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Surface telescopic water intake: A review

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Abstract:

The scope of use of surface telescopic water intake at various water sources had explored. Working conditions of the vertical telescopic water intake in reservoirs, were analyzed. The effectiveness of the use of this hydra technical structure in large and medium reservoirs has been established. The influence of all possible factors on the operation of vertical telescopic intake in the reservoir was studied. An analysis of the effective use of vertical telescopic water intake in a lake was conducted. All possible factors acting on the water intake in the lake were studied and the most optimal location of the hydraulic system was proposed. The working conditions of vertical telescopic water intake in rivers and mountain rivers were studied. The advantages and disadvantages of using vertical telescopic water intake in this type of reservoirs are established. The features of the vertical telescopic water intake in the channels were studied.

1 Introduction

Surface water intakes are used to take water from a source and supply it to consumer needs, such as hydropower, drinking and domestic water supply, industrial needs and irrigation. Water sources for the above purposes may vary. In general, the main sources of water supply can be storage reservoirs, lakes, large and medium-sized reservoirs, rivers, etc.

The source of water supply must provide a stable supply of water for the entire period of water supply. The water in the source of water supply must meet the quality requirements of the consumer.

Vertical telescopic water intake is designed to take water from the top layers, which are free of sediments. This working feature of telescopic water intake increases the quality of water taken by intake and reduces cost for purification. This structure can provide constant flow and temperature of water despite of water level fluctuations in the water source. Vertical telescopic water intake is applicable to use in reservoirs, lakes, rivers and main channels [1].

Vertical telescopic water intake has certain operational restrictions, such as limited operation depth and stability. The operation depth of telescopic water intake cannot be less than the critical submergence depth for this particular structure, and cannot be higher than the depth ensuring [2]. Active ice drift and intensive movement of ships negatively affect structural stability of telescopic water intake.

Considering above-mentioned working features telescopic water intake, research has been carried out to investigate working efficiency of this intake in different types of water supply sources. Available information from the literature review revealed benefits and drawbacks of telescopic water intake installation in each type of water supply sources. The purpose of this study is to analyze effectiveness of use of vertical telescopic water intake in four different types of water supply sources. This study also aims to enrich available data in the literature on working conditions of telescopic water intake in order to reach a better understanding of its behavior.

2 Water intake facilities

In this paper, the use of vertical telescopic water intake in 4 sources of water supply was considered. The advantages and disadvantages of using this water intake facility in each type of reservoirs separately were studied.

2.1 Features of water intake from storage reservoirs

The conditions for water intake in storage reservoirs are significantly different from the rivers in their natural state [31]. The construction of the reservoir makes serious changes to the natural hydrological state in the river. Fluctuation of water levels in the reservoir are different from the river flow regime. When taking water from closed water bodies such as reservoirs and lakes, a number of factors should be taken into account, such as the effects of waves generated by wind and ship movements, changes in water levels, currents along the coast, ice formation, etc.

Basically, water intakes built on reservoirs are of two types: combined with a dam structure and separate.

While choosing a place for water intake, one should be guided by the conditions of hydrology, topography, and geology, and the following specificity requirements of reservoir dynamics:

– place for vertical telescopic intake should have a water quality that meets consumer requirements;

– the chosen place should be free from ice slush and active ship traffic;

– the leeward side is the most favorable for the location of the intake.

While studying water intake in reservoirs, it was found that the outfall of large bays is the most optimal place for water intake, in case if it is protected from the formation of large waves; in the place of capes, consisting of rocky soils, in places free of sediment deposits. If the capes are composed of erosive soils, then they quickly turn into a wide beach with stability, which prevents further erosion of the coast. The need to shift the structure of water intake from the coast arises in the event of water turbidity in the coastal zone and erosion of the coast with the formation of large waves. In this case, the design of the vertical telescopic intake can be installed at the required distance from the shore for water intake from the upper layers without turbidity and sediment.

The depth of the reservoir plays a significant role in choosing the design of a vertical telescopic intake. Because this design solution is most effective at medium and large depths.

