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Hydraulic regimes and hydrostatic pressure of the flow on the elements of fastenings of the downstream of water outlets

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Abstract. A comprehensive study of the flow of water plays an important role in the design of the area of the lower reaches of the drainage and drainage structures of hydraulic structures. In particular, the complex processes associated with the flow movement in the lower reaches of low and medium pressure reservoirs play an important role in the selection of the appearance of the structure, structural elements and their shapes, sizes and location conditions. One of the important issues is to assess the strength of the elements of the lower basins of water intake facilities and hydropower plants in the current reservoirs, to determine the mode of connection of the basins, to improve the methods of quenching kinetic energy in the reinforced areas of the lower basin. Based on the 2 schemes adopted in this article, the hydrostatic pressures of several types of power extinguishers installed in the area of the water injection well, providing the bottom pound strength, were determined for the experimental device.

1 Introduction

The current entering the bottom of the structure will have very large energy and destructive ability. Therefore, quenching its excess kinetic energy increases its safe operation and service life. Experimental studies show that the quenched amount of flow energy is 60-70% [1, 2]. To increase the extinction of excess energy of the water flow, to improve the hydraulic conditions of the lower pound, to eliminate general and local washes in the lower pound, to change the mode of movement of the water flow along the seabed to the surface in the apron, to reduce or eliminate the flow platform, waterproof wall, platform, checkerboard, flow directing wall or spreading walls are designed.

The results of effective research in this area have been presented in several technical [1-4] publications. It is advisable that these fire extinguishers meet the following requirements:

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• maximum suppression of the high-velocity flow of water in the injection well along the bottom of the well;

• a change in the velocity distribution diagram in the vertical direction at depth due to a decrease in velocity in the apron and the transition to the surface mode in which the main consumption is observed on the surface;

• hydraulic jump in the compressed section due to the increase in the water flow rate of power extinguishers;

• the spread of the flow in the lower basin;

• decreased flow flux due to the distribution of energy in the fortified area at the bottom of hydraulic structures;

As a result, the effect of these power switches on the flow simplifies the construction of the structure, increases the level of operational reliability of the structure, along with improving the hydraulic conditions of the discharge or discharge of water flow into the lower basin [5-9].

The effect of energy extinguishers built on the lower reaches of low and medium pressure reservoirs on the flow can be divided into three types [10-17]: 1 is reactive; 2 is dissipative, and 3 is disseminating.

1. Energy extinguishers generate reaction forces in the opposite direction to its motion when a current strikes it. This reaction force is added by hydrostatic pressure (with a reverse signal), and as a result, the buried appearance of the hydraulic jump occurs at values smaller than the contact depths determined by applying the hydraulic jump equations [7] for smooth bottom valleys in classical hydraulics. The essence of the reactive effect of the energy extinguisher is the acquisition of a buried hydraulic jump in the case of the location of this water injection well at a high altitude mark. As a result of the reactive effect of power extinguishers, a decrease in the length of the hydraulic jump and a decrease in the depth of the second connection is observed, which is a key factor in determining the length of the water injection well.

2. We know that the dissipative effect of an energy extinguisher on the movement of a stream of water is understood to be influenced by an increase in the absorption of the flow of energy. Power dampers installed in water injection wells and apron form additional water circulation areas, in which velocity gradients have high values [2-3]. This condition increases the turbulence of the current, causing an increase in the pulsating voltages of the reciprocating moving current, leading to rapid absorption of excess kinetic energy. This process dissipates large-scale rotations and leads to the extinction of flow turbulence. The area length after the hydraulic jump is shortened, reducing local flushing. Extinguishers that effectively carry out the dissipative effect on the water flow are in the form of checkerboard, cut and toothed platforms, which additionally distribute the flow to several streams and enlarge the surfaces of the splitting surfaces [18-29].

