Elements of technical water supply system of pumping units

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Abstract. The ongoing research aims to develop an optimal variant of the industrial water supply scheme, selected based on a comparison of several possible solutions. It is recommended to use a block-by-aggregate technical water supply system at stations equipped with any number of main units with a large flow of the main pumps, more than 5 m^3/s. If there is a significant amount of sediment in the water at the stations, settling tanks are needed at the water intake devices of the technical water supply systems. Filling with water from pumps installed above the source level can be performed using vacuum pumps, ejectors, the self-suction method, using suction pipes with a raised elbow, or storage tanks. The authors investigated a new process water supply system for a large pumping station in Kiziltepa with control devices and a flow meter on the service water supply inlet pipeline. The calculation of the reliability of the operation of the described structures includes a new reliability criterion, which is taken as the turbidity of the flow at the outlet of the settler.

1 Introduction

The need for technically pure water for cooling and lubricating process equipment is relevant for pumping stations and the entire hydropower system. Currently, the requirements for the equipment of the technical water supply system are accepted according to manufacturers' data. In modern conditions, it is necessary to use the recommendations of Uzbek engineers for reconstructing these systems at existing pumping stations (PS) to improve their performance. The authors used the experience of increasing the stability of the operation of the process water supply system of large PSs at the Amubukhara (ABMC) and Karshi (KMC) cascades [1,2]. On these PSs, it is required to regularly flush the sills of horizontal structures, settling chambers, and vertical sand traps. It is necessary to carefully monitor the hydraulic machines, particularly the abrasive wear of the blades and seals, which ensures the serviceability of the entire complex of technological equipment of the stations, the reliability and non-failure operation of the equipment. This is one of the most important indicators of the quality of equipment and the level of its operation.

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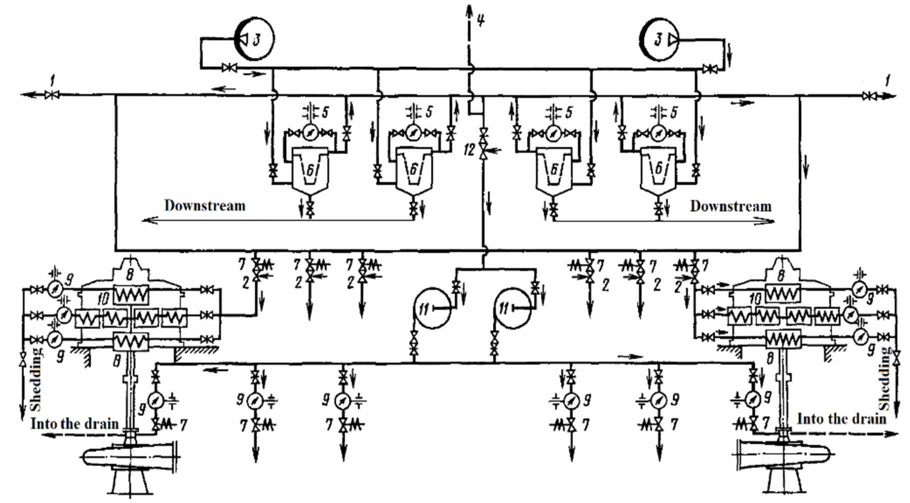
2 Methods

The article uses methods for designing elements of the technical water supply system of pumping units. The methodological foundations of the ongoing research are based on the experience of operating pumping stations, taking into account complex physical phenomena that arise under the conditions of a complex of factors protecting auxiliary pump systems from fin and sediment. Research methods include generalizing available field data using modern technical instruments and published materials for testing experiments on introducing new elements [3, 4].

3 Results and Discussion

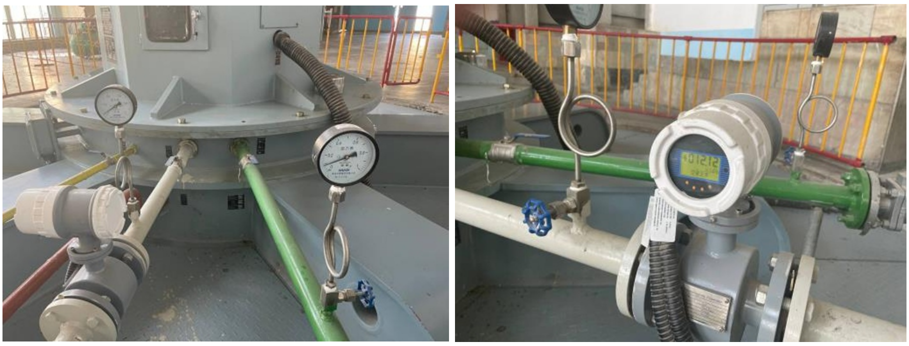
Depending on the number, supply, and power of the main units on the PS, three schemes of technical water supply can be used: centralized, group, and block. As a rule, the centralized scheme is used at medium and large stations with water supplied to this system by special booster pumps with water intake from two pressure pipelines with type B pumps (Fig. 1).