2.2 Water intake facilities on lakes

The principle of water intake from a lake is similar to that of reservoirs. The lake has a natural origin in contrast to the reservoir.

Constantly increasing water needs are often met or overcome through the use of lakes as a source of water supply [1]. For this purpose, reservoirs are also being built to accumulate water during high-water periods of the year and continue to provide uninterrupted water supply to settlements and agriculture during periods of water shortage.

The use of fresh lakes for water supply of settlements and industrial enterprises is under widespread. In lakes, the water level is more stable and fewer fluctuations are observed in contrast to reservoirs [4].

There are three groups of lake water intakes: water intakes from small lakes, from large and deep, from wide lakes of small depth.

Telescopic water intake facilities should be used on lakes and bodies of water with a large change in water level and sufficient depth. At shallow depths, use of telescopic column will not be effective for several reasons. Firstly, the shallow depth does not provide the minimum critical submergence depth of intake for the collection of large volumes of water [2]. Secondly, water bodies of small depth do not have a large temperature difference throughout the depth; therefore, water intake from the surface makes no sense [14].

In case of water intake construction on a large lake of small depth, it is removed from the coast to the required distance in order to obtain the necessary depth. In this case, the use of vertical telescopic water intake is most effective.

2.3 Water intake facilities on rivers

The main tasks while taking water from rivers are to prevent large sediment from entering the water intake structure and to ensure a continuous supply of water [20]. This task is more dependent on the hydrological conditions of the river at the water intake location. Generally, increasing the efficiency of water intake requires a complex of adjustment and protective works in the river channel at the water intake site. Such works have a number of specific details and features that are different for damless and dam water intakes.

Mountain rivers differ significantly from the plain ones by dynamics of the flow. [6] The main feature of mountain rivers is uneven flow both daily and throughout the year. Regulation of flow through the construction of reservoirs is difficult due to the large number of bottom and suspended sediments. Since these sediments quickly fill up the reservoir. Water intakes constructed on mountainous sections of rivers require the use of special devices to protect against floating waste and sediment of various shapes. Special design solutions for water inlets are required for water intake from mountain rivers, taking into account the peculiarities of their hydrological regime. The high flow rates of mountain rivers caused by significant longitudinal slopes of the channels lead to various deformations of the coasts. Ice phenomena and the formation of sludge greatly complicate water intake and require the application of protective devices.

Above-mentioned properties of the hydrological regime of mountain rivers introduce specific features into the layout and design of water intakes [23]. For example, high turbidity of water requires the inclusion of primary sedimentation tanks as part of the site of water intake structures. Special protective structures to protect the water intake from destruction are provided on rivers where mudflows are observed.

Permafrost areas may have different environmental conditions, but they are all united by the severity of the climate and the presence of permafrost [16]. Most structures of water intake facilities are not able to work in such conditions due to their inconsistency with the natural conditions of the North.

The rivers of small and medium sizes have a factor of freezing in the winter time every year. Some middle rivers freeze only during years of severe frost or for a short period of the winter. Rivers of permafrost areas are subdivided according to the conditions of water intake into the following:

– large rivers have a depth greater than the depth of freezing and provide continuous water supply throughout the year;

– medium non-freezing rivers maintain ice flow throughout the winter. This allows water to be taken from these rivers without flow regulation by filtering or infiltration water intakes;

– rivers of small and medium sizes keep at the bottom of the zone with a positive water temperature. Such rivers allow limited water intake through filtering under-water intakes;

– small rivers freeze along with the underlying aluvium. In such rivers, water intake is possible only with flow control.

2.4 Water intake facilities on canals

Very often consumers take water from sources located at a great distance from them [29]. Open channels can be used to solve this problem and transport water to the place of its use. Such channels, due to their large lengths, are called main canals. According to their parameters and depth, they are suitable for placing a vertical telescopic intake. The intake of water from a canal is similar in principle to the water intake from a river.