3. In the control of the flow of outgoing water in a hydraulic structure by means of a moving barrier - the effect of the distribution of the shunting power switch plays an important role. In this case, the extinguisher changes the surface movement mode on the surface of the stream, moving along the bottom of the stream, tilting the flow of water to the water level. Redistributing the amount of flow will move more of the surface to the surface, and the flow rate of water at the bottom of the stream will decrease. In addition, the direction of movement of the water flow will change in the plan. As a result, there is a decrease in the velocity of water flow in the area close to the bottom of the river.

However, the problems that occur in the lower reaches of drainage structures can be divided into the following types:

• washing at the end of the aprons, washing the bottom and edges of the outlet channels;

• noise and breakdown of connected joints;

• breakdown of extinguishers;

• hydrodynamic effects of water flow on areas of ground foundations and concrete-reinforced foundations;

• the process of growth and turbidity of various plants in the outlet [1].

In overcoming these problems, of course, the results obtained from the experimental device are of great importance when considering energy extinguishers in general.

2 Methods

In the physical modeling of hydraulic phenomena, geometric similarity, the similarity of initial and boundary conditions for the model, dynamic and kinematic similarity laws corresponding to the forces involved in the formation of the flow are required to ensure similarity of laws.

Fulfilling these requirements is a difficult task in practice. In the implementation of physical modeling of the pound connection in the lower pound of low and medium-pressure reservoirs, the ratio of gravitational forces, i.e. the force of gravity, is mainly taken as the main force in the movement.

In experimental studies aimed at studying the flow dynamics in the field of low-and medium-pressure reservoir discharge structures, the similarity of the Froude and Reynolds numbers is sufficient.

Schemes of the location of power extinguishers in water injection wells in the lower reaches of low and medium pressure reservoirs were adopted. Using the experimental device, the hydraulic regimes and hydrostatic pressure of the water flow in the lower pound reinforced area were determined.

3 Results and Discussion

In the physical modeling of hydraulic phenomena, it is necessary to ensure the similarity of the following laws:

1. Geometric similarity;
2. Similarity of initial and boundary conditions for the model;
3. The laws of dynamic and kinematic similarity corresponding to the forces involved in the formation of the flow.

Fulfilling these requirements is a difficult task in practice. In the implementation of physical modeling of the connection of the pound in the lower pound of low and medium-pressure reservoirs, the ratio of gravitational forces, i.e. gravity, is taken as the main force in the movement. This situation is characterized by the Froude number. Achieving Froude numerical similarity has been recognized as a key factor in many scientific studies [30-35]:

$$Fr_n = Fr_m = idem \quad (1)$$

$$Fr = \frac{v^2}{gh_{av}} \quad (2)$$

Fr_n and Fr_m are Froudu number for the current flowing in the corresponding nature and model; υ is average flow rate, g=9.81 м/s^2 acceleration of free fall; h_{av} is the average depth of water flow in the area under consideration.

Experimental studies aimed at studying the flow dynamics in the field of low-and medium-pressure reservoir discharge structures have only confirmed the similarity of the Froude number and confirmed that the following conditions are sufficient for the Reynolds number [7]:

$$Re_n = Re_m = idem \quad (3)$$

$$Re_n > Re_{value} \quad (4)$$

where: Re_n and Re_m are the Reynolds number for the flow in nature and in the model [7].

$$Re = \frac{vl}{\nu}, \quad (4)$$

l is a characteristic linear dimension of the flow in an open vessel $\left(l = 4R = 4\frac{\omega}{\chi}\right)$ determined by the formula; R is the hydraulic radius; ω is cutting surface for moving flow; χ is wet perimeter; υ is the average flow rate at the point at which the Froude numerical value is determined; ν is kinematic viscosity coefficient, $м^2/c$; Re_{value} is the limit value of the Reynolds number corresponding to the lowest boundary region of the square resistance field, this quantity can be determined using the following experimental formula:

$$Re_{value} = \frac{14R}{\sqrt{\lambda}\Delta}, \quad (5)$$

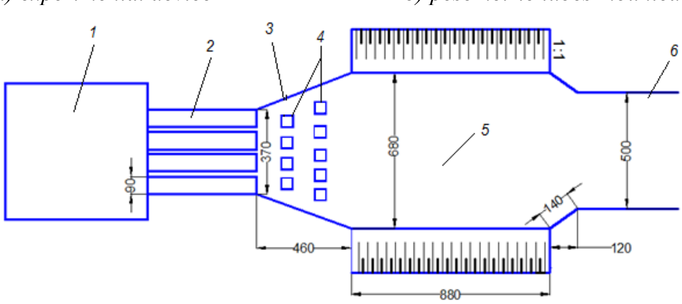
Δ is the value of the absolute roughness determined by the size of the hydraulic radius; λ is hydraulic friction or Darcy coefficient.

At present, the dependence of the horizontal and vertical elements of the process of connection of the lower reaches of the water discharge structures of low and medium pressure reservoirs on the flow parameters is divided into the following stages:

In the first stage, the results of large-scale laboratory studies were adopted. To study the physical nature of the hydraulic jump, an experimental 1:50 scale model of the Ak-Darya reservoir was constructed to increase the energy efficiency of the lower basins of low and medium pressure reservoirs (Figure 1).

a) experimental device

b) pesometric tubes mounted on the device



c) device diagram

Fig. 1. An experimental device built to study the processes in the lower reaches of low- and medium-pressure reservoirs: 1 is vessel, 2 are pipes, 3 are expansion sections, 4 are power extinguishers, 5 are water injection wells, 6 are channels.

In the second phase of the study, 2- and 4-pipe structures were selected to monitor the hydrodynamic stresses of the lower basin elements of the low- and medium-pressure reservoirs. Parameters of the device on which the experimental research was conducted: pipe diameter *d*=0.09*м*, pressure relative to the inlet part of the pipe $H = (1...1.5)d$, depth at the outlet $h_2 = (0.5...2.3)d$, the total specific energy of the water flow at the outlet of the pipe $Э_1 = h_1 + u_1^2/2g$, where h1 and v1 are the depth and velocity at the exit of the water outlet pipe, (1.5…4.5)h_1 tube difference $p = (0...1.4)d$. Spread angle at the exit portal $24^0…46^0$. Experiments are basically $\theta=46^0$ and p=0 was carried out when the conditions were met. Reynolds number in the field of modeling, while maintaining the gravitational similarity criterion in the modeling processes of all-purpose research($l = 10h_1$; $Re = 20000$ ч 75000).

Determination of the voltage in the water injection well and risberma elements were carried out for a specific energy parameter - constant consumption, which corresponds to the following three corresponding modes of connection in the lower basin: (radical, external and mixed modes). In this case, the burial coefficient $n = \frac{h_2 - p}{h_1}$ determined by the formula 0.5 ... 2.5 change in the interval was observed. The water capacity of the drainage facility was changed in the range of 10 ... 30 l/sec.

The positioning conditions of the pesometers used in the first phase studies are shown in Figure 2:

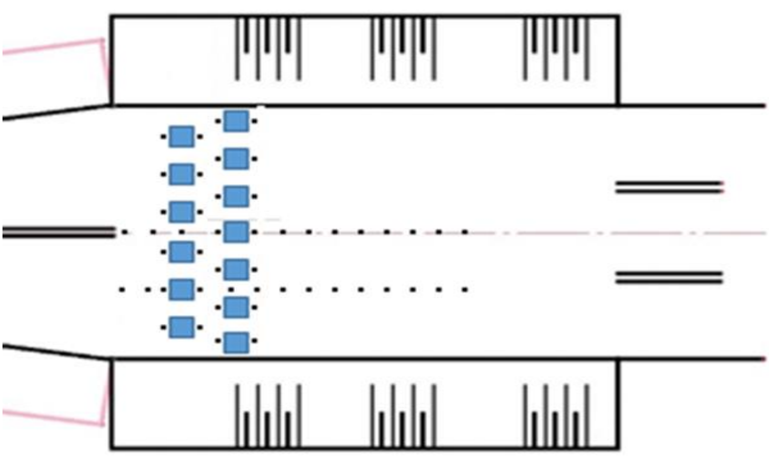


Fig. 2. Positioning conditions of piezometers

Determination of the voltage in the water injection well and risberma elements were carried out for a specific energy parameter - constant consumption, which corresponds to the following three corresponding modes of connection in the lower basin: (tubular, external and mixed modes). In this case, the burial coefficient $n = \frac{h_2 - p}{h_1}$ determined by the formula and observed in the range of 0.5 ... 2.5. The water capacity of the drainage facility was changed in the range of 10...30 *l/sec*.

The positioning conditions of the piezometers used in the first phase studies are shown in Figure 2:

Recording of pressure pulsation at water injection wells and risberma points made it possible to determine its maximum value (2Amax) for all modes. The amplitude changes of this process were analyzed statically. As a result of the study, the error in determining the pulsating pressure characteristics was 2-5%.

Schemes of 3 different types were adopted for conducting experimental studies. Two rows in Scheme 1 - 1 row is a rectangle,

Row 2 trapezoidal checkers were selected, and Scheme 2 selected two rows of straight rectangular checkers (Figure 3).

In experimental studies, three forms of byef connection were observed:

- remote hydraulic jump;
- stable, normal jump connection of the current in the lower basin;
- Embedded hydraulic jump.

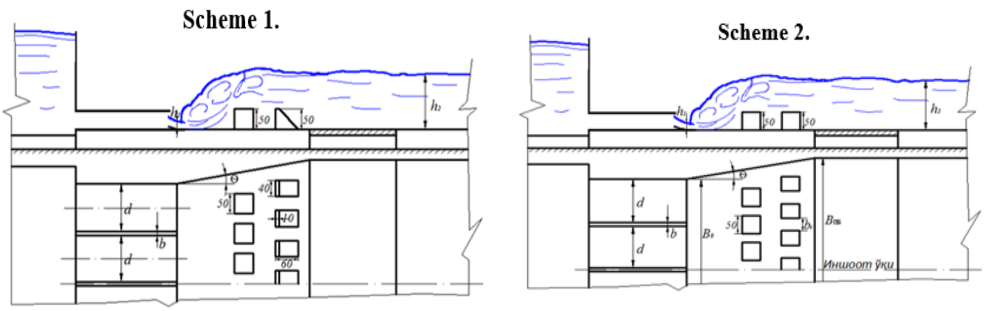


Fig. 3. Diagrams of location of power extinguishers in water injection wells in the lower reaches of low and medium pressure reservoirs

The values of the ranges performed in the experiments are as follows:

$$\frac{E_1+p}{h_1} = 1{,}5 \div 4{,}5;\ n = 0{,}5 \div 2{,}5;\ \theta = 24 \div 46.$$

in this, $E_1 = h_1 + v_1^2/2g$ is the total specific energy of the water flow at the outlet of the pipe; v_1 is average velocity of water flow at the outlet of the pipe; $n = \frac{h_2-p}{h_1}$ is buried coefficient of the pipe at the outlet; h_1, h_2 is flow depth at the outlet of the structure and in the outlet channel; p are bottom marks at the exit from the structure and in the exit channel; θ is the angle of expansion of the water injection well.

For them, the energy parameter to the change in the shape of the pounds connection $\frac{E_1+p}{h_1}$ it was observed that the structural properties of extinguishers, their location and location are affected by the degree of burial on the lower side, depending on the location boundary condition of the hydraulic jump.

