

**PROVIDE A MODEL FOR MEASURING AND INCREASING THE
EFFECTIVENESS OF LEARNING IN VIRTUAL (ELECTRONIC) EDUCATION
SYSTEMS**

***FORNECER UM MODELO PARA MEDIR E AUMENTAR A EFICÁCIA DA
APRENDIZAGEM EM SISTEMAS EDUCACIONAIS VIRTUAIS (ELETRÔNICOS)***

***PROPORCIONAR UN MODELO PARA MEDIR Y AUMENTAR LA EFECTIVIDAD
DEL APRENDIZAJE EN LOS SISTEMAS EDUCATIVOS VIRTUALES
(ELECTRÓNICOS)***

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ABSTRACT: The main purpose of virtual or e-learning systems, like traditional systems based on physical presence, is to transfer maximum concepts from published sources, especially from the teacher to the recipient of knowledge. Improvement in this process is possible only with the achievement of the goal, or in other words, the effectiveness of the knowledge transfer process, is measured appropriately and validly. Although different models have been proposed to measure the effectiveness of education in traditional systems, new and virtual education systems have fundamental differences with previous types that make the use of those models inappropriate. In this paper, considering the specific features of e-learning systems, a model for measuring their effectiveness has been developed, emphasizing measuring learning rather than measuring education. In this model, the factors affecting learning in e-learning systems are identified, and a preliminary equation is derived to determine their relationship.

KEYWORDS: E-learning. Traditional systems. Education. E-learning systems.

RESUMO: *O principal objetivo dos sistemas virtuais ou de e-learning, como os sistemas tradicionais baseados na presença física, é transferir o máximo de conceitos de fontes publicadas, especialmente do professor para o receptor do conhecimento. A melhoria neste processo só é possível com o alcance do objetivo, ou seja, a eficácia do processo de transferência de conhecimento, é medida de forma adequada e válida. Embora diferentes modelos tenham sido propostos para medir a eficácia da educação em sistemas tradicionais,*

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os sistemas de educação novos e virtuais têm diferenças fundamentais com os tipos anteriores que tornam o uso desses modelos inadequado. Neste artigo, considerando as características específicas dos sistemas de e-learning, foi desenvolvido um modelo para medir sua eficácia, enfatizando a medição da aprendizagem em vez da medição da educação. Neste modelo, os fatores que afetam a aprendizagem em sistemas de e-learning são identificados, e uma equação preliminar é derivada para determinar sua relação.

PALAVRAS-CHAVE: *E-learning. Sistemas tradicionais. Educação. Sistemas de e-learning.*

RESUMEN: *El objetivo principal de los sistemas virtuales o e-learning, al igual que los sistemas tradicionales basados en la presencia física, es transferir el máximo de conceptos de las fuentes publicadas, especialmente del docente al receptor del conocimiento. La mejora en este proceso solo es posible con el logro de la meta, o en otras palabras, la efectividad del proceso de transferencia de conocimiento, se mide de manera adecuada y válida. Aunque se han propuesto diferentes modelos para medir la efectividad de la educación en los sistemas tradicionales, los sistemas de educación nuevos y virtuales tienen diferencias fundamentales con los tipos anteriores que hacen que el uso de esos modelos sea inapropiado. En este artículo, considerando las características específicas de los sistemas de e-learning, se ha desarrollado un modelo para medir su efectividad, enfatizando la medición del aprendizaje en lugar de la medición de la educación. En este modelo se identifican los factores que afectan el aprendizaje en los sistemas de e-learning y se deriva una ecuación preliminar para determinar su relación.*

PALABRAS CLAVE: *E-learning. Sistemas tradicionales. Educación. Sistemas de e-learning.*

Introduction

With the increasing advancement of digital teaching methods, in many cases supplanting and complementing traditional methods, the most diverse areas of teaching and research receive these pedagogical innovations in their ways of passing on knowledge. Digital learning enabling a faster and more dynamic transfer of knowledge in some cases, but also facing some difficulties in other areas, such as the question of the possible lack of the figure of the teacher, such as face-to-face teaching. Even so, the most diverse study and research niches are contemplated and begin to enter this new teaching environment. Thus, in this article, one of the several themes that can be contemplated and improved with the inclusion of an efficient digital teaching system is shown, which collaborates beyond teaching only for the development of research and scientific communication.

