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FIELD STUDIES OF THE THROUGHPUT OF THE TUNNEL OUTLET OF THE AKHANGARAN HYDROELECTRIC COMPLEX

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ABSTRACT: The article presents the results of field studies to determine the discharge coefficient of the tunnel outlet of the Akhangaran hydroelectric complex.

Key research questions included

- full-scale hydraulic studies of the outlet structure in the working range of water levels in the reservoir with a pressure of 15 to 65 m and gate openings "a" from 0.15 to 2 m

- selection of calculated dependencies and determination of actual flow rates.

The research procedure was as follows:

- the setting of a given water flow through the structure is carried out.

- having achieved a steady flow regime in the canal and at the structure, characterized by the stabilization of water levels, the water flow is determined by the channel multi-point method at various pressures and gate openings.

The resulting gradient-level graphs can be used in the operating range of gate openings from 0.15 to 2.0 m and pressure fluctuations from 15 to 65 m.

Key words: Tunnel water outlet, graduation, water metering gate, gauging station, flow rate, level, head, speed, area, steady state, water flow.

INTRODUCTION

One of the most important issues in water management is the rational use of water, the basis of which is the accounting and distribution of irrigation water among consumers. In this regard, improving efficiency by correctly measuring the water flow is of particular importance. In this direction, special attention in the practice of many countries, including the USA, England, China, Holland, Russia, Uzbekistan, etc. is given to the issues of improving structures and methods of metering water consumption. In the world, it has become especially important to carry out targeted scientific research work devoted to improving channel and hydraulic methods for measuring water, developing new designs of water measuring devices, and ensuring automation of water metering.

According to the concept of water management for 2020-2030, comprehensive measures are being taken in the Republic to improve the reclamation state of irrigated lands, rational use of water resources, and improve methods of accounting for water consumption. This also applies to metering and distribution of water at tubular and tunnel water outlets of hydroelectric power plants arranged as part of water storage facilities.

Regulation and accounting of water at the structures of the outlet structure of the Akhangaran hydroelectric complex is one of the important and complex tasks of the operation management. The fact is that the process of establishing the flow rate of water discharged through the outlet is laborious and time-consuming, and the flow rate is measured by the channel multi-point method “speed x area” at the gauging station located about 7 km from the outlet. In addition, in the measurement section, a retaining variable mode is observed, which requires almost daily measurements.

At the same time, the installed segment gates at the end of the pressure tunnel allow, when calibrating them, to significantly reduce the difficulties in measuring water flow, increase the measurement accuracy and further automate water metering.

It should be noted that there are calibration curves for the outlet of the Akhangaran hydroelectric complex, compiled by the designers. However, these curves are practically impossible to use for the following reasons.:

- the calibration curves are constructed mainly for gate openings from 0.6 m to 5 m, while the operating range is from 0.15 to 2 m.

- the comparison showed that the relative measurement errors reach up to 25 ± 40%, which is unacceptable.

The investigated drainage structure of a tunnel type, designed for a flow rate of 480 m3 / s, has an inner diameter of 7.8 m with a chamber of control gates at the outlet. The tunnel has a split wall 3.0 m high, which allows it to be inspected and repaired at low water flow rates. To regulate the flow of water from the reservoir, at the outlet head of the pressure tunnel, there are two main segmental gates and a cone valve for passing low flows (up to 23 m^3/s). In front of the main gates, flat emergency gates are provided.

A damper well is located between the inlet head of the pressure tunnel and the outlet head of the free-flow tunnel. The free-flow tunnel with a length of 3352 m with a throughput of 540 m^3/s, as well as the pressure tunnel, has a cross-section with a diameter of d = 7.8 m with a dividing wall allowing its inspection and repair. The free-flow tunnel is followed by an open concrete channel where the gauging station is located.