For all the studied variants, a reduction in the area of the bottom hydraulic jump connection was observed when the position of the valves changed. The increase in burial height is when a pipe $\frac{E_1+p}{h_1} \geq 3{,}5$ unstable fluctuating currents of the current were observed when the condition was met. At the same time, the dynamic axis of the flow was tilted towards the open pipe. As a result, the energy quenching efficiency is significantly reduced, and the extinction of the average flow velocities is slowed down. This result has also been observed in several studies [140, 142, 143]. In addition, it is necessary to ensure that the switches are installed strictly symmetrically for the circuits studied. Otherwise $\frac{E_1}{h_1} > 1{,}5$ in the case where there is an unstable state of flow throughout the structure - a fluctuating flow is observed. An unstable state of flow is also observed when this condition is operated along the entire lower pound front.

The analysis of the average water flow patterns showed that the schemes I and II for the four-pipe structures with water flow in all pipes showed the effectiveness of the study. For all three circuits with four pipes, the water flow velocities in the area close to the bottom $l = (11 \dots 16)d$ for length $\bar{\upsilon} = (0{,}7 \dots 0{,}9)\upsilon_2$ formed. In the first phase of the study, the mean pressures on the water injection wells and apron plates were determined for each hydraulic regime using pesometric lines drawn relative to the water injection well and risber mark, and the average hydrodynamic pressure change across the entire flow front in the water injection wells was investigated. this change was observed for all schemes (Figure 4).