The preservation of water source ecosystems, including ichthyofauna, under the conditions of an ever-increasing anthropogenic load, manifested by water consumption increase, is one of the acute problems of our time. Prevention of juvenile fish into water intakes by the means of a fish protection structure is associated with the need to divert protected

juvenile fish (fish outlet) to a safe place while maintaining its viability.

Generally, a fish outlet of a fish protection structure is a complex of devices and elements, including: an inlet portal; a fish-diverting tract (channel, chute); an outlet portal. If a section with a large terrain slope occurs on the route of a fish-diverting tract, then a connecting structure is provided.

The existing layout and design solutions for fish-diverting systems are currently based on the use of fish behavior peculiarities and patterns (PAVLOV; PAKHORUKOV, 1983), as well as on domestic and foreign experience concerning the design and operation of fish-diverting systems (Protected fish diversion systems from fish protection devices, 1986; MIKHEEV *et al.*, 1997; MIKHEEV; PERELYGIN, 2007; MIKHEEV; PERLYGIN, 2014; LARINIER; TRAVADE, 1999). At the same time, the variety of biological, hydraulic, technical, layout features and conditions make a significant impact on the successful solution of fish moving problems to a safe place of a water source. It should be noted that the nature of the fish outlet flow movement within the inlet portal in the area between the protective screen (mesh, blinds, drums etc.) and the fish-diverting tract is generally the main criterion while developing a fish outlet structure. At the same time, the layout solution, the design of the elements, the conditions for conjugation of the bottom (horizontal or a sloped one), flow characteristics within the inlet portal must meet the fish safety requirements.

In this regard, the development of principles for the selection of structural elements of fish diverters (outlets) based on existing hydraulic and biological approaches and requirements, will allow to avoid errors in their design, and fish diversion losses.

Materials and methods

To develop the main directions in design optimization for the inlet portal of the fish outlet, the principle of operation, functional features and possible ways of its constituent element optimization are considered. Subsequent analysis is limited only by the design of the inlet portals of open gravity fish outlets.

Inlet part. The entrance is the most functionally significant element, which provides the efficiency of protected fish diversion due to the properties of suction and involvement of juvenile fish with the flow. In open flows, the suction (vacuum) effect is manifested under certain conditions in the zones of flow separation and in whirlpool currents.

Receiving section. As a rule, the receiving section in the flow dividing unit occupies an intermediate position and, when analyzed the flow under rarefaction conditions, it can be

considered between the conventional open water intake scheme and the nozzle scheme, therefore this section should have the smallest possible width.

Transitional section. The movement of fish along the channels (galleries and pipes) is dangerous for them, especially in the transitional (initial) section of the conjugation with the fish diversion tract, since the likelihood of injury from walls, protrusions etc. is high, which increases with the length and number of local resistances rising, therefore, the hydraulic conditions and the length of the fish outlets should be optimal.

