GALAXY INTERNATIONAL INTERDISCIPLINARY RESEARCH JOURNAL (GIIRJ)
ISSN (E): 2347-6915
Vol. 13, Issue 11 November (2025)

PRESSURE DISTRIBUTION BEHIND SLUICE GATES OF PRESSURE CONDUITS

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ABSTRACT

Usually, when examining the outflow pattern under a gate in a pressure conduit [1,2], the pressure distribution below the gate is assumed to follow the hydrostatic law.

However, as the jet flows out from under the gate, it curves, inevitably generating centrifugal forces that press the transit flow toward the bottom. As a result, the pressure distribution in this area deviates from the hydrostatic one. Some authors [3,4] noted this phenomenon, but their studies were conducted for free-surface flow.

Studying the nature of pressure distribution behind gates is especially important in pressure conduits, because it affects the load on the gallery lining and gate, as well as the possibility of cavitation phenomena occurring behind the gate. This article presents the results of a study on pressure distribution behind the gates of water-conveying galleries.

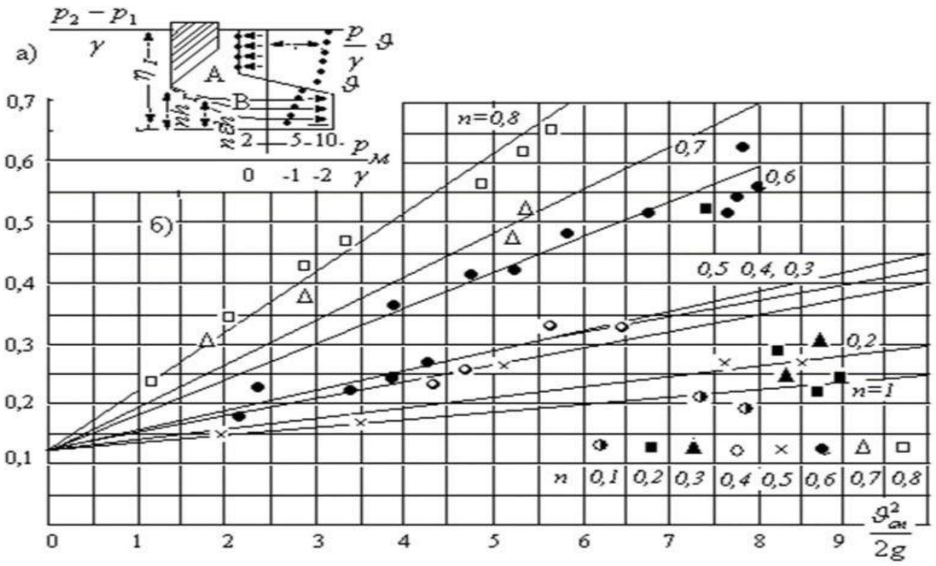

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Figure 1. Effect of gate opening on gallery pressure distribution. a) Pressure and velocity plots; Q = 47.5 l/sec, n = 0.5; b is the difference between the gallery bottom and ceiling pressures.

The section of the gallery below the gate can be divided into three zones (Fig. 1,a): a transit jet with high velocities (C), a roller, in which the velocities are relatively low (A), and a boundary layer (B), which is characterized by a large change in velocity with height. The pressure in the roller and in the transit stream is distributed hydrostatically, but varies significantly along the same vertical axis in different zones. In the boundary layer, the pressure changes sharply. This pressure jump is clearly visible in Figure 1a, which shows the pressure and velocity diagrams obtained in one of the experiments.

The magnitude of the difference in pressure on the ceiling and on the bottom of the gallery (excluding hydrostatics) Δp should depend on the speed of water in the compressed section $\vartheta_{сж}$, its density ρ, the height of the gallery $h_Г$, the distance from the gate knife to the measurement section l and on the relative opening of the gate n, since with a change in n the compression coefficient and the shape of the transit jet change.. We replace the values of n and $h_Г$ with the value of the shutter opening $a = nh_Г$. Thus, we can write $\Delta p = f(\vartheta_{сж}, \rho, l, a)$.

