. leads to fracture of the first wave crest. The main crest hollow or suddenly increase its value, which may affect the integrity lozhakanalu.

Effect of water withdrawal from the channel by the amount of movement of the wave shown in Fig. 4.



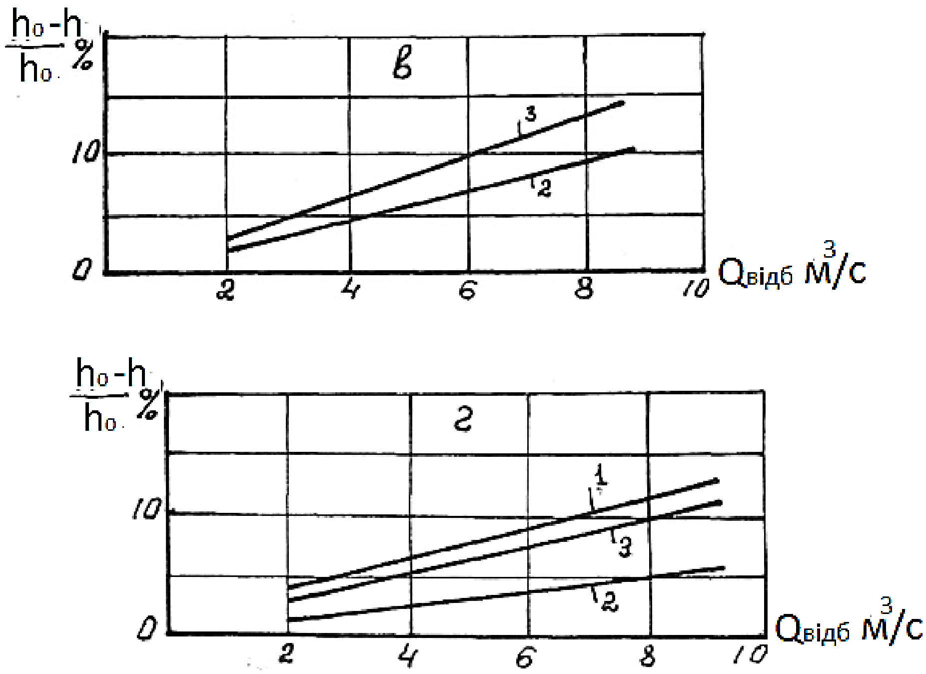


Fig. 4. Change the wave height dependingthe velychynyvidboru Q: A - 9 m^3/s; b - 18m^3/s; in - 27 m^3/s; D. 36 m^3/s; 1 - b'yef1; 2- pond 2; 3 - 3 pond.

As can be seen from the figure in the presence of water in the pond selection, a decrease of positive and negative waves increasing displacement. Moreover, the waveform is not changed in comparison with the wave form without selection. The biggest impact of selection occurs when disconnecting a pump. This pattern is observed at different depths of water in the canal. The influence of long headrace when selecting the magnitude of the wave - the longer the pond, the less influence the selection of the magnitude of the wave. Studies have shown that considering the wave movement should distinguish between two fundamentally different periods: initial, formed when waves profile and kvazi-vsteady time when the generated wave moves without changing the profile. For the second occurrence (kvazi-vsteady) period should be enough channel length between pumping stations.

Theoretical studies Initial period of formation of waves dedicated work Dober and Marv who zadachizastosuvaly for solving differential equations and solution algorithm Bussineska via PC. But from the point of view of the practice is most intense during the formation of the second wave when a positive wave reaches its maximum height. This height is 15 ... 25% of the initial water depth in the channel such as when disconnecting the pump station connecting channel (Q = 105 m3 / s) height of the first wave of positive crest is 0,98m at Karshi channel when disconnecting the five pumping units (Q = 195 m3 / s) - 1,45m, and the Kakhovskoe channel (Q = 530 m3 / s) - 1,4m.

The height and wave form except for the speed and depth of the water in the channel depends on the changes in costs ΔQ, on what was noted above. The impact of the last factor on the pitch and waveform parameter may characterize FrΔ, which is determined by the formula [6]:

$$Fr_{\Delta}=\frac{\Delta Q}{\omega\sqrt{g\frac{\omega}{B}}}, \qquad (3)$$

where ΔQ – the change in costs.

This dimensionless parameter numerically characterizes the change of momentum in the initial alignment, which is caused by the change in the cost and uniquely associated with the emerging wave height. At the same dimensionless parameter FrΔvyznachaye effect on wave height type installed at the station pumping equipment.

The distance from the origin of wave alignment to the alignment where it ends its formation may be determined according to Table 1.

Table 1. The length of the plot (share) channel formation peremischennya.y waves.