1 is system pipeline; 2 is valve; 3 is water intake from pressure pipelines; 4 is pipeline from special treatment facilities; 5 is measurement of pressure drop in filters; 6 is filters; 7 is latches; 8 is oil coolers; 9 is jet relays; 10 is air coolers of main electric motors; 11 is booster pumps.

Fig. 1. Scheme of technical water supply of large pumping station

The authors studied a new industrial water supply system of the PS Kiziltepa ABMC with pressure gauges on pipelines with valves (Fig. 2a) and a flow meter installed on the inlet pipeline of industrial water supply (Fig. 2b).



a) *b)*

Fig. 2. Service water supply system of Kiziltepa pumping station

Water is taken from the pressure pipelines of the main pumps and purified in two independent groups of strainers connected to a common line. Branches are provided from this line, equipped with electric gate valves, through which water is supplied to the air and oil coolers of the main electric motors (Fig. 3).

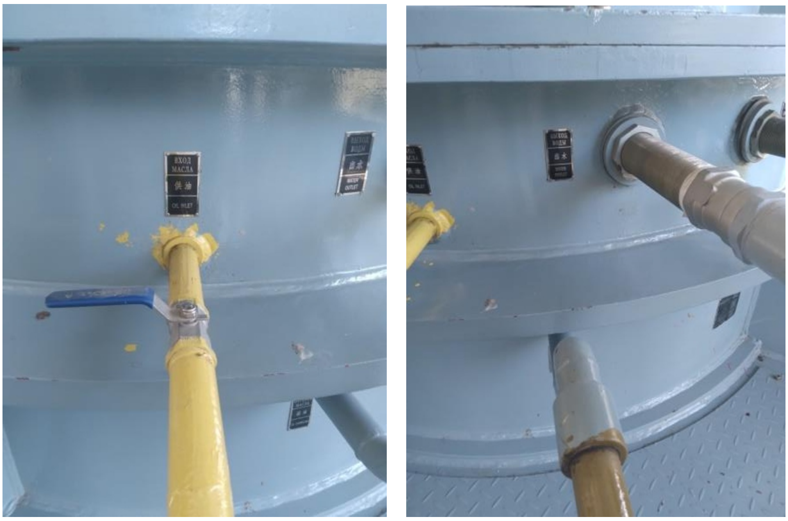


Fig. 3. Electric motor technical support pipelines (oil supply and service water discharge)

According to this scheme, various modifications are possible. For example, you can get a group one by placing valves on the main pipeline instead of a centralized scheme system. Technically, clean water for lubricating the bearings of the main pumps should be taken from a separate sump when pumping contaminated water. Water can be taken not from pressure pipelines but from downstream. In this case, a separate circuit system will take place.

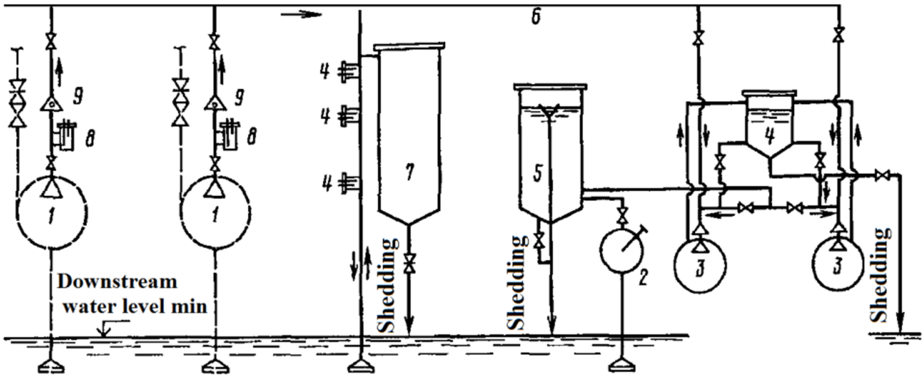
The described scheme is used at stations with any number of units. The group system of technical water supply schemes is used at stations with more than five main units [5, 6]. The authors researched NS with ten pumping units Kiziltepa 82 V 17, V 20-13/45, PS-7 KMC 1600V-10/40, 2400VR-25/25.