The ratio of dimensions will look like this:

$$\frac{M}{LT^2} = \left(\frac{L}{T}\right)^x \left(\frac{M}{L^3}\right)^y L^z L^q$$

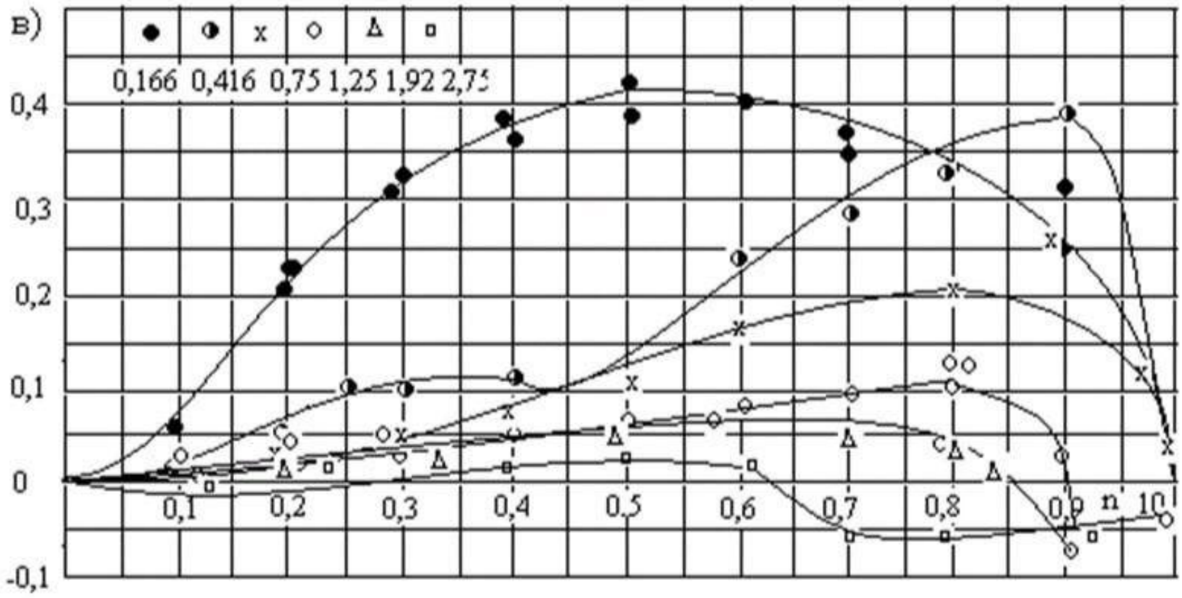

Figure 1a. The effect of the valve opening value on the pressure distribution in the gallery. in excess of the pressure at the bottom of the gallery over the hydrostatic pressure.

Comparing the exponents of the same dimensions, we obtain the following relationship:

$$\Delta p = k\rho\vartheta_{сж}^2 \left(\frac{a}{l}\right)^q$$

where k is the proportionality coefficient. This type of formula is also confirmed by physical considerations: since the pressure difference is determined by centrifugal forces, which are proportional to the square of the velocity, then $\vartheta_{сж}$ must be included in the formula to the second power. To determine the values of k and q, experiments were carried out on a model of a gallery section with a cross-section of 12x12 cm with a flat sealed shutter. The length of the gallery section below the shutter is 85 cm. In preliminary experiments it was established that at a flow rate $Q > 33\frac{л}{сек}$, which corresponded to $\mathrm{Re} > 5{,}5\cdot 10^4$ (where $\mathrm{Re} = \frac{\vartheta R}{\nu}$; R is the hydraulic radius of the gallery), the studies were carried out in a self-similar region.

Using piezometers, the pressure on the gallery floor and ceiling was measured at various distances from the gate, as well as the vertical velocity and pressure distribution near the compressed section of the Pitot tube.