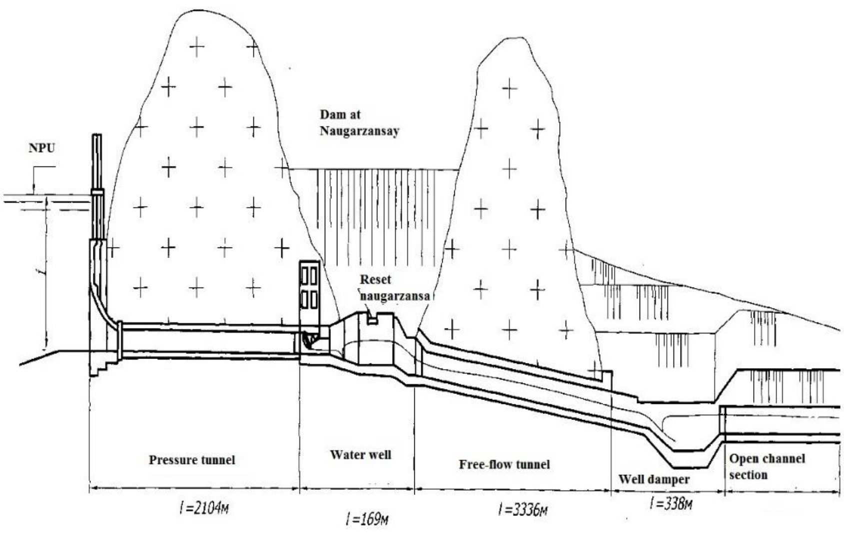

Fig 1. Scheme of the tunnel outlet of the Akhangaran hydroelectric complex

The gauging station, at which the measurements were carried out, is equipped with a cradle ferry with a winch and a rail for determining the water level. Velocities were measured using a hydrometric spinner. Velocities were measured in accordance with the “Guidelines for Calibration and Verification of Means for Measuring Water Flow in Open Channels by the“ Velocity-Area ”Method.

The main research questions included: a) full-scale hydraulic studies of the outlet structure in the working range of water levels in the reservoir with a pressure of 15 to 65 m and gate openings "a" from 0.15 to 2 m

b) selection of calculated dependencies and determination of actual flow rates.

c) construction of gradient-level dependencies.

As you know, the flow rate of water flowing through the tunnel outlet. operating in pressure mode, calculated by the formula [1,2,6]

$$Q = \mu ab\sqrt{2\,gH} \qquad (1)$$

Where: μ – consumption coefficient; b - hole width in m; a- opening height in m; g - acceleration of gravity m/s ^{2}; H – effective head in m;

With regard to the scheme under consideration, where the outflow from under the segmented valve into the free-flow pipe occurs, formula (1) takes the following form [6,20,] ;

$$Q = \mu\, ba\sqrt{2\,g\,(H - \varepsilon a} \qquad (2)$$

where ε - vertical compression ratio at expiration from under the segment valve, determined by the formula (3)

$$\varepsilon = \frac{1}{1+\sqrt{K\,(1-n^2)}} \qquad (3)$$

where: K= 0,4 sinθ; θ – tilt angle of the segment shutter to the horizon

$$\eta = \frac{a}{h}$$

Where: d – tunnel diameter, m

The consumption coefficient is determined by the formula (4)

$$\mu = \frac{1}{\sqrt{\xi + \xi_c}} \qquad (4)$$

where: ξ_c – coefficient of local hydraulic losses of the spillway;

The coefficient of local hydraulic losses is determined by the formula

$$\xi_c = \sum \xi i (\frac{\omega \partial}{\omega i}) \qquad (5)$$

Where: $\xi i -$ coefficient of local hydraulic losses on i- plot.

$\omega\partial -$ outlet area (area of the compressed section when flowing out from under the valve);

ωi – the area of characteristic sections of the spillway, to which the values of the corresponding coefficients of hydraulic losses are assigned;

The coefficient of hydraulic losses for friction along the length is produced by the formula:

Where: λ_{Ri} – drag coefficient related to hydraulic radius; C_i – Chezy coefficient; L_i – length of the i-th section of the spillway in m;

R – hydraulic radius in m; χ_i – wetted perimeter in m.