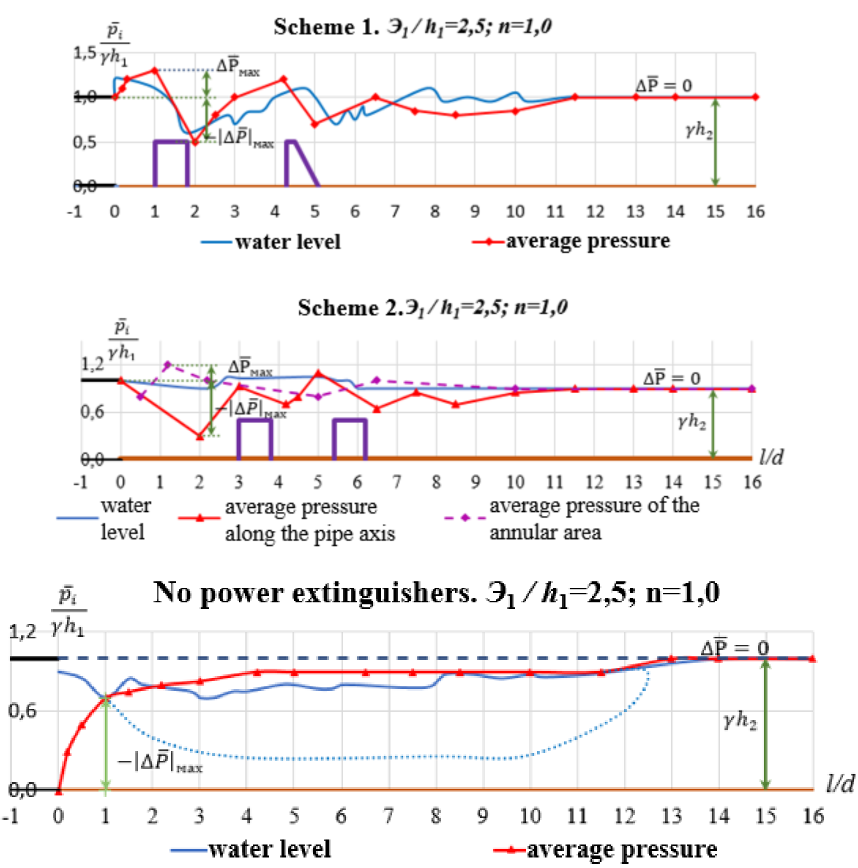


Fig. 4. Average pesometric level at the points of water injection well and apron

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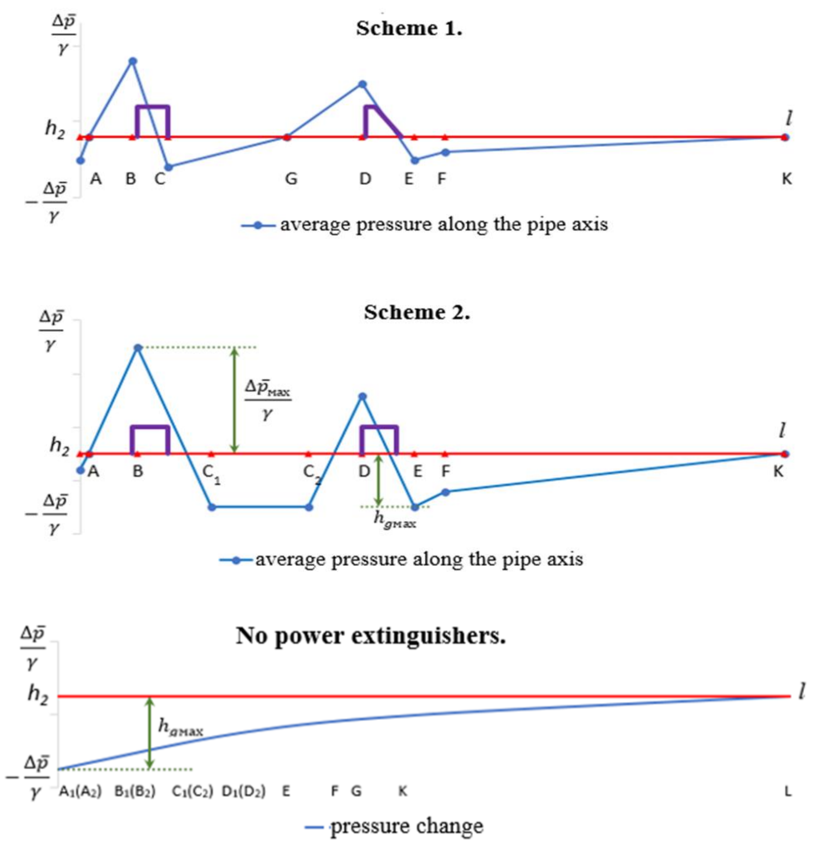

Fig. 5. Computational diagrams of pressure changes in the water injection well and apron

As a result of the flow of water through the power extinguishers, the increase in pressure at the front of each energy extinguisher leads to a significant increase in the average pressure force at the bottom.

4 Conclusions

The first phase of their experiments focused on identifying static constituents of pressure. It should be noted that at this stage, the main focus was on the data obtained from the experiments conducted using a high level and wide range of applications and the identified patterns;

The location of the extinguishing structures in the injection wells, which are built to extinguish the full energy of the flow in the lower reaches of the discharge structures of low and medium pressure reservoirs, evenly distributes the impact force of the flow. Due to the lack of pressure in water injection wells without power extinguishers, the stability of water injection wells is reduced by 30-50%. An increase in the angle of expansion does not affect the pulsation and average pressure distribution in the expansion water injection well and subsequent areas at the outlet of the structure.

By observing the average pressures exerted on the lower basin reinforcement area of the dewatering structure, the study obtained general graphs depending on the hydraulic regime of the flow and the position of the calculated section, which allows constructing a calculation diagram of the average pressure stress.