In case of water intake from a transit channel, water intake facilities are located directly on the shore [30]. In general, they consist of a bucket that connects the channel with the water intake, and the water intake itself, from which water is drawn in by the suction pipes of the pumps. This type of water intake is used for water intake at small and medium capacity stations.

However, use of vertical telescopic intake directly in the channel will reduce the cost and simplify the design of the water intake.

3 3.1 Working conditions

3.1 Working conditions of vertical telescopic water intake on storage reservoirs

Construction of a vertical telescopic water intake does not require large preparatory work and the construction of additional hydro technical structures. (Fig. 1.)

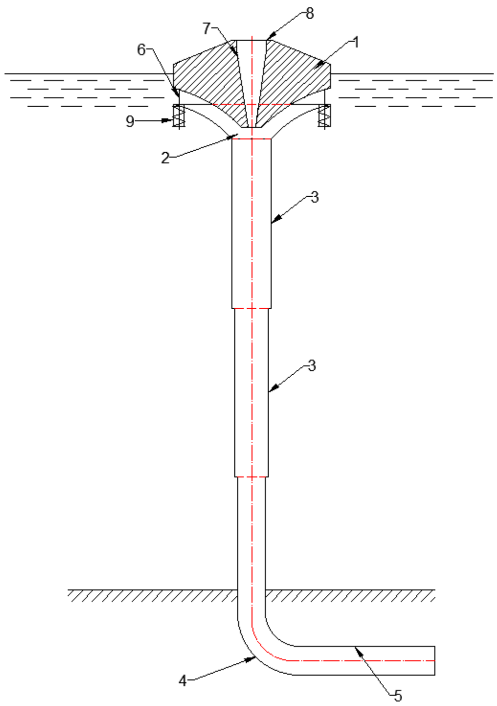

Fig. 1. Vertical telescopic water intake: 1- floatation pontoon, 2- inlet funnel, 3- telescopically connected pipes (tapering downward), 4- elbow, 5- discharge pipe, 6- connecting elements, 7- air supply conical tube, 8- protrusions, 9- springs.

Construction of water intake facility combined with a dam assembly is effective if acceptable according to customer requirements. The advantage of this design solution is that in this case a vertical telescopic water intake can be used, which can also serve as a spillway or outlet, this solution can reduce the cost of constructing a water intake structure, in addition, it becomes possible to take water of the best quality from the most favorable levels. Design patterns of water intake facilities depend on the type of dam. The use of concrete dams significantly simplifies the design of the intake structure. The design of the water intake is getting more complicated in case of using earthen and stone dams.

Considering above mentioned features of water intake from the reservoir, the use of a telescopic surface water intake is effective in case of integration with dam hydraulic system or separated, if optimum depth for its operation is ensured.

3.2 Working conditions of vertical telescopic water intake on lakes

In case of water intake construction on a large lakes of small depth, it is removed from the coast to the required distance in order to obtain the necessary depth. In this case, the use of vertical telescopic water intake is most effective.

Considering all features of water intake from lakes, surface water intake of the telescopic type is effective for this type of water body. Use of this structure will be most optimal on large and medium-sized lakes while providing the necessary depth for work. The height of the waves caused by the wind and the movement of vessels should be taken into account while choosing a place for water intake. When taking water from the lake, ice formation should also be considered.

The main advantage of using a telescopic water intake in a closed reservoir is the temperature stability of the water taken. Since there are almost no undercurrents and other processes in a closed body of water that affect the mixing of waters of different layers, the temperature of the water on the surface of the water body always remains the highest. The surface layer of water has a high temperature due to interaction with environment, warming up by sunlight, evaporation from the water surface, etc. The intake of heated water is important for irrigation of crops, because low temperatures of irrigated water can significantly reduce their fertility.