In accordance with the design scheme (Fig. 9), the coefficients of local hydraulic losses related to the area of the compressed section will be equal.

$$\sum \xi_m = \xi_{vx}\left(\frac{\omega}{\omega_{vx}}\right)^2 + \xi_{paz}\left(\frac{\omega}{\omega_{paz}}\right)^2 + \xi_{2paz}\left(\frac{\omega}{\omega_{paz}}\right)^2 + \xi_{pr}\left(\frac{\omega}{\omega_{pr}}\right)^2 + \xi_{3paz}\left(\frac{\omega}{\omega_{paz}}\right)^2 + \xi_{pr}\left(\frac{\omega}{\omega_{pr}}\right)^2; \quad (6)$$

$$\xi vx = 0{,}18 \text{ [2]}; \quad \text{here } \frac{R}{h} = \frac{11}{14{,}3} = 0{,}77;$$

$$\xi_{вх}\left(\frac{\omega}{\omega_{вх}}\right)^2 = 0{,}18\left(\frac{14{,}5}{4\times 27{,}5}\right)^2 = 0{,}000023;$$

$$\xi_{1паз} = 0{,}1\frac{l_{паз}}{в} \text{ [2]};$$

$$\xi_{1паз}\left(\frac{\omega}{\omega_{паз}}\right)^2 = 0{,}1\frac{1}{4}\left(\frac{14{,}5}{4\times 15}\right)^2 = 0{,}00014;$$

$$\xi_{1паз} = \xi_{2паз} = 0{,}00014;$$

$$\xi_{aperture} = 0{,}05\frac{l_{pr}}{в} \text{ [2]};$$

$$\xi_{aperture}\left(\frac{\omega}{\omega_{пр}}\right)^2 = 0{,}05\frac{5}{14}\left(\frac{14{,}5}{4\times 14{,}3}\right)^2 = 0{,}00011;$$

$$\xi_{3paz} = 0{,}1\frac{l_{paz}}{в};$$

$$\xi_{3паз}\left(\frac{\omega}{\omega_{паз}}\right)^2 = 0{,}1\frac{1{,}2}{4{,}5}\left(\frac{14{,}5}{4{,}5\times 5{,}84}\right)^2 = 0{,}00078;$$

$$\xi_{2aperture} = 0{,}05\frac{laperture}{h};$$

$$\xi_{2aperture}\left(\frac{\omega}{\omega_{пр}}\right)^2 = 0{,}05\frac{2{,}2}{5}\left(\frac{14{,}5}{5\times 4{,}5}\right)^2 = 0{,}00087.$$

Then the sum of local hydraulic losses will be equal to.

$$\sum \xi_m = 0{,}000023 + 0{,}00014 + 0{,}00014 + 0{,}00011 + 0{,}00078 + 0{,}00087 = 0{,}00206 \text{ m.}$$

The coefficient of hydraulic losses due to friction along the length is determined by the formula (6,)

$$\xi_l = \lambda \ \frac{L_i}{R}\left(\frac{\omega}{\omega_1}\right)^2 [2],$$

where: λ_{Ri} – drag coefficient related to hydraulic radius; C_i – Chezy coefficient; λ = 0,04 – for concrete surfaces

L_i – discharge tunnel length in m;

L_i = 2103 m;

R – hydraulic radius determined by the formula:

$$R = \frac{d}{4}[2]$$

$$R = \frac{7{,}8}{4} = 1{,}95 \text{ m}$$

Then $\xi_l = 0{,}04\frac{2103}{1{,}95}\left(\frac{14{,}5*4}{3{,}14\times 7{,}8^2}\right)^2 = 0{,}04 \times 1100 \times 0{,}0089 = 3{,}9$

Having determined by the formula (4) flow rate μ we get

$$\mu = \frac{1}{\sqrt{0{,}00206+3.9}} = \frac{1}{1.97} = 0{,}51.$$

As seen from the above, the flow rate «μ» it will be difficult to obtain with acceptable accuracy, since it is theoretically impossible to take into account such factors as hydraulic resistance coefficients, because the outlines and sizes of structural elements, approach conditions, etc., as a rule, differ from their projected values.