References

1. Khidirov, S., Norkulov, B., Ishankulov, Z., Nurmatov, P., Gayur, A. Linked pools culverts facilities. IOP Conf. Ser. Mater. Sci. Eng., **883**(1), 012004 (2020)
2. Bazarov D., Vatin N., Obidov B., and Vokhidov O. Hydrodynamic effects of the flow on the slab of the stand in the presence of cavitation. IOP Conf. Ser. Mater. Sci. Eng. **1030**, 012110 (2021).
3. Krutov A., Choriev R., Norkulov B., Mavlyanova D. and Shomurodov A. Mathematical modelling of bottom deformations in the kinematic wave approximation. IOP Conf. Ser. Mater. Sci. Eng. **1030**, 012147 (2021).
4. Bazarov D., Markova I., Norkulov B. and Vokhidov O. Hydraulic aspects of the layout of head structures during water intake from lowland rivers. IOP Conf. Ser. Mater. Sci. Eng. **1015**, 012041 (2021).
5. Uralov B., Rakhmatov N., Khidirov S., Uljaev F., Raimova I. Hydraulic modes of damless water intake. IOP Conf. Ser. Mater. Sci. Eng. **1030**(1), 012123 (2021)
6. Uralov, B., Khidirov, S., Artykbekova, F., Shodiev, B. Influence of the roughness and shape of the canal of trapezoidal canals on the pressure loss of hydropower structures. Lecture Notes in Civil Engineering, **141**, pp. 35–46, (2021)
7. Krutov A., Norkulov B., Uljaev F., and Jamalov F. Results of a numerical study of currents in the vicinity of a damless water intake. IOP Conf. Ser. Mater. Sci. Eng. **1030**, 012121 (2021).
8. Bazarov D., Markova I., Sultanov S. and Kattakulov F. Dynamics of the hydraulic and alluvial regime of the lower reaches of the Amudarya after the commissioning of the Takhiatash and Tuyamuyun hydrosystems. IOP Conf. Ser. Mater. Sci. Eng. 1030, 012110 (2021).
9. Khidirov S., Jumaboeva G., Ishankulov Z., Nishanbaev K., Egamberdieva S. Hydraulic mode of operation of the Takhiatash hydroelectric complex, IOP Conference Series: Materials Science and Engineering, 1030 (1), 012120, (2021)
10. Krutov A., Norkulov B., Mavlyanova D. Simulation of spreading of non-conservative passive substances in water bodies. IOP Conf. Ser. Mater. Sci. Eng. **883**(1), 012028 (2020)
11. Bazarov D. and Vokhidov O. Extinguishing Excess Flow Energy in Spillway Structures. In book: Proceedings of EECE 2020, LNCE 150, pp. 535-545, (2021) DOI: 10.1007/978-3-030-72404-7_52
12. Bazarov D., Markova I., Norkulov B., Isabaev K., Sapaeva M. Operational efficiency of water damless intake. IOP Conf. Ser. Mater. Sci. Eng. 869(7), 072051, (2020)
13. Matyakubov B., Begmatov I., Raimova I. and Teplova G. Factors for the efficient use of water distribution facilities. IOP Conf. Ser. Mater. Sci. Eng. 883, 012025 (2020).
14. Obidov B., Vokhidov O., Tadjieva D., Kurbanova, U., Isakov A. Hydrodynamic effects on the flow elements of the downstream devices in the presence of cavitation. IOP Conf. Ser. Mater. Sci. Eng. 1030, 012114 (2021).
15. Bazarov D., Norkulov B., Vokhidov O., Uljaev F., Ishankulov, Z. Two-dimensional flow movement in the area of protective regulatory structures. IOP Conf. Ser. Mater. Sci. Eng. 890, 012162 (2020)