The experiments demonstrated the validity of the above considerations.Figure 1b shows the difference in pressure between the bottom and ceiling of the gallery as a function of the velocity pressure in the compressed section. Considering that the gallery height is , it becomes clear that the constant component (at $\vartheta_{сж} = 0$) corresponds to hydrostatics. Fig. 2 shows the difference between the pressure at the bottom and the ceiling of the gallery (without taking into account hydrostatics, i.e.

$$\frac{\Delta p}{\gamma} = \frac{p_2}{\gamma} - \frac{p_1}{\gamma} - h_Г$$

Relative to the velocity pressure in a compressed cross-section, depending on the relative opening for different measurement points. Of primary interest, of course, are the data for $\frac{l}{h_Г} < 1$, i.e., near the valve.

With an increase in the opening of the gate, $\frac{\Delta p}{\frac{\rho \vartheta_{сж}^2}{2}}$ - gradually increases to a certain value, then decreases sharply and, at large openings in remote sections, changes sign, which is explained by the presence of a second roller at the bottom of the gallery, located slightly below the first downstream. With increasing distance l, the maximum value of $\frac{\Delta p}{\frac{\rho \vartheta_{сж}^2}{2}}$ - decreases and occurs at smaller openings п. The difference in the nature of the dependence for $\frac{l}{h_Г} = 0{,}166$ from other cases is explained by the fact that with large openings $n > 0{,}6$, a niche is formed in the ceiling, the flow pattern near which changes.

Fig. 2, a shows the same values as in Fig. 1, c $\frac{\Delta p}{\frac{\rho \vartheta_{сж}^2}{2}}$, but now depending on the relative distance from the shutter $\frac{l}{a}$.