In this case, to increase the system's reliability and reduce the unevenness of costs, the circuit system is divided into several groups based on the calculation that each group serves no more than four main units. All groups are autonomous but have a common water intake device.

At large stations, at least two independent water intakes are provided, accessible for cleaning, and equipped with trash screens or coarse mesh. Mesh filters for purifying water from algae and grass are installed near water intakes so that any of them can be cleaned and replaced without disturbing the entire system's operation.

For the service water supply system, centrifugal pumps of types K, KM, and D are used or, with special justification, vertical submersible pumps [7, 8]. The number of pumps must be at least two (one of them is redundant with automatic switching) for a centralized or group scheme. With many main units (five or more), the number of pumps is increased to three. With a block diagram of the technical water supply scheme, it can install one pump per unit, provided that the station has a warehouse with a reserve of 1 ... 2 sets. Install service water pumps below the minimum water level in the source or with an automatic pump primer.

Filling with water from pumps installed above the source level can be performed using vacuum pumps, ejectors, the self-suction method, using suction pipes with a raised elbow, or storage tanks. Pumps using rotary vacuum pumps are poured at pumping stations of any capacity. With frequent starts (several times a day), it is recommended to use vacuum boilers in vacuum systems, which ensure that the pumps are constantly flooded with water and ready for start-up (Fig. 4).



1 is main pumps of the system; 2 is vertical sump pump; 3 is vacuum pumps; 4 is water separator of the vacuum pump; 5 is pouring vertical sump; 6 is air line; 7 is vacuum boiler; 8 is level indicator; 9 is air release valves.

Fig. 4. Scheme of centralized filling of pumps

It is advisable to prime the pumps with the help of water-air ejectors at a relatively low suction height of up $h_{v\max}$ to 2.5 m). To feed the ejectors, it is recommended to use water from pressure pipelines or from a special high-pressure pump.

At stations where the constant operation of one unit is provided, the so-called auto-suction method can be used. In this case, the suction pipe of the running pump is connected to the pipe of the non-working pump, creating the necessary vacuum in it. Supply of vacuum pumps

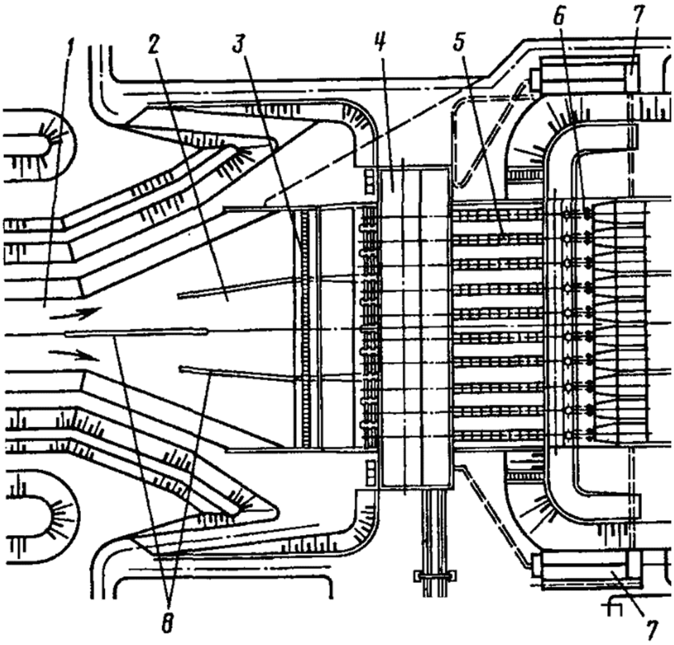
$$Q = H_{ch} WK / T\left(H_a - h_{v\max}\right) \qquad (1)$$

where H_{ch} is the water level in the fore-chamber, m; Q is the volumetric flow rate of liquid through the pump, m^3/s; T is time, s.

The coefficient K is selected from the condition of obtaining a minimum relative velocity of fluid entry into the impeller. There is no fin protection in this scheme. During operation, a combined debris protection device of the water intake structure is used [9, 10].

The optimal variant of the industrial water supply scheme should be selected based on comparing several possible solutions [11, 12].

A block (by unit) process water supply system is used at stations equipped with any number of main units with a main pump flow of more than 5 m^3/ s. If there is a significant amount of sediment in the water, sedimentation tanks are required at the stations [13,14]. Industrial water supply systems include water intakes and settling tanks (Fig. 5).



1 is supply channel; 2 is fore-chamber; 3 is trash-retaining facilities; 4 is building; 5 is pressure pipeline; 6 is outlet structure; 7 is sump of the technical water supply system; 8 is guide walls.