Results and discussion

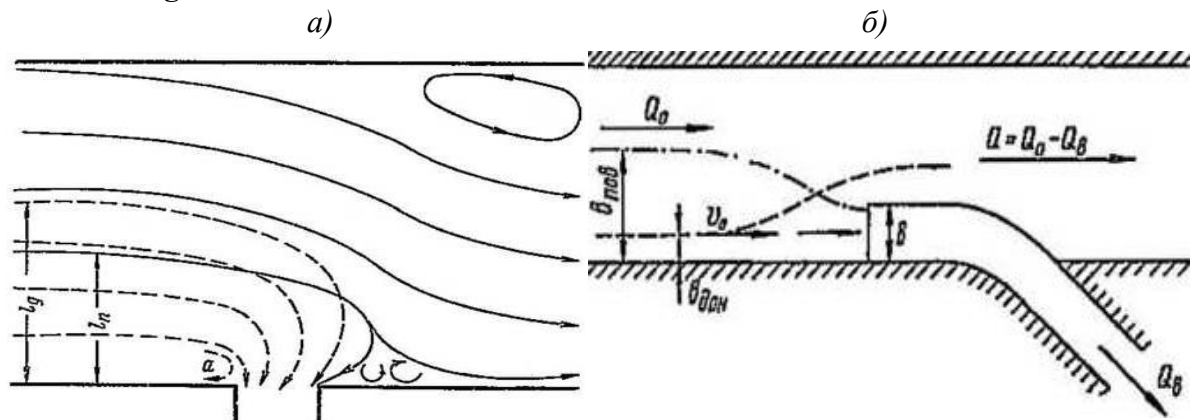
Assessment of conditions in the influence zone of the inlet portal of fish outlet. Water intake into the fish outlet should be considered as a water intake without a dam, since water is drained by gravity from the inlet chamber of the fish protection structure to the fish outlet. The lateral water outlet makes significant changes to the flow movement regime.

If during the design of water intakes, the main task is to combat sediment, then the main task for a fish outlet is to ensure the safety of fish diversion. The danger for fish is represented by increased turbulence (large gradients of transverse velocities, pulsations), the presence of separated flow currents with the formation of circulation zones, intense transverse circulation, etc. Accordingly, a laminar (smooth) velocity profile for fish is always preferable to a turbulent one. The entrapment of sediments is also an undesirable phenomenon, since their deposition in the channel of the fish diverting tract will change its cross-section, flow characteristics and regime.

Based on these positions, the characteristic features of the flow current formation in the influence zone of water intake are considered.

Figure 1 shows the character of a flat flow with the options for water intake at a right angle to the coastline and along the approaching flow front (CHUGAEV, 1978; ZAMARIN. FANDEEV, 1965).

Figure 1 – The flow current scheme at water intake from a water source



a – at lateral outlet; b – at front intake
Source: Devised by the authors

With a lateral outlet (see Figure 1, a), before entering the water intake at point a, a vortex with a vertical axis is created in front of the water intake inlet face. The bottom lines of currents (dashed lines) are pulled into this low-pressure zone, which involve bottom sediments, and, consequently, benthic fish, into the water intake.

According to V. A. Shaumyan, the zone of bottom jet capture l_n is larger than the zone of surface jet capture l_n , their values are determined by the following formulas

$$l_n = 1,17(k + 0,4)b; \quad l_n = 0,73(k + 0,05)b,$$

where b – the outlet width; $k = q_{outlet}/q_{river}$.

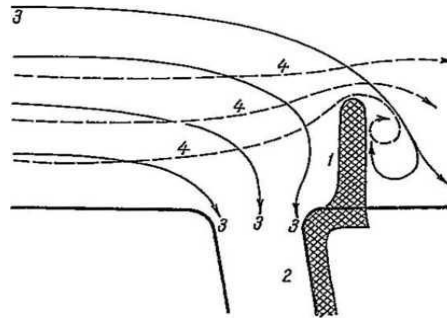
It is known that the width of the capture zone of bottom jets significantly exceeds the width of the capture zone of surface jets (without considering the river width, depth, the share of discharge diversion etc.). The attempts to reduce the capture of bottom sediments by the means of a threshold setting at the entrance to the water intake are ineffective, and in fish diversion, the setting of thresholds is not permissible, since this will impede the passage of benthic fish species. With a wide front of the water intake, the axis of the vortex moves to the water intake, forming a circulating flow here.

At frontal water intake (Figure 1, b) the capture from the bottom layers of the flow is minimized.