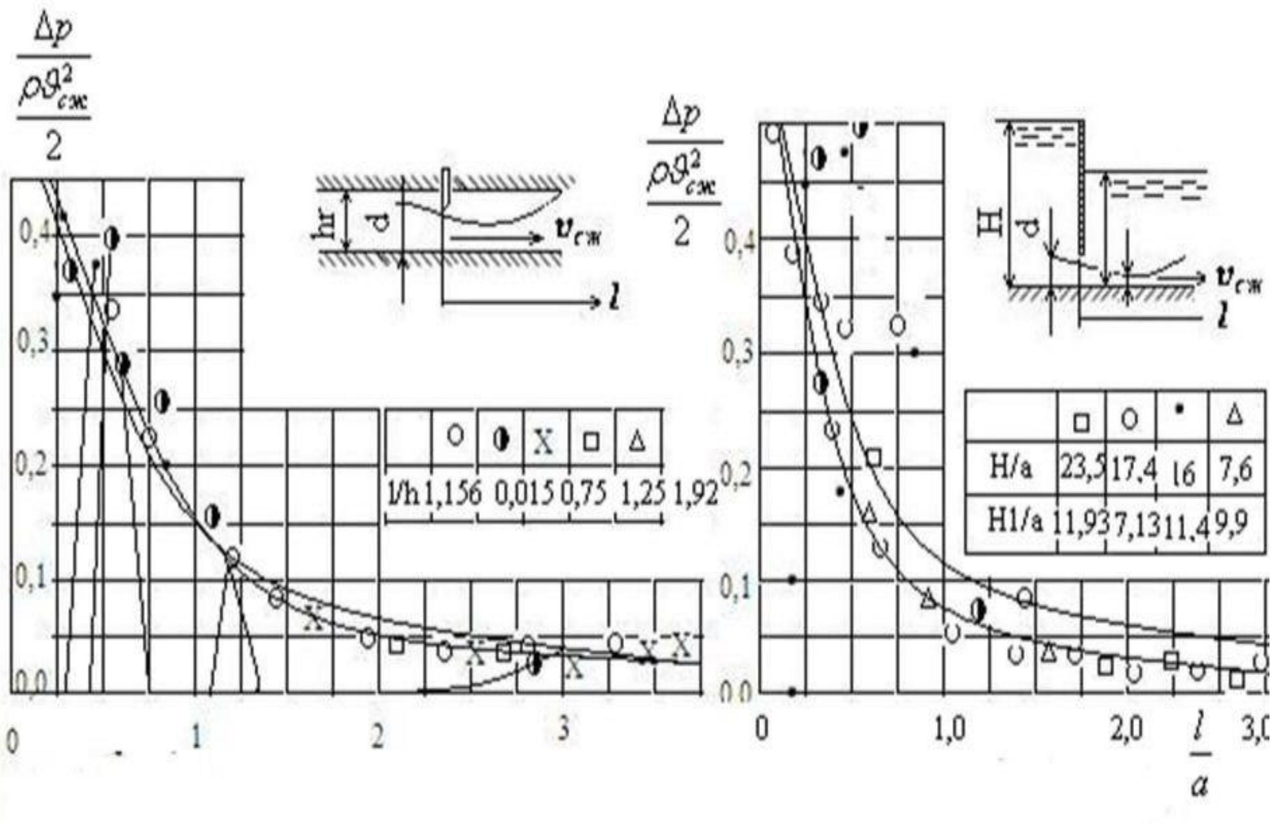

Figure 2. Excess pressure at the gallery bottom above the hydrostatic pressure.
a) Author's experiments;b) Rajaratnam and Subraman's experiments

The graph of this dependence (solid line in Fig. 2, a) is plotted as a dotted line in Fig. 2, b, which shows the data obtained by Rajaratnam for gravity flow [4]. The good agreement of the results, despite the completely different boundary conditions, indicates a single cause causing the pressure distribution to differ from hydrostatic. And since the magnitude of the centrifugal forces causing this difference depends on the radius of curvature of the jets, i.e. on the shape of the transit jet, such a close match shows that the shape of the transit jet in both cases is very close. The experimental curve for $\frac{l}{a} > 0{,}4$ ((Fig. 2,a) can be approximated by a hyperbola with proportionality coefficient $k = 0{,}16$ (dashed line in Fig. 2,a). Thus, formula (1) is reduced to the form:

$$\Delta p = 0{,}16 k \rho \vartheta_{сж}^{2} \frac{1}{2}\left(\frac{a}{l}\right) = 0{,}08 \vartheta_{сж}^{2} \frac{a}{l}$$

It should be noted that at large apertures, this dependence changes sharply, as at $a - h_{\Gamma}, \Delta p \to 0$, and as the shutter approaches, this change occurs at large apertures. This is shown in Fig. 2a by the thin lines.

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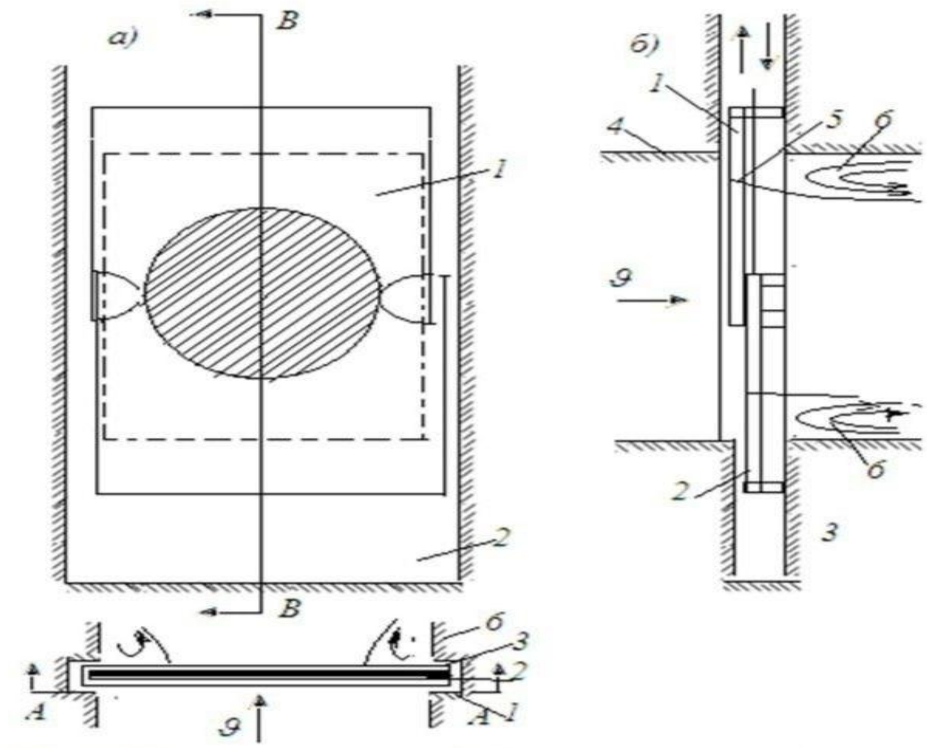