3.3 Working conditions of vertical telescopic water intake on rivers

Given the above features of the rivers, the telescopic water intake will most effectively work on the flat sections of the rivers. A place for the location of water intake should be chosen in the area with minimum flow rates, in areas with minimal suspended sediment. It is also necessary to ensure the stability of the waterworks taking into account the pressure of the moving water masses and the pressure from the possible formation of ice. Due to these reasons, it is not recommended to place telescopic surface water intake in permafrost areas because of abundant ice drift. This will require additional measures to ensure stability, which can lead to a significant increase in the cost of the structure and its economic inefficiency. In general, the use of telescopic water intake for water supply on mountain rivers will not be effective. Because mountain rivers generally have high-speed bubbling streams containing sediments of different sizes and shapes. Telescopic water intake is not designed to work in such conditions.

3.4 Working conditions of vertical telescopic water intake on canals

The design of the vertical telescopic intake allows to take big volumes of water. To prevent sediment, water intakes are equipped with trash racks. The size and design of the gratings should be chosen taking into account the maximum particle size that the water intake can consume without disturbing its operation.

The principle of operation of the vertical telescopic water intake in the main canal is similar to its work in the river. Such a constructive solution will allow you to effectively take water from the channel.

4 Conclusion

In this research, the use of vertical telescopic intake in 4 water sources of various types was reviewed. Study on the expansion of the scope of vertical telescopic water intake was carried out. The following conclusions were obtained as a result of this study:

1. It has been established that a vertical telescopic water intake can be used in a reservoir while ensuring sufficient operation depth. The main factors affecting the water intake in this reservoir were identified and the most favorable location for its installation was determined. The possibility of using the water intake together with a dam of various types or separately from it.
2. The operation of the vertical telescopic water intake in the lake was studied. It has been established that the principle of operation of this hydraulic system in the lake is similar to the conditions in the reservoir. The advantages of using vertical telescopic water intake in a closed reservoir are identified.
3. The work of vertical telescopic water intake in rivers was investigated. The effectiveness of use of this water intake on the flat sections of the rivers is revealed. Design flaws of vertical telescopic water intake on mountain rivers and in permafrost areas have been identified.
4. The operation of the vertical telescopic water intake in the conditions of the main canals was studied. It has been established that the principle of operation is similar to the intake of water from rivers on a flat site and, if sufficient depth is provided, the vertical telescopic intake can work effectively in such a reservoir.

