IMPROVEMENT OF THE DESIGNS OF HYDROPOWER PLANTS' WATER-INTAKE AND OUTLET FACILITIES

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At present, a quite significant number of hydroelectric (HES), pumped-storage hydroelectric (PSHES), and pumping stations (PS) is in operation in our country and abroad. The water-intake and outlet facilities of these hydropower plants (HPP) provide the necessary strength, operational reliability, and high hydropower qualities. We owe these achievements to the use of many years of operating experience, and also to numerous full-scale and laboratory investigations of their operation.

In their design and the functions they perform, water intakes and outlets have much in common. The flow of water in them changes from a free-flowing stream to a pressure flow and/or vice versa. In their design, these structures are very complex facilities with a large number of interrelated elements, the most important of which are the water-intake (outlet) chamber formed by a foundation slab, piers, and a head wall; the inlet (outlet) section; the section (one or several) with grooves for installing gates; and the transition section, in which the cross section is gradually transformed to round.

For the purpose of performing its basic functions — providing for reliable delivery (removal) of the necessary flow rate of water in accordance with the load of the HPP's generating set and the possibility of quickly shutting off the flow of water in emergency situations, preventing floating objects and trash from getting into the water line, and creating smooth movement of the flow with minimum energy losses — water-intake and outlet facilities are equipped with various mechanical equipment, trash-catching grates, maintenance enclosures, emergency-repair shutoff valves with individual lifts, mobile lift mechanisms, and much more.

In spite of the uniqueness of each hydropower facility, which is due to the specific topographic, geological, and hydrological conditions, water intakes and outlets often duplicate the design solutions of existing analogs. However, we should note that they are never completely copied. This is prevented by the following circumstances.

1. Water-intake and outlet facilities, like any other technical systems, undergo their own development in the direction of improvement. So, new solutions achieve a decrease in energy losses and a rise in the HPP's overall efficiency. In a number of cases, developments are aimed at making water intakes (outlets) cheaper by reducing the amount of materials used or replacing expensive materials with cheaper ones, and also by improving the design forms, and decreasing the amount of work or increasing the technological efficiency of erecting them.

2. The requirements imposed on the structures under consideration, like hydropower as a whole, have changed, especially recently. In particular, requirements have risen sharply for environmental protection, increasing the reliability and safety of the facilities' operation, and improving working conditions for service personnel. In connection with this, changes and additions are constantly being made in the design of water intakes and outlets.

3. Previously unknown materials with the necessary new properties are now at the disposal of design organizations, and new technologies are used, as well as other achievements of domestic and foreign science and technology.

We will consider ways of improving HPP water-intake and outlet facilities on the basis of examples of designs suggested by scientists and engineers of the department of renewable energy sources of St. Petersburg State Technical University, and of the Department of Hydraulic Engineering of the Samara Architectural and Construction Institute with the author's direct participation.

One such direction is the development of new geometric forms and configurations of water intakes (outlets) or individual parts of them, and improvement of the dimensions of the elements and the relationship between them.

This direction can be illustrated by a water intake of the elbowed-ring type, which was developed for a pumping station equipped with vertical blade impellers (Fig. 1). This water-intake facility, which contains an inlet convergent channel 1, a connecting chamber 2, a guiding cone 3, a vertical outlet convergent channel 4 and inlet 5, is equipped with a cylindrical section 6 and an elbow 7, and the connecting chamber is made in a toroidal shape and is connected with the elbow with the help of a cylindrical section [1].

The use of such a form of the water intake makes it possible to reduce the amount of excavation for constructing a pumping station, on account of digging in the connecting chamber alone. In this case, deeper placement of the convergent channel, which is a very large part of the structure, is practically not required. Moreover, the bottom of the approach section before the inlet convergent channel can also be made at significantly higher levels, and this will make it possible to reduce the volume of excavation necessary for its construction even more. Thus, the use of this form of water-intake facility will provide a considerable economic effect, especially if the PS is built on a rocky base.

Often, additional elements are introduced in water intakes (outlets) in the form of guiding or diverting walls, which improve the hydraulic conditions of the water flow. Thus, Fig. 2 depicts the water intake of a channel HES. If the reservoir has a large drawdown, then when the station is operating with high and medium levels of water in the reservoir the boom, which is placed under dead space, sharply compresses the flow in a vertical plane.

As a result of this, the transit flow remains compressed along the whole length of the water-intake chamber, and a whirlpool zone of significant size forms above it, with a horizontal axis of rotation.

To eliminate the indicated shortcoming, in [2] it is suggested that the boom be made with a flow-guiding deflector. In this design, the flow expands behind the boom, and on account of this the working height of the trash-catching grate is increased. The economic effect from using the deflector results from a reduction in the average flow rate on the grate and, consequently, a decrease in pressure losses on it. Besides that, the volume of the whirlpool zone above the transit flow is reduced, which entails a decrease in the flow's energy losses for maintaining the circulation current. This solution is effective for low-head channel HES that have piers sticking out into the upper pool.

A water intake and outlet for a PSHES was developed in [3], in which it is suggested that the water-intake and outlet chamber be made with flow-guiding elements in the form of shields installed in its corners with a 45° slope. It is recommended that the distance of these shields from the chamber’s corners be taken as equal to 0.15-0.30 of the height of the water line’s cross section. In this case, the transition part should be made with an initial cross section in the form of a polygon.