Figure 3. Double flat gate valve with curved opposing edges. a - view along A -A;
6 - view along B-B - upper shield; 2 - lower shield; 3 - gate grooves; 4 - water conduit; 5 - seals; 6 - roller zone.

Despite the significant difference in pressure distribution from hydrostatic pressure near the gate, the flow characteristics in the gallery at the compressed cross-section can be determined with an accuracy of 5-7% using formulas derived without taking this phenomenon into account. The pressure at the gallery ceiling is determined using formula [1].

$$\frac{p}{\gamma} = h - \left(1 - 2\sqrt{\varsigma_{зm}} - \varsigma_2\right)\mu^2 H_0 \qquad (3)$$

Where h is the depth of the gallery ceiling below the tailwater level; $\varsigma_{зm}$— is the gate resistance coefficient; ς_2 - is the total resistance coefficient of the gallery section below the gate; H_0 - is the effective pressure; μ is the gallery flow coefficient. ϑ the resistance coefficient $\varsigma_{зm}$— for gates without a slot is determined by the formula:

$$\varsigma_{зm} = \left(\frac{1}{n\varepsilon} - 1\right)$$

Where the vertical compression coefficient can be taken from N. E. Zhukovsky. Most of the experiments that revealed the difference in pressure distribution from hydrostatics were conducted for a gate without grooves. Verification experiments conducted with grooves showed that the distribution remained the same.If, during the construction of the shutter chamber, a cavity remains under the lining, connecting with the gallery, and this happens quite often [5], then, due to the difference in pressure in the transit stream and in the upper part of the gallery, significant forces may arise, applied to the lining and directed inward into the gallery, i.e. tearing off the lining,Moreover, the point of application of the resulting force moves as the valve opens. Therefore, the lining near the valve must be installed with particular care.

It should be noted that the minimum pressure in a number of cases was recorded within the boundary layer (zone B in Fig. 1a). Velocity and pressure fluctuations here are also large, and the velocity gradient is small.Due to the large pressure difference across the boundaries of the boundary layer, a large pressure gradient develops within it, leading to tensile stresses in the fluid that increase as it approaches the valve. Thus, favorable conditions for cavitation are created in the boundary layer near the valve.

A similar pattern is observed not only in seal chambers but also in other structures characterized by high-speed flow separation. To reduce the cavitation effect in such structures, it has been proposed to remove the boundary layer1 from the walls, i.e., to transition to so-called "supercavitation."In this case, the closure of cavitation cavities occurs not on the surface of the structure, but within the flow.

One way to implement this idea is a double valve with curved opposing edges.2 Figure 3 shows this valve partially open.The gate consists of two flat shields 1 and 2, moving in a vertical (or horizontal) direction in grooves 3 and blocking the water conduit 4. Its main feature is that the opposing edges of the shields have a curvilinear outline.

When the gate is fully closed, the shields overlap slightly.

As it begins to open, the gate shields move apart, forming an opening between the curved edges (shaded in Fig. 3a), through which water flows. A roller 6 is formed between the transit stream and the walls of the water conduit. The water velocity in this roller is lower than in the transit stream, and the transition zone is removed from the walls of the water conduit. This protects the walls from cavitation erosion. When fully opened, shield 1 rises into the shaft, and shield 2 descends into the niche.The water main only opens to its full width at the end of the gate opening, when the potential for cavitation is significantly reduced. With partial openings, the stream moves only in the central section, leaving a significant layer of water between it and the water main walls.When using such valves on round and oval cross-section water pipelines, the transit flow touches the walls only when the valve is fully open.