16. Krutov A., Norkulov B., Nurmatov P., Mirzaev M. Applicability of zero-dimensional equations to forecast nonconservative components concentration in water bodies. IOP Conf. Ser. Mater. Sci. Eng. 883(1), 012028 (2020)
17. Eshev S., Latipov S., Qurbonov A., Berdiev M., Mamatov N. Non-eroding speed of water flow of channels running in cohesive soils. IOP Conf. Ser. Mater. Sci. Eng. 1030, 012131 (2021).
18. Shokirov B., Norkulov B., Nishanbaev Kh., Khurazbaev M., Nazarov B. Computer simulation of channel processes. E3S Web of Conferences, 97, 05012, (2019)
19. Eshev S., Rakhimov A., Gayimnazarov I., Shodiev B., Bobomurodov F. Dynamically stable sections of large soil canals taking into account wind waves. IOP Conf. Ser. Mater. Sci. Eng. 1030, 012134 (2021).
20. Shomayramov, M., Norkulov B., Rakhmanov J., Tadjiyeva D., Suyunov J. Experimental researches of hydraulic vacuum breakdown devices of siphon outlets of pumping stations. E3S Web of Conferences, **97**, 05009, (2019)
21. Yangiev A., Eshev S., Panjiev S., Rakhimov A. Calculation of sediment flow in channels taking into account passing and counter wind waves. IOP Conf. Ser. Mater. Sci. Eng., **883**, 012036 (2020)
22. Eshev S.S., Khazratov A.N., Rahimov A.R., Latipov S.A. Influence of wind waves on the flow in flowing reservoirs. IIUM Engineering Journal, **21**(2), pp. 125–132, (2020)
23. Bazarov D., Markova I., Raimova I., Sultanov Sh. Water flow motion in the vehicle of main channels. IOP Conf. Ser. Mater. Sci. Eng. **883**, 012025 (2020).
24. Gur'ev,A.P., Kozlov D.V., Khanov N.V., Abidov M.M., Safonova N.A. Alternative Solutions for the Energy Dissipation of Idle Discharges at the Rogun HPP, Power Technology and Engineering, 2020, 54(1), pp. 7–12
25. Baranov E.V., Gur'yev A.P., Khanov N.V. Recommendations for Hydraulic Calculations of Anti-Erosion Lining with the Use of Spatial Geogrid with Coarse Fragmental Soil, Power Technology and Engineering, 2020, 53(5), pp. 553–556
26. Khanov N.V., Martynov D.Y., Novichenko A.I., Lagutina N.V., Rodionova S.M. Outlook and Special Properties of Earth Anchors and Screw Piles in Burial of Modular Protection Dikes in Nonrocky Ground, Power Technology and Engineering, 2018, 52(4), pp. 405–412
27. Kurbanov S.O., Khanov N.V. To calculation of the critical depths of the canals with polygonal profile (PP), Gidrotekhnicheskoe Stroitel'stvo, 2004, (3), pp. 42–44
28. Kurbanov S.O., Khanov N.V. To hydraulic calculation of the most favorable sections of the power diversion canals (PDC) of a polygonal profile, Gidrotekhnicheskoe Stroitel'stvo, 2003, (7), pp. 40–43
29. Khanov N.V. Hydraulic characteristics of chamber-free tangential vortex flow generators, Hydrotechnical Construction, 1999, 33(2), pp. 99–103
30. Anghesom A. Ghebrehiwot, Kozlov D.V. Spatial and Statistical Variability Analyses of Satellite-Based Climatic Data in Mereb-Gash Basin, Water Resources, 48(1), pp. 146–157, (2021)
31. Bednaruk S.E., Chukanov V.V., Klenov E.M., Kozlov D.V. Accounting for the Thermal State of the Sayano-Shushenskaya Dam to Determine the Safe Maximum Water Levels in the Reservoir in Developing Its Dispatch Schedules, Power Technology and Engineering, 54(4), pp. 451–455, (2020)

32. Kozlov D., Yurchenko A. The role of inspection of hydraulic structures in the assessment of their technical condition, IOP Conference Series: Materials Science and Engineering, 883(1), 012049, (2020)
33. Kozlov D., Ghebrehiwot A. Integrated design and construction approach to hydrotechnical structures in Eritrea, IOP Conference Series: Materials Science and Engineering, 869(7), 072012, (2020)
34. Kattakulov F., Muslimov T., Khusainov A., Vokhidov O., Sultanov S. Water resource saving in irrigation networks through improving the efficiency of reinforced concrete coatings, IOP Conference Series: Materials Science and Engineering, 883(1), 012053, (2020)
35. Kozlov D.V., Kuleshov S.L. Multidimensional Data Analysis in the Assessment of Ice-Jam Formation in River Basins, Water Resources, 46(2), pp. 152–159, (2019)