The width of the capture zone of the bottom layers of the flow (b_{bot}) at the frontal water intake can be determined approximately by the following formula (CHUGAEV, 1978; ZAMARIN; FANDEEV, 1965): $b_{bot} = 2(k - 0,5)b$, where $k = q_{out}/q_{river}$, thus, at $k \leq 0,5$ the capture of the flow into the outlet from the bottom layers is excluded $b_{bot} = 0$.

To increase the pressure a short water-capturing spur is installed in front of the water intake (Figure 2), due to which the water level in the river before the entrance to the water intake rises by 0.5-0.6 from the velocity head $v^2/2g$, where v – the average flow velocity of the river near the water intake.

Figure 2 – Short water intake spur (Zamarin & Fandeev, 1965).



Subtitle: 1 – spur; 2 – water intake; 3 – surface jets; 4 – bottom jets
Source: Zamarin and Fandeev (1965)

Based on the recommendations for the design of water intakes, an obvious conclusion is made that the frontal type of water intake is preferable for designing the inlet portal of the fish outlet, since it provides uniform intake (capture) of juvenile fish in depth. Besides, the frontal type of water intake fits harmoniously into the design of the fish protection structure with a protective screen installed at an acute angle to the flow, being a natural continuation of the screen - a kind of fish trap.

The design of the receiving section of the inlet portal of the fish outlet. A flat jet flowing from a reservoir into a narrow chute is compressed in the horizontal plane. The degree of its compression in depth will not be the same - the jet is compressed more on the surface (in the vacuum-free zone) than at depth (SCHLICHTING, 1969). Based on this, to optimize the receiving section, we will use the principle of comparing the hydraulic operating conditions of the inlet portal of the fish outlet with the hydraulic conditions of the nozzles, while the evaluation criterion of the nozzle design will be flow characteristics that is safe for fish, ideally a non-vortex (laminar) flow.

As it is known, external nozzles are divided into three main groups: cylindrical, conical (diverging and converging) and conoidal - with the edges rounded in the form of jet compression (CHUGAEV, 1978; PATRASHEV, 1953). The flow characteristics within the nozzle includes two independent parts: the central (axial), where the fluid particles move only

forward, and the coaxial, in which the fluid particles are circulated. The minimum area of the free cross-section of the forward flow in the central part is called the compressed cross-section.

A vacuum is formed at the inlet part of the nozzle, which somewhat expands the compressed section and causes the flow discharge increase through the nozzle (in comparison with the thin wall hole), the flow coefficient $\mu = 0.82$. With the nozzles longer than 40-50 diameters, the suction effect does not compensate for the increasing hydraulic losses along the nozzle length.

Conical converging nozzles (used in hydraulic turbine nozzles, jet monitors etc.) are capable of providing smooth, almost irrotational flow acceleration up to the maximum speed in the compressed section (throat). The jet leaving the converging nozzle has a high specific kinetic energy and outlet velocity (due to the small value of hydraulic resistance), which makes it possible to use them for fish capture. The discharge coefficient reaches its highest value $\mu = 0.946$ at the angle equal to $13^{\circ}24' \approx 13,5^{\circ}$ (CHUGAEV, 1978; PATRASHEV, 1953).

Conical converging nozzles are capable of providing a smooth, almost irrotational acceleration of the flow up to the critical (for fish) velocity in the throat (which is assigned in accordance with the SP requirements) (SP101.1333.2012 Retaining walls, navigational locks).

In conical diverging nozzles, the fluid jet velocity in the compressed section is greater than the jet velocity at the nozzle outlet, and the pressure, on the contrary, is less, since there is a vacuum in the compressed section of the nozzle. The vacuum in the diverging nozzle is greater than the vacuum in the outer cylindrical nozzle and it grows with the taper angle increase, which should be sufficiently small $\theta = 5-7^{\circ}$. The flow discharge through such a nozzle is much higher than the flow through the external nozzle, and the output speeds are much lower. It should be noted here that the expansion of the channel is a fact of salvation for fish in a narrow space, since it reduces the likelihood of injury due to the free area increase. Therefore, it is better to use a smoothly expanding chute to divert the fish from the throat.