CONCLUSIONS

1. The pressure distribution near the valve differs significantly from the hydrostatic one.
2. The difference between the piezometric pressure on the bottom and ceiling of the gallery can be determined using formula (2).
3. The shapes of the jets flowing out from under the valve in a pressure water pipeline and during submerged flow in an open stream differ slightly.
4. The pressure in the compressed section and the resistance coefficient of the valve can be determined with sufficient accuracy using formulas (3) and (4).
5. Since favorable conditions for the occurrence of cavitation are created in the boundary layer, it is advisable to remove it from the gallery walls using various structural elements to reduce cavitation erosion.

REFERENCES

1. Kachanovsky B. D. Hydraulics of shipping locks. Rechisdat, 1951.
2. Faktorovich M. E. Determination of hydrodynamic pressure behind flat valves in pressure water pipelines of any cross-section. Izvestiya VNIIG, v. 76, 1964.

3. Rajaratnam and Subramanya K. Flow immediately below- submerged sluice gate. Journal of the Hydroulics division, Proceedings of the ASCE vol. 93, N HY4, 1967.
4. Kuznetsov L. A., Lysenko P. E. Operation of steel spillway linings under cavitation and dynamic effects. Proceedings of the coordination meetings on hydraulic engineering, issue 52, 1969.
5. U. I. Begimov, N. A. Usmonova, H. M. Yakubova, S. I. Khudaykulov "Modeling of a shock pulse in the outlet pipeline of the Karkidon reservoir." Journal "Problems of Mechanics". - Tashkent, 2020. - No. 4. - P. 45-48.
6. Begimov U. I., Khudaykulov S.I., Narmanov O. A. «Formations of Ventilated Caves and Their Influence on the Safety of Engineering Structures» International Journal of Academic Information Systems Research (IJAISR) ISSN: 2643-9026 Vol. 5 Issue 1, January - 2021, Pages: 105-109. 1,05 импакт фактор Impact Factor.
7. N.A. Usmonova, Prof. S.I. Khudaykulov. Spatial caverns in flows with their perturbations impact on the safety of the karkidon reservoir. 3rd Global Congress on Contemporary Science and Advancements Hosted From New York USA www.econferenceglobe.com. TECHMIND-2021, 126-130.
8. Khudaykulov S.I., Zhovliev U.T., Usmonova N.A. Schemes of cavitation flows of multiphase liquid. Uzbekistan republics oliy va urta makhsus talim vazirligi Farghona polytechnic institute "Modern building - actual problems of design, construction, reconstruction and modernization of structures and their structures"Collection of materials of the republican online scientific-practical conference. April 21-22. Fergana 2021.S: 277-280
9. Jovliev U.T., Kazakov E., Yakubov G. "Extension Of Tubular Water Discharge Limitations With Water Flow Extinguishers" "International journal of scientific & technology research volume 8, issue 12, december 2019 issn 2277-8616 Pp-2080-2082 www.ijstr.org "(ScopusISSN 2277-8616) IF.4.850
10. Jovliev U.T., Khudaykulov S.I. Algorithm for accounting for vortex zones at the pump inlet. Bulletin of the Turin Polytechnic University in Tashkent, issue 1/2018. pp. 58-60. (05.00.00; No. 25)
11. Jovliev U.T., Mannopova H., Khudaykulov B.S. "Correlation of the zone of low or high pressure with characteristic changes in the velocity head" J: Problems of Mechanics. No. 3, Tashkent 2018 pp. 87-91. (05.00.00; No. 6)13.
12. Jovliyev U.T., "Vibration processes in water movement in high-pressure hydraulic structures" J. Agro Ilm No. 2, Tashkent 2019, P. 96-98.(05.00.00; No. 3)14.
13. U. Jovliev. "Hydraulic parameters of high-pressure flow in high-pressure structures" scientific supplement to the journal of agriculture and water management of uzbekistan. "Agro-ilm" tashkent 2019. No. 3, p. 66-67. (05.00.00; No. 3)