Lightweight constructions in technical water supply systems of thermal and nuclear power plants

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Abstract. Based on the analysis of constructive-technological, functional operation of technical water supply systems of thermal and nuclear power plants (TPP, NPP and CHP) it is determined, that using water flow rates up to 100 m³/s and more for cooling, which are taken from the water bodies (reservoirs, large rivers) and dumping the same amount of water heated to 8-10 degrees back, causes a multifunctional change in the aquatic environment. In order to balance the anthropogenic load on the water body used as a reservoir-cooler, various design solutions are currently used in selecting the estimated water discharges and dumping the heated water into a water body. The reservoirs are made of traditional building materials that require large capital expenditures, and most important, they are ineffective in protecting alluvial stations from the indication of various species young fish and in the distribution of the heated water on the water surface of the reservoir-cooler. Based on the results of innovative and constructive studies of lightweight water intake structures and jet distribution structures made of high-strength synthetic fabric materials of domestic production, the soft floating structures (SFSs) have been developed. They provide protection of pumping units from young fish with an efficiency up to 90% as well as the environmentally necessary management of the distribution of heated waters on the surface of the reservoir-cooler. The achieved research results have successfully passed the industrial approbation at the Konakovskaya and Stavropol regional power stations.

Introduction

The water factor in the modern society development is the most adequate indicator of sustainable development, both in the ecological, economic and social sense [1-10].

The modern concept of water resources rational use provides an ecosystem approach, which allows considering water bodies within the spatial limits of basin ecosystems, where the quantitative and qualitative water flow indicators (surface and subsurface) are formed, almost all types of economic activity, including the generation of electrical energy from thermal and nuclear power plants (thermal power plants, nuclear power plants, central heating plants). The use of water resources in the technical water supply systems of thermal power plants, nuclear power plants, central heating plants, requires...
the environmental protection measures to ensure the environmentally sustainable state (ESS) both in water bodies and in the catchment area of the basin geosystem.

The environmental approach of using water resources in technical water supply systems of TPP, NPP and CHP determines a set of environmental measures aimed at reproducing the required technological and environmentally acceptable selection of the water flow from a water body and at the same time ensuring environmental safety by maintaining a balanced anthropogenic load on water resources regulation and management of the processes occurring in water bodies.

Maintaining a balance of anthropogenic load caused by the selection of the estimated water flow from a water body and continuously flowing hydrological, hydro-chemical and hydro-biological processes of vital activity at the water body under consideration has identified a number of the key tasks requiring research in their development.

Research methods
To cool the turbine units at TPPs and NPPs large water flows are required from 100m$^3$/s and more, and the same the amount of water heated to 8-10 degrees in summer and 11-14 degrees in winter [10-17] is discharged, which causes multifunctional changes in the cooling pond caused by the temperature factor, the changes in the living conditions of the ichthyofauna and phytoplankton. Those measures ultimately do not ensure the environmental safety in the water body. It should be noted that lowering the temperature of the selected water by 1 degree reduces the consumption of equivalent fuel to produce a unit of electrical energy within 5-10 g, which is equivalent to reducing the atmospheric emissions of thousands of tons of pollutants from a single turbine unit with a modalitity of 300,000 MW [17-20]. An important environmental factor in the technical water supply systems of thermal power plants, nuclear power plants and central heating plants is the preservation of fish species composition in a water body when selecting estimated water flow rates up to 100 m$^3$/s and more, since the various types of fish protection devices (FPD) used are not effective.