The conoidal nozzle is outlined by the jet shape flowing out of the hole: the inlet part is made along a complex surface of double curvature, and the outlet part has a cylindrical shape, which eliminates the disadvantage of the conical converging nozzle consisting in the compression of the liquid jet when it leaves the nozzle, that is, the compression ratio is equal to one in the conoidal nozzle. Therefore, the velocity and flow discharge coefficients for this nozzle are approximately equal to each other $\mu = \varphi = 0.97-0.99$ (depending on the pressure and the quality of the nozzle inner surface processing).

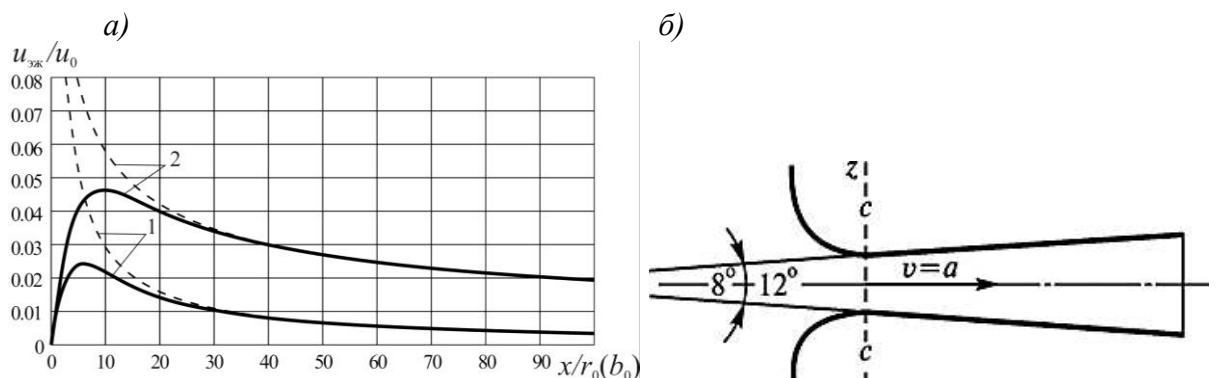
Thus, the basis for the optimization of the layout and design of the inlet portal of the fish outlet is based on the features of nozzle operation with axial symmetry, in which fish safe conditions can be created by the following combination of nozzles:

- at the inlet (to increase the capturing and suction capacity) - conical confuser or conoidal (to increase the throughput of the fish outlet);
- in a compressed section (throat) - a cylindrical nozzle;
- at the outlet (for a smooth and safe diversion of fish) - a conical diffuser.

However, when considering flat jet flows, it is necessary to consider their distinctive features from axisymmetric ones, which consist, first of all, in the intensity of the jet expansion, which, in turn, affects the ejection ability of jets. For comparison, Figure 3 shows the graphical patterns of changes in the relative velocity of ejection along the length x for round (nozzle radius r_0) and flat (hole width b_0) jets in the form of the ratio of the average jet velocity (u_0) in the section and the rate of fluid inflow from the surrounding area to the outer boundary (u_{ej}) (MIKHEEV; BOROVSKOY, 2015).

Obviously, the ejection capacity of a flat jet is much higher than that of an axisymmetric jet, the maximum ejection velocity falls approximately in the middle of the initial section. In contrast to the axisymmetric jet, the peak of the flat curved jet is shifted to the right and the maximum ejection velocity falls on the second half of the initial section. It is important to emphasize that a flat jet, limited by the walls of the fish diverting chute, is capable of creating a much greater vacuum than a round one, and, therefore, it expands much more in the diffuser channel of the fish outlet.