References

1. Avakyan A.B., Lebedeva I.P. Reservoirs of the twentieth century as a global geographical phenomenon. Bulletin of the Russian Academy of Sciences. Geographical series. 2002. 3. Pp. 13-20. URL: https://cyberleninka.ru/article/n/issledovanie-donnyh-otlozheniy-chiryurtskogo-vodohranilischa-s-tselyu-ih-ispolzovaniya-pri-rekultivatsii-zemel-posle-tehnogennogo (date of application: 10.02.2021).
2. Anwar H.O. Prevention of vortices at intakes. Water Power. 1968. (October). Pp. 393-401.
3. Urazmetov I.A. Hydrology of rivers: a manual. Kazan: Publishing House. 2007. 95 p. URL: https://kpfu.ru/portal/docs/F1216016683/Uchebnoe.posobie.Gidrologiya.rek.pdf (date of application: 10.02.2021).
4. Anne R., Korkka-Niemi, Kirsti Boreal. Environment Research. 2011. 16(5) Pp. 363-380.
5. The United Nations World Water Development Report 2018. Nature-based Solutions for Water. Paris, UNESCO. Paris, UNESCO, 2018. ISBN:978-92-3-100264-9. 139 p.
6. Loginov G.I., Hydraulic processes during water intake from small mountain rivers, 2nd edition, revised and supplemented. Bishkek. 2014. 195 p. URL: http://lib.krsu.edu.kg/uploads/files/public/5878.pdf (accessed 10.02.2021).
7. Johnson, P.L. Hydro-Power Intake Design Considerations. Journal of Hydraulic Engineering. 1988. 114(6). Pp. 651–661. DOI:10.1061/(asce)0733-9429(1988)114:6(651). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9429%281988%29114%3A6%28651%29 (date of application: 10.02.2021).
8. Khan, L.A., Wicklein, E.A., Rashid, M., Ebner, L.L., Richards, N.A. Computational fluid dynamics modeling of turbine intake hydraulics at a hydropower plant. Journal of Hydraulic Research. 2004. 42(1). Pp. 61–69. DOI:10.1080/00221686.2004.9641184. URL: https://www.tandfonline.com/doi/abs/10.1080/00221686.2004.9641184 (date of application: 10.02.2021).
9. Huang C.C., Lai J.S., Lee F.Z., Tan Y.C., Physical Model-Based Investigation of Reservoir Sedimentation Processes. Water. 2018 10(4). 352 p.
10. Ven te Chow: A compendium of water resources technology. Handbook of applied hydrology. McGraw-Hill Book Company, 1964. 1468 p.
11. WMO: Guide to hydrological practices. Third edition. WMO No. 168, Secretariat of the World Meteorological Organization, Geneva, Switzerland, 1974. 302 p.
12. Wang, Y., Odgaard, A.J., Melville, B.W., Jain, S.C. Sediment Control at Water Intakes. Journal of Hydraulic Engineering. 1996. 122(6). Pp. 353–356. DOI:10.1061/(asce)0733-9429(1996)122:6(353). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9429%281996%29122%3A6%28353%29 (date of application: 11.02.2021).
13. Zahabi, H., Torabi, M., Alamatian, E., Bahiraei, M., Goodarzi, M. Effects of Geometry and Hydraulic Characteristics of Shallow Reservoirs on Sediment Entrapment. Water. 2018. 10(12). Pp. 1725. DOI:10.3390/w10121725. URL: http://www.mdpi.com/2073-4441/10/12/1725 (date of application: 11.02.2021).
14. Abbasi, A., Annor, F., van de Giesen, N. Investigation of Temperature Dynamics in Small and Shallow Reservoirs, Case Study: Lake Binaba, Upper East Region of Ghana. Water. 2016. 8(3). Pp. 84. DOI:10.3390/w8030084. URL: http://www.mdpi.com/2073-4441/8/3/84 (date of application: 11.02.2021).
15. Ferrara, V., Erpicum, S., Archambeau, P., Pirotton, M., Dewals, B. Flow field in shallow reservoir with varying inlet and outlet position. Journal of Hydraulic Research. 2018. 56(5). Pp. 689–696. DOI:10.1080/00221686.2017.1399937. URL: https://www.tandfonline.com/doi/abs/10.1080/00221686.2017.1399937 (date of application: 11.02.2021).