To regulate and control the temperature regime in a water body used in the technical water supply system of TPP, NPP and CHP various designs of regulating hydraulic structures (RHS) made of traditional building materials (metal, concrete, stone, etc.) are used. So, the selection from the lower, colder, layers of a water body is carried out by the radiation intake structures made of several lines of large-diameter water lines (2000-5000 mm) laid on the bottom. Operating experience of this type of water intake facilities, as shown by the results of ichthyological studies, does not protect young fish from getting into the pumping units of the water supply system of thermal power plants, nuclear power plants and central heating plants [12-19]. Different types of water outlets at the end section of the catchment channel in the form of a filtering dam, a jet distributor, perforated pipelines, metal grids do not fully provide the necessary formation of the temperature-density distribution of the heated flow in the near zone of the cooling pond [20]. The research has shown that the nature of the heated water masses spreading in the outlet zone is higher than the absolute value of the Froude density number [13], where the optimum value of the Froude number is considered to be 0.6 [14]. When Fn ent. ≥1.0 as established by the research, the intense mixing of the heated stream with cold layers of the cooling reservoir is observed [8]. When Fn ent. <1.0 the mixing is not observed, which provides the necessary temperature stratification and, accordingly, the cooling efficiency of the discharged heated water.

Based on the analysis of the functional operation of the water intake and water outlet structures made of traditional materials in the existing systems of technical water supply of TPP, NPP and CHP when solving the main tasks of ensuring environmental safety in the water bodies, the domestic results of the innovative constructive direction of high-strength synthetic fabric materials of domestic production used in the creation of the water intake and water distribution structures built and, hereinafter referred to as soft floating structures (SFS) [23,25].

Research results
Based on the results of complex and full-scale studies of soft floating structures (SFSs) of the water observation structure, which is a vertically positioned movable screen of specified shape, the upper
edge of which is attached to the system of the surface floats, the lower edge is attached to the system of the buried floats, which are fixed in plan and in depth water object anchoring devices with flexible connections. The SFS of the water distribution structure, which is installed on the end portion of the heated water discharge into the reservoir, is the cooling reservoir providing a vertically positioned movable screen, the upper edge of which is attached to the system of surface floats, the below perforation is located at a depth (18-20%) with circular diameter holes (25-30 cm) staggered. The lower edge of the vertical movable screen is fixed to the base of the end section of the discharge channel.

Based on the results of the theoretical and experimental studies, the system of calculation equations described by the stress-strain state of SFS as a soft shell in a water flow, which are used to calculate the force (kN / m) and the shape in a movable vertical screen (panel), flexible connections and, accordingly, the anchor devices. For the SFSs of a stream distribution structure, a method for calculating a perforated screen, the optimal percentage of throughput of which is 18–20% is justified.

To ensure the specified functional work for the selection of the estimated water flow from the lower layers of the cooling reservoir (reservoir), the SFS installation site is placed in the open area of the reservoir water area, which allows using the formed hydraulic structure of the currents in the reservoir to drain the bottom and surface fish species both young and adults from the water intake window in the lower part of the vertical movable screen, which provides the necessary speed of water flow $V <0.1$ m / s. The depth mobility and the created shape of the vertical screen ensures stable functional operation when exposed to the wind waves up to 3 m high. The selection of the estimated water flow from the lower layers of the reservoir protection against the ingress of fish into the intake chamber of the pumping station (up to 90%).

The experimental studies on isothermal and thermal physical laboratory equipment of the SFS jet-distribution structure determined the optimal parameters of the penetration percentage (18-20%), the nature of the round holes placement on the vertical movable screen (chess), ensuring the sufficient functional performance of the innovative design compared to the structures of the jet-distribution structures made of the traditional materials.

Summary

On the basis of the constructive-technological studies, lightweight designs of a water intake structure and a distribution structure have been developed to ensure the environmental safety in reservoir-coolers, using the high-strength synthetic fabric materials of domestic production.

The soft floating structure (SFS) of the water intake structure provides the estimated water flow selection of (100 m$^3$/s and more) from the lower layers of the cooling reservoir and the protection of the pump units of the technical water supply system of the TPP, NPP and CHP from penetration of young and adult fish of various kinds with efficiency up to 90%.

The soft floating structure (SFS) of the thermal power plants, nuclear power plants and central heating technical water supply system stream distributing structure ensures the management of the distribution of the heated water on the water surface of the reservoir-cooler, which eliminates its mixing with cold layers.

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