All these factors are integrally taken into account when determining the flow rate based on in-situ measurements of water flow. The graduation of the outlet structure of the Akhangaran hydroelectric complex was carried out using a hydraulic method, which is based on the use of hydraulic formulas and the determination of the actual values of the discharge coefficients. At the same time, a series of measurements of water flow rates at the gauging station is carried out with the corresponding variable and constant parameters at the structure.

As a result of the inspection of the structure, it was established: that in both openings of the outlet structure there are small water leaks through the side seals of the gates, the gates are remotely controlled with output to the control room (factory-made gates position sensors are installed on each gate); to measure the water pressure in front of the structure on the reservoir (on the slopes), measuring rods are installed. In general, the outlet is in a satisfactory condition.

We chose the gauging station for measuring water flow rates at the existing station located at the end section of the open channel.

When measuring water flow rates at the gauging station, the "velocity-area" method was used with the use of hydrometric propellers.

The research procedure was as follows:

- the setting of a given water flow through the structure is carried out.

- Having achieved a steady flow regime in the canal and on the structure, characterized by the stabilization of water levels with an amplitude of fluctuations of no more than ± 1%, the water flow rate is determined. At the same time, the water level was measured along the rail in the upper head of the structure (in the reservoir) with an error of ± 1 cm, as well as the opening height of the gates according to the readings of the sensors with an error of ± 1 cm. Next, the actual flow coefficient was calculated:

$$\mu = \frac{Q}{ba\sqrt{2g(H-\varepsilon a}} \qquad (7)$$

Based on the obtained actual flow rates, we built a graph $\mu = f(^a/_H)$.

By mathematical processing (least squares method) of the measurement results, a dependence was obtained that has the following form:

$$\mu = 0{,}418 + 3{,}5\frac{a}{H} \qquad (8)$$

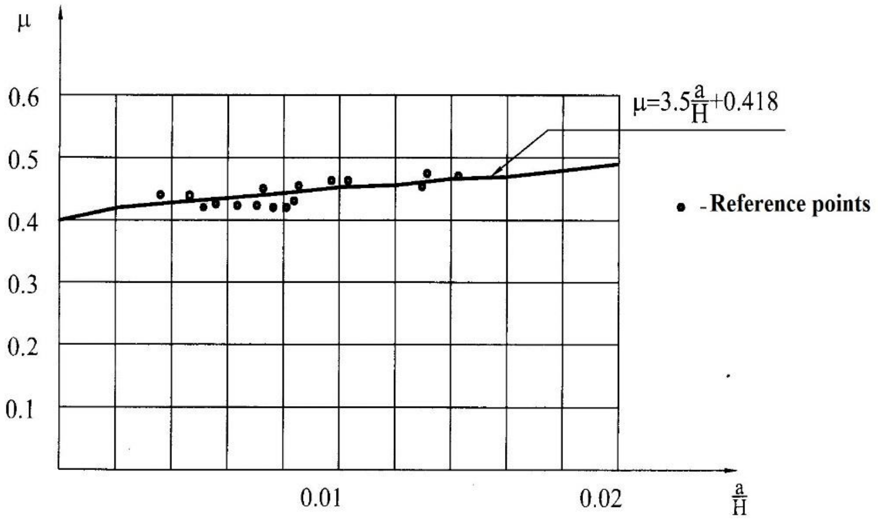

Fig 2. Dependence of the flow coefficient "μ" on the relative opening the tunnel spillway

By calculating the water flow rate according to the formula (2), table No. 1 of the water flow rate was compiled depending on the opening height of the gates at water pressures from 15 to 65 m