Figure 3 – Conformity to the combined nozzle shape to the ejection ability of the submerged jet



a - the graph of the ejection velocity change along the length of the circular (1) and flat (2) hyperboloid jet; *b* - combined nozzle

Source: Mikheev and Borovskoy (2015)

As can be seen on Figure 3, the ejection ability of the submerged jet corresponds to the combined nozzle shape.

Estimation of the flow characteristics in the inlet portal sections. An important factor influencing the conditions of fish outlet is the flow characteristics, namely, the degree of turbulence, which is assessed by the Reynolds criterion. It indirectly characterizes the flow safety for fish. The results of Reynolds and Gibson's experiments show (PATRASHEV, 1953; PRANDTL, 2000) that the value of Re_r is significantly influenced by the sign of the longitudinal velocity gradient, which is not the same in the nozzles. In confusor flows, in which the downstream velocity increases and, therefore, the velocity gradient is positive, the critical Reynolds numbers are significantly more than 10 times higher than those indicated for cylindrical pipes, and they are the larger, the greater the taper angle (confusion angle) is. This testifies to the laminarization of the flow in the confusor nozzles. On the contrary, in diffusers, in which the downstream velocity decreases and, therefore, the named gradient is negative, the critical Reynolds numbers are much lower than for cylindrical sections. This is well illustrated by Gibson's experiments, in which a laminar regime was simultaneously observed in the confusor part of the flow, and turbulent regime - in the diffuser part.

Experience in the development of highly efficient nozzles, including supersonic nozzles (Laval, Stentan, Frankl etc.) (SAMOILOVICH, 1990), indicates the need to maintain a smooth sequential conjunction of all elements of this sequence, in particular for fish outlet conditions, these are the inlet chamber + confusor; confusor + cylinder; cylinder + diffuser; diffuser + conoidal outlet channel (tract).

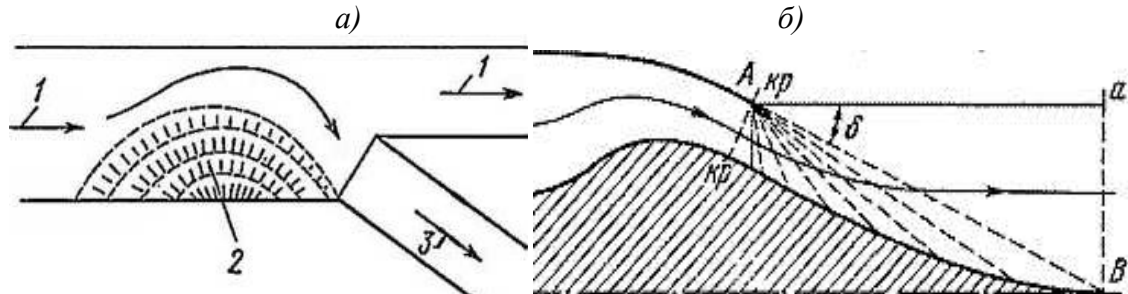
Such nozzles are known and used to increase the throughput both for liquids (for water turbines, pumps, etc.) and for gases to overcome the critical speed in steam, aircraft turbines, rocket engines, etc. Laval's nozzle is a gas channel with a special profile (with a narrowing) to change the gas flow velocity passing through it (PRANDTL, 2000; SAMOILOVICH, 1990). In the simplest case, Laval's nozzle can consist of a pair of truncated cones conjugated with narrow ends. Both versions have a lot in common - there are all elements (confusor, cylinder, diffuser) smoothly merging into each other.

When designing a fish outlet, it is necessary to strive for the smallest possible change in the upstream flow regime (inlet chamber) and to the water velocity decrease before the fish outlet.

If the location of the water intake and flushing openings in the upstream flow is unsuccessful, there is a threat of sediments when approaching the water intake opening. In this

case, the flow can be largely displaced from the water intake openings in the approach section by deposited sediments, which is naturally undesirable (Figure 4, a) (CHUGAEV, 1978).