Fr_{Δ}	0,05	0,10	0,15	0,20	0,25	0,30	0,40	0,50
l_1/φ_{max}	1500	950	600	400	240	150	80	50

In the initial stages of designing distance before the kvazivstanovlenoho period may be determined by the formula

l_1= cT,

where T - time during which comes kvazivstanovlenyy period defined by the formula [2]

$$T = \frac{2}{3}\sqrt{\frac{\omega}{B}}\frac{c}{a_0} / \left(1 - \frac{1}{3}\frac{\omega}{B}\frac{dB}{d\omega}\right),$$

where a_0 - $\frac{dQ}{dt}$ - rate of change of water flow in the initial alignment; c - the speed of wave propagation, which is defined by the formula

$$C = \sqrt{g\frac{\omega}{B}\left(1 + \frac{3}{2}\frac{B}{\omega}h\right)} \pm v;$$

where h - the height of the wave.

For gentle waves (waves shower and reflux) velocity distribution may be determined by the formula

$$C = \sqrt{g\frac{\omega}{B}} \pm v.$$

Analysis of the results of research carried out in the field bilyakrytychnyh trends showed that all the waves that occur in the channel can be brought to the wave of so-called embodied and knoidalnyh.

The possibility of a particular type of waves depends on the Fr_{Δ} [6]. Full-scale study on channels with a cascade of pumping stations have shown that more frequent they knoidalni waves that are the most dangerous due to the dynamic influence on mainstream channels.

Studies have shown that the wave height at the channel slopes somewhat higher than vpodovzh its axis [3].

The maximum wave height h_{ser} obtained from the above described solution can be obtained by increasing the magnitude of h_{max} (1.3 ... 1.35) h_{ser}.

In the event that you need to know not only the maximum wave height, but its other options, then for this purpose may apply depending obtained A.A.Tursunovym [7].

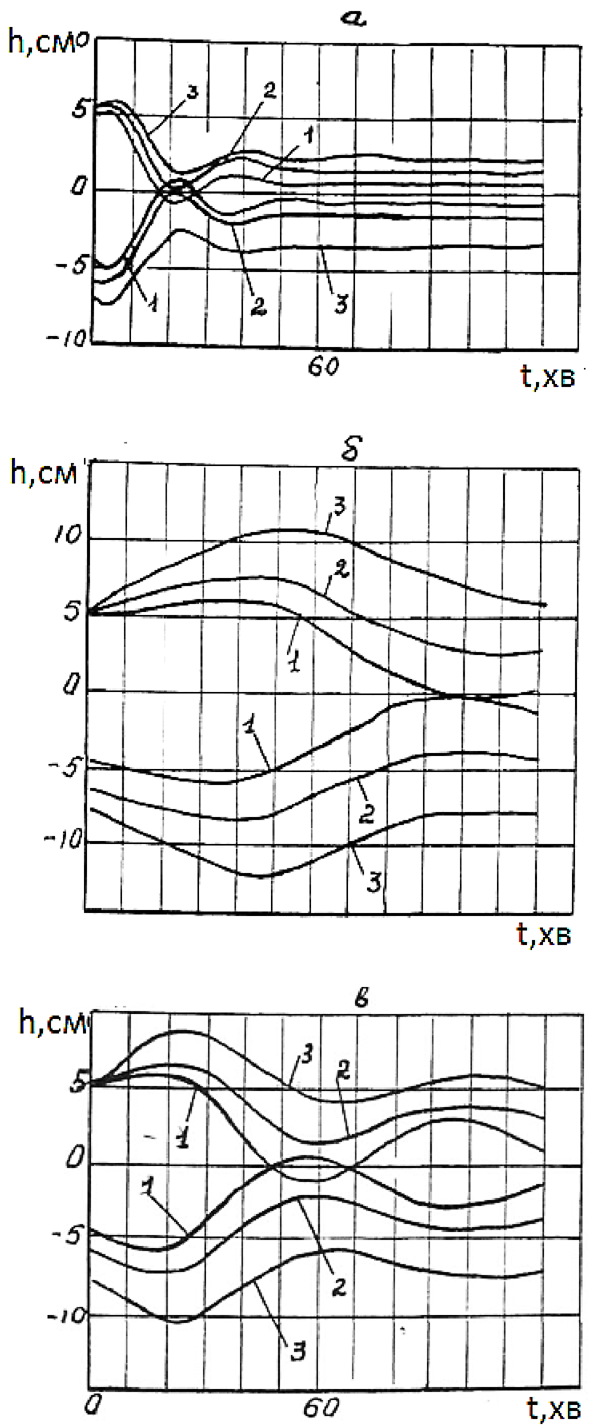


Fig. 5. Changes in levels pond at different feeds pumping stations and turn them on one pump: and - the pond I; b pond 2; in - pond 3; Q, m3 / s: 1-9; 2 - 18; 3 - 27.