Table №1. Water flow rate

Head in front of the structure H, m	Opening shield a,m	Measured Q_1 м^3/s	Calculated by the formula Q_2 m^3/s	$\nabla Q=Q_1-Q_2$ m^3/s	$\delta = \frac{\Delta Q}{Q_2}100\%$ %	δ^2 %
1	2	3	4	5	6	7
62,67	0,55	78,58	77,8	+0,78	1,00	1,0
62,60	0,35	47,23	48,2	-0,97	-2,01	4,05
62,87	0,31	43,2	42,5	+0,76	1,79	3,2
62,89	0,33	44,55	45,4	-0,85	-1,87	3,51
63,18	0,30	41,97	41,1	+0,87	2,12	4,48
63,25	0,35	47,78	48,4	-0,62	-1,28	1,64
66,04	0,45	64,6	64,2	+0,4	0,62	0,39
66,02	0,43	59,79	61,2	-1,41	-2,3	5,3
66,12	0,49	72,46	70,3	+2,16	3,07	9,42
66,06	0,65	97,98	95,5	+2,48	2,59	6,7
65,96	0,57	82,94	82,0	+0,94	1,14	1,3
65,92	0,50	72,28	71,5	+0,78	1,09	1,19
65,91	0,47	65,29	67,1	-1,81	2,69	7,24
64,00	0,23	32,18	31,4	+0,78	2,48	6,15
41,96	0,34	77,18	39,0	-1,82	4,6	21,16
42,31	0,355	40,18	41,01	-0,83	2,02	4,08
41,37	0,31	35,32	35,2	+0,21	0,5	0,25
41,19	0,30	31,77	33,6	-1,83	5,3	29,5
42,25	0,325	35,27	37,1	-1,83	4,9	24,0
24,95	0,33	31,27	30,4	+0,87	2,8	7,84

24,67	0,32	28,58	29,2	-0,62	2,1	4,41
24,11	0,345	31,79	31,6	+0,11	0,3	0,09
23,76	0,34	30,8	30,9	-0,1	0,3	0,09

The root mean square relative error in measurements was: $\sigma_Q = \pm$ 2,6%.

Thus, the carried out full-scale hydraulic studies of the outlet structure of the Akhangaran reservoir made it possible to draw the following conclusions:

- the resulting gradient-level graphs can be used in the operating range of gate openings from 0.15 to 2.0 m and pressure fluctuations from 15 to 65 m.

- the proposed calibration curves constructed using formula (8) will significantly reduce the measurement time.

REFERENCES:

1. Madzhidov I.I., Fayziev U.Kh., Khusankhodjaev U.I., Rakhmatov.N. Hydraulic structures. Tashkent 2019 327 p,
2. Kiselev P.G 2011 Handbook of hydraulic calculations *Publishing House Ecolit* Moscow
3. Levi 11 1967 Modeling hydraulic phenomena *Publishing House "Energy"* Moscow
4. Nesterov M.V 2018 Waterworks M INFRAM Uzbekistan Tashkent
5. Ilyushin V.F., Dubinchik E.I. Underground spillways. - M .: Energoatomizdat, 1983.104 p.
6. Girgidov A.D. Mechanics of liquid and gas (hydraulics). Textbook. Infarm. M. 2021
7. Vizgo M.S 1996 Operational measures and ways to reduce local erosion behind hydraulic structures *Ed. Science Uzbekistan* Tashkent
8. Bradlow D. Palmiery A 2003 Salman Regnlatory Framework for Dam Safaly Uzbekistan Tashkent
9. Wexler A.B 2002 Reliability social and environmental facilities: risk assessment and decision making M Sankt - Peterburg
10. Mirtskhulaeva S.E 1974 Reliability of irrigation and drainage facilities Asr Uzbekistan Tashkent.
11. Astafev V.A. Barkov N K. 1965 Hydroturbines and their operation Moskow and Leningrad *Publishing House'«Energy»*
12. Achkasov G.P. Ivanov E S. 1984 Technology and organization of repair of meliorative hyrotechnical constructions Moskow *Publishing House Kolos*
13. Bakiyev M. Nosirov B. Khajakulov R. 2004 Hydraulic structures Textbook Tashkent "Vilim" publishing house.NR 23.13330.2011. Foundations of hydraulic structures.
14. Stories of L.N. and other hydraulic structures. T. I, II. PH .: Stroyizdat, 2010. - 880 p.