Figure 4. Substantiation of the inlet part shape of the fish outlet



a – sedimentation in front of the entrance water intake opening;

b – an adjustable nozzle diagram with a central body;

1 - river; 2 - sediment deposition area; 3 - water intake into the channel

Source: Devised by the authors

The reference point for designing the inlet part of the fish outlet is a nozzle with a central body to regulate the flow discharge, a schematic diagram of which is shown on Figure 4, b (PRANDTL, 2000; LOYTSYANSKY, 1987).

In such a nozzle, the gas flows through a coaxial channel (between the central body and the shell); the critical section can be regulated by the longitudinal movement of the central body. The flow at the outlet turns to the axis of symmetry, which in the receiving section design corresponds to the flow bending towards the fish outlet and is an advantage of this design.

The profile of the central body is selected in such a way that at the reduction point of any characteristics, the direction of the flow behind it coincides with the direction of the wall, the critical section and the angular point of the flow are located on the shell cut. In this case, the gas expansion is one-sided, and the critical section is inclined to the axis by the angle δ equal to the gas flow rotation angle around the point A. The shell must be parallel to the wall of the central body in the critical section of the nozzle. This leads to additional frontal resistance due to the losses on the external flow around the shell converging part. If the calculated values of the Mach number ($Ma \leq 2$) are large, the central body can be made conical. In the case of a flat nozzle, the contour of the central body is the streamline of the Prandtl-Mayer flow (near a convex angle) with a flat sonic line (PRANDTL, 2000). The contour of the axisymmetric central body is close to the flat flow streamline. For fish diversion conditions, the advantage of this nozzle is that it matches the shape of the combined nozzle and ensures smooth rotation for fish diversion.

The angle of flow diversion plays a significant role in the flow characteristics within the

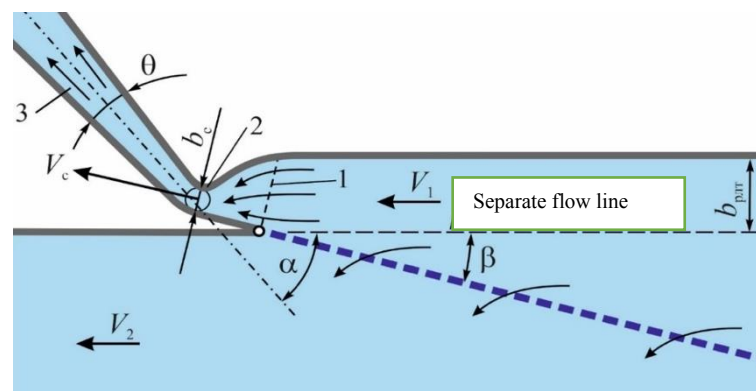
fish outlet. Taking the flow diversion angle of the water intake, they strive to obtain, possibly, a smoother conjugation of the channel with the river, otherwise, if there are sufficiently high velocities in the river, the likelihood of extensive whirlpool zone occurrence, lateral compression of the flow, uneven inflow and water discharge reduction increases.

For damless side water intakes, the angle of flow diversion is assigned within the range $\alpha_{po} = 35-75^\circ$, large angles (up to 90°) are taken under appropriate topographic conditions and relatively low water flow discharge intakes, and the design of water intakes becomes much more complicated at the angles less than 35° (CHUGAEV, 1978). Regarding the conditions of fish diversion they evaluate, first of all, the transverse circulation of the flow arising at the turn and affecting the distribution of juvenile fish in the cross section. In the course of studying the inlet portals of fish-passage-spawning channels (BOROVSKOY, 1990), it was found that the optimal angle for fish attraction is $\alpha_{po} \approx 36^\circ$, at which the transverse circulation covers the entire cross-section in the flow attracting fish.

In real conditions, the angle of diversion is taken by considering the general layout of the water intake facilities, the terrain, the location of the outlet portal in the downstream as the part of the structure node (relative to the RZS, the dam section), the tract length, etc.