16. Richard, M., Morse, B. Multiple frazil ice blockages at a water intake in the St. Lawrence River. Cold Regions Science and Technology. 2008. 53(2). Pp. 131–149. DOI:10.1016/j.coldregions.2007.10.003.
17. Walski, T.M., Condra, J.S., Cable, K. Procedure for Estimating Surface-Water Intake Costs. Journal of Environmental Engineering. 1984. 110(2). Pp. 381–391. DOI:10.1061/(asce)0733-9372(1984)110:2(381). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9372%281984%29110%3A2%28381%29 (date of application: 11.02.2021).
18. Chang, H.H., Stow, D. Mathematical Modeling of Fluvial Sand Delivery. Journal of Waterway, Port, Coastal, and Ocean Engineering. 1989. 115(3). Pp. 311–326. DOI:10.1061/(ASCE)0733-950X(1989)115:3(311). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-950X%281989%29115%3A3%28311%29 (date of application: 11.02.2021).
19. Yasi, M., Hamzepouri, R., Yasi, A. Evaluation of Sediment Transport Rate in Coarse-Bed Rivers. 2010. Pp. 834–843. DOI:10.1061/41147(392)83. URL: https://ascelibrary.org/doi/10.1061/41147%28392%2983 (date of application: 11.02.2021).
20. Johnson, J.C., Ettema, R. Passive Intake System for Shallow Sand-Bed River. Journal of Hydraulic Engineering. 1988. 114(6). Pp. 662–674. DOI:10.1061/(asce)0733-9429(1988)114:6(662). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9429%281988%29114%3A6%28662%29 (date of application: 11.02.2021).
21. Michell, F., Ettema, R., Muste, M. Case Study: Sediment Control at Water Intake for Large Thermal-Power Station on a Small River. Journal of Hydraulic Engineering. 2006. 132(5). Pp. 440–449. DOI:10.1061/(ASCE)0733-9429(2006)132:5(440). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9429%282006%29132%3A5%28440%29 (date of application: 11.02.2021).
22. Nakato, T., Ogden, F.L. Sediment Control at Water Intakes along Sand-Bed Rivers. Journal of Hydraulic Engineering. 1998. 124(6). Pp. 589–596. DOI:10.1061/(asce)0733-9429(1998)124:6(589). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9429%281998%29124%3A6%28589%29 (date of application: 11.02.2021).
23. Wang, Y., Odgaard, A.J., Melville, B.W., Jain, S.C. Sediment Control at Water Intakes. Journal of Hydraulic Engineering. 1996. 122(6). Pp. 353–356. DOI:10.1061/(ASCE)0733-9429(1996)122:6(353). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9429%281996%29122%3A6%28353%29 (date of application: 11.02.2021).
24. Walski, T.M., Condra, J.S., Cable, K. Procedure for Estimating Surface-Water Intake Costs. Journal of Environmental Engineering. 1984. 110(2). Pp. 381–391. DOI:10.1061/(asce)0733-9372(1984)110:2(381). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9372%281984%29110%3A2%28381%29 (date of application: 11.02.2021).
25. Sharp, J.J., Parchure, T.M. Critical Submergence in Two-Layer Stratified Flow. Journal of Hydraulic Engineering. 1991. 117(7). Pp. 924–928. DOI:10.1061/(ASCE)0733-9429(1991)117:7(924). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9429%281991%29117%3A7%28924%29 (date of application: 11.02.2021).
26. Johnson, P.L. Hydro-Power Intake Design Considerations. Journal of Hydraulic Engineering. 1988. 114(6). Pp. 651–661. DOI:10.1061/(asce)0733-9429(1988)114:6(651). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9429%281988%29114%3A6%28651%29 (date of application: 11.02.2021).
27. Ho, J., Coonrod, J., Gill, T., Mefford, B. Case Study: Movable Bed Model Scaling for Bed Load Sediment Exclusion at Intake Structure on Rio Grande. Journal of Hydraulic Engineering. 2010. 136(4). Pp. 247–250. DOI:10.1061/(asce)hy.1943-7900.0000149. URL: https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29HY.1943-7900.0000149 (date of application: 11.02.2021).

28. Sharp, J.J., Parchure, T.M. Selective Withdrawal Using Circular, Partly Submerged Intake Structures. Journal of Hydraulic Engineering. 1993. 119(5). Pp. 615–627. DOI:10.1061/(ASCE)0733-9429(1993)119:5(615). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9429%281993%29119%3A5%28615%29 (date of application: 11.02.2021).
29. Dixon, R.M., Peterson, A.E. Water Infiltration Control: a Channel System Concept. Soil Science Society of America Journal. 1971. 35(6). Pp. 968–973. DOI:10.2136/sssaj1971.03615995003500060033x. URL: http://doi.wiley.com/10.2136/sssaj1971.03615995003500060033x (date of application: 11.02.2021).
30. Warburton, J. Observations of bed load transport and channel bed changes in a proglacial mountain stream. Arctic & Alpine Research. 1992. 24(3). Pp. 195–203. DOI:10.2307/1551657.
31. Gelda, R.K., Effler, S.W. Simulation of Operations and Water Quality Performance of Reservoir Multilevel Intake Configurations. Journal of Water Resources Planning and Management. 2007. 133(1). Pp. 78–86. DOI:10.1061/(asce)0733-9496(2007)133:1(78). URL: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9496%282007%29133%3A1%2878%29 (date of application: 11.02.2021).