Fig. 5. Layout of the pumping station facilities.

A modernized sump of the technical water supply system was made at the PS Kiziltepa [15,16]. Three reinforced concrete galleries run under the bottom of the sedimentation tanks, supplying water to three units (Fig. 6).

Fig. 6. Settling tanks for technical water of PS Kiziltepa.

In the buildings of the National Assembly, vertical sedimentation tanks are used, which are called sand traps in operation (Fig. 4). The cross-sectional area of the vertical settler includes the area of ω_0 the settling zone and the area of the flocculation chamber. The area of the sedimentation zone should be determined by the formula:

$$F = \beta Q \omega_0 \tag{2}$$

where β is the coefficient of volumetric use of the sump, taken within 1.3-1.5 (the lower limit is for the ratio of diameter to height 1.0, the upper limit is for the ratio 1.5). The height of the sedimentation zone is taken in the range of 4 to 5 m, and the ratio of the diameter of the sump to the height of its sedimentation zone is not more than 1.5.

The calculation of the reliability of the operation of the described nano-conveying structures and settling tanks includes a new reliability criterion for which the turbidity of the flow at the outlet of the settling tank is taken [17, 18]. The length of sediment sedimentation is determined by the equation of sedimentation dynamics:

$$L = \frac{VH}{\vartheta_{part}} \frac{\rho_{in} - \rho_{fin}}{\rho_{in} - \rho_{cr}} \tag{3}$$

where V, H are the average speed and depth of the flow; ϑ_{part} is velocity of fall of sediment particles in turbulent flow; $\rho_{in,}\rho_{fin}$ are initial and final turbidity of the flow at the inlet and outlet of the settler; ρ_{cr} is critical flow turbidity in the settler, corresponding to its transporting capacity and determined based on the formulas:

$$q_{bot} = \rho_r q_{bot} \mathrm{P}_{mob} \overline{D}^2_{\partial в} \frac{\tau_c - \overline{D}_{mob} / \overline{U}_\Delta}{t_\Delta - D_{mob} / \overline{U}_\Delta} \cdot \frac{\ell_{bot}}{t_{bot}} \cdot \frac{\nu_w}{U_c} \tag{4}$$

$$q_{susp} = \rho_r \, \mathrm{P}_{susp} q_{mob} \, \overline{D}_{susp} \overline{D}_{mob} \frac{\tau_c - \overline{D}_{mob} \,/\, \overline{U}_\Delta}{t_\Delta - D_{mob} \,/\, \overline{U}_\Delta} \cdot \frac{\ell_{susp}}{\tau_c} \cdot \frac{\nu_w}{\overline{U}_\Delta} \qquad (5)$$

where q_{bot}, q_{susp} are limiting weight consumption of bottom and suspended sediments; ρ_{chan} is channel sediment density; $\overline{D}_{mob}$, $\overline{D}_{susp}$ are average sizes of mobile and suspended soil fractions; P_{mob}, P_{susp} are relative weight content of mobile and suspended soil fractions; $\overline{U}_\Delta$ is average bottom flow velocity; ℓ_{bot}, ℓ_{susp} are length of jumps of bottom and suspended sediments during the time t_{bot}; t_Δ is particle shedding duration; $\tau_{c.}$ is duration of emissions of the longitudinal component of the bottom velocity $\overline{U}_\Delta$; ν_w is particle weighing frequency.

Based on analytical, full-scale, and model studies, the obtained dependencies of the transporting capacity for the modernization of the operation of the head settling tanks of the inlet channels of the PS make it possible to increase the efficiency of controlling the irrigation system operation [19-23].

4 Conclusions

1. Currently, the requirements for the equipment of technical water supply systems of pumping stations are increasing. The need for technically pure water for cooling and lubricating process equipment is relevant for pumping stations and the entire hydropower system. In modern conditions, recommendations are being developed for reconstructing these systems with thresholds in horizontal structures, sedimentation chambers, and elements of vertical sand traps at existing pumping stations.

2. The authors investigated a new process water supply system for a large pumping station in Kiziltepa with control devices and a flow meter on the service water supply inlet pipeline. The described process water supply scheme is used at stations with more than five main units. In this case, to increase the system's reliability and reduce the unevenness of costs, the system is divided into several groups based on the calculation that each group serves no more than four main units.

3. The calculation of the reliability of the operation of the described nano-conveying structures and settling tanks includes a new reliability criterion, which is taken as the turbidity of the flow at the outlet of the settling tank. The sedimentation length is determined by the equations of sedimentation dynamics.

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