The performed complex analysis made it possible to propose a schematic diagram of the arrangement of the main elements (Figure 5) of the fish outlet suction head capable of providing optimal conditions for the safe diversion of fish (BOROVSKOY; TERNOVOY, 2021).

Figure 5 – Schematic layout diagram of the inlet portal main elements of open fish outlet

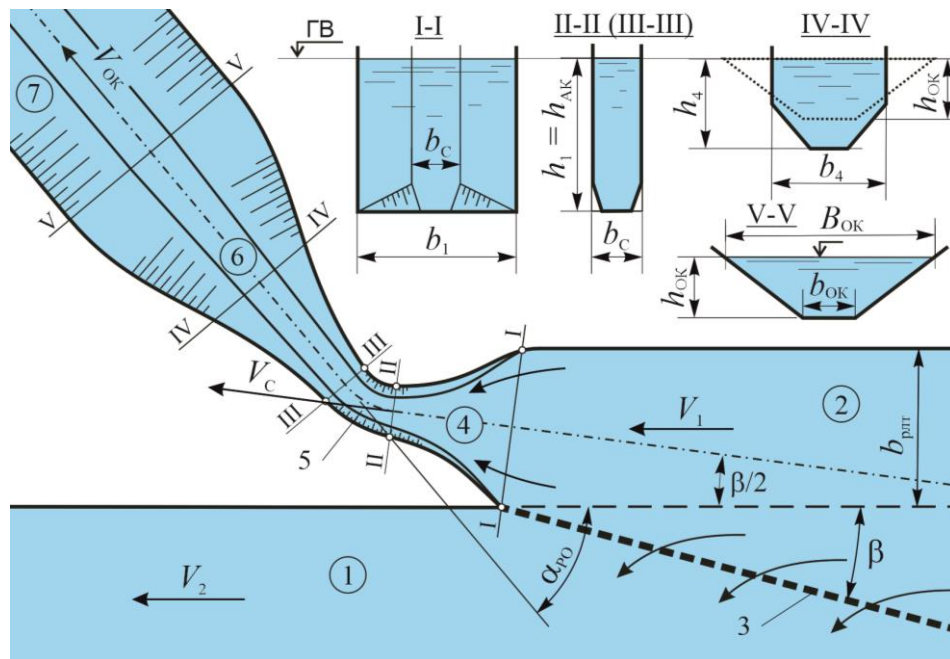


1 – inlet section; 2 – critical section; 3 – transitional section

Source: Devised by the authors

Based on the analysis, a diagram of the layout-constructive solution of the inlet portal of an open gravity fish outlet is proposed (Figure 6),

Figure 6 – Layout and constructive solution of the inlet portal of open gravity fish outlet



I-I – V-V – cross-sections of the inlet portal;

1 – water source; 2 – inlet chamber of fish protection structure; 3 – protective screen; 4 – entrance area;

5 – receiving area; 6 – transitional area; 7 – fish-diverting tract

Source: Devised by the authors

Technically, the portal includes the sequence of the following elements:

- inlet part (entrance area) in the form of a narrowing inlet chamber with a horizontal bottom;
- receiving area (throat) in the form of a narrow prismatic chute;
- transition area in the form of a chute with variable depth and width.

The transformation of the inlet portal cross-section of the fish outlet is represented by cross-sections from I-I to V-V (see Figure 6). The main condition for a continuous flow in the transition (mating) area is the observance of the change linearity concerning its hydraulic diameter at the optimal taper angle θ_{opt} .

Conclusions

The principles of the inlet portal design optimization of open gravity fish outlets are based on a set of sequential basic regularities of the flow planned division, the operation features of nozzles with axial symmetry, the specifics of the conditions for the formation of the flow characteristics on the inlet portal sections, which constructively allows to provide safe hydraulic conditions for the transfer of protected fish into a water source while maintaining its viability.

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