Comparison of the results of research when the pump unit at all pumping stations with giving Q = 9 m^3/s at a cost to be included in the channel pump unit 9,18 and

27 m^3/s made it possible to detect the initial wave height depending on water flow in the channel before switching the pump , the greater height of the first wave crest (Fig. 5).

The calculations considered the issue sequences include pumps tostation stage. Studies have shown that when disconnected

one of the two operating pumps at the pumping station №1 and two pumps at the pumping station №2 water level in the pond №1 begins to decline after 60 minutes and is reduced by 25 cm. So late to include in the pumping station №2 after turning at the pumping station №2 after turning off the pump at the pumping station №1 may be allowed in within 30 - 40 minutes.

Note that the maximum levels of engineering calculations in channels to determine the dry stock dams may apply numerical methods presented in [11].

The results of studies of the dynamics levels in pond pump stations when changing modes of water feed showed that in channels with a cascade of pumping stations there are more complex hydraulic processes through faster changes in costs (8min.27s. Depending on the type of pump) compared to irrigation canals which of course is smoothly regulated water supply by opening or closing the gates blocking structures. In this regard, implementation of schemes of regulation in the canals with a cascade of pump stations associated with some difficulties [5,10].

The research showed that the most appropriate way of regulation is regulation by "upper pool" and "with constant volume."

According to the first circuit power on and shutdown of pumping stations sequentially starting from the station located at the end of the headrace. State level in the upper pond is controlled by the previous station. Adjusting for the second scheme involves the simultaneous inclusion (off) pumping stations at the beginning and end of the headrace. Definite effect on the quality of transients in channels with a cascade of pumping stations with parameters adjustment and geometric characteristics of the channel. When feeder channels with a cascade of pumping stations important to select a single feed pump unit and the initial state flow (to be calm state of water or uniform motion). Our research and study in [11] demonstrated that the state of motion of water in the channel of the regulation "of constant volume" water depth to some extent affected, but to a lesser extent than in the regulation on the "upper pool". Studies have shown that when using the regulation "of constant volume" expanding choice feeding pump units, ie takoyishemy regulation feed pump unit has little effect regime change rivnivv pond.

Established in designing channels with a cascade of pumping stations bow to the bottom of the channel may take close to zero. This will reduce the volume of excavation.

When designing channels with a cascade of pumping stations is determined by the length of the pond terrain and bow bottom channel set from 0.0003 to 0.00008, which as indicated little effect on the dynamics of the water level in the pond. Accordingly, the geometric characteristics of variation of only slopes laying channel m will influence the transition process.

The issue of capacity values when adjusting for "upper pool" in the first approximation can be resolved by determining the minimum length depending on the headrace, taking into account the time dobihannya waves caused by the inclusion of the pump unit at the end of headrace to the pumping station located at the beginning headrace and the inclusion of the term pumping unit at the beginning of headrace.

$$\frac{2}{3}mi^2l^3 + (b+2mh)il^2 - 2\frac{lk}{\sqrt{g\frac{(b+mh)h}{b+2mh)}} - v_0} - Q_{arp}t_{arp} = 0, \qquad (5)$$

where l - the minimum length of headrace; t_{ahr}- you switch the pump unit to work; k- factor equal to 1.1 ... 1.5; Q_{ahr} - feed pump unit.

Expression (5) is similar to addiction, which is used in the design of irrigation channels where regulation is blocking structures with electrical and hydraulic drive. Dependence (5) does not account for the complex dynamics of transients associated with the work of the cascade pumping stations, but noted previously enables the desired length between stations pond, which further refined calculations.

To address the issue of the use of one or another regulatory scheme in each case must compare them on the dynamic properties and technical and economic indicators.

With automated management of the cascade pumping stations importantly uniform loading time pumping equipment during the period of work. Meanwhile technically possible to implement stations with pumping units with no restriction on the number of inclusions and stops. Of course it is pumping units with relatively small feeds. One solution of this problem is given in [11].

Conclusions. Studies have shown that the transition process in the pond canal with a cascade of pump stations can be calculated using a mathematical model based on roz'vyazku Saint-Venant equations. Found that side of the pond water selection leads to a reduction of positive and negative waves increase. The dynamics of a pond with cascade regulating most influential zakladennyavidkosiv. If regulation cascade pumping stations on the channel can be applied regulatory scheme on the "upper pool" and "flowing volumes.

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