LAYOUT OF MONITORING AND MEASURING INSTRUMENTS 
IN HYDRAULIC STRUCTURES

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Problems of the safety and reliability of water-raising hydraulic structures (dams) have been discussed widely by the engineering community in recent years. Many useful suggestions, recommendations, and critical comments were expressed in a series of articles published by the journal "Gidrotekhnicheskoe Stroitel'stvo" (No. 12, 1993).

Problems of the safety of dams and other hydraulic structures are quite urgent. They are closely related to the state of the economy and management system of the sector as well as to legislation, the environment, and other aspects.

We will touch briefly on the question of the significance of on-site observations with the use of information of monitoring and measuring instruments (MMIs) in providing safety of hydraulic structures. The information obtained from MMIs is the primary source for evaluating the state and safety of structures.

The building codes and other standards establish the requirements with respect to the number and types of MMIs for structures of various importance classes as well as the requirements on the need to develop the layout of MMIs, composition, and program of observations.

Rather many instruments, numbering in the thousands, able to issue necessary and sufficiently complete information about the behavior of structures are installed according to the layout of MMIs at hydraulic structures. However, when the structures come under a head and their operation begins, it is found that a considerable number of the instruments installed in the structures are inoperable for various reasons. We will give some data.

At the Kolyma hydrostation as of February 1991, 762 of the 2216 MIIs installed were in an operating state, i.e., 34%; on the earth-and-rock dam 398 of the 907 installed instruments operated, or 44%. In connection with this, of the five sites in the dam equipped with MMIs, it became impossible to obtain complete information from a single site. Additional holes drilled in the left-bank abutment of the dam in connection with emergency situations that occurred in 1988 and 1989 were equipped with additional MMIs; and due to them it was possible to improve the situation with information about the behavior of the dam.

At the Sayano-Shushenskoe hydrostation 20% of the instruments did not work, 42% of them failed through the fault of the builders and 50% due to their poor quality [1]. About 800 instruments were installed in the dam of the Vilyui 1 and 2 hydrostations, after 10 years of operation about 70% of the instruments were in an operable state [2].

Among certain specialists there was (and possibly there still is) the opinion that the low technological level of construction and the builders’ poor understanding of the role of MMIs are the reasons why a considerable part of the MMIs is disrupted during construction. We can agree with this, but only partially. Practice shows that during construction of structures the MMIs are installed in almost the full number specified by the plans. It is possible to provide preservation and performance of the MMIs far from completely.

Here the causes lie not only in the level of construction but also in the unsatisfactory quality of the design documents with respect to the arrangement of the MMIs. This was validly brought up for the first time on the pages of the journal in the article by engineers V. I. Bryzgalov and V. A. Stafievskii [1]. We share many assessments of the article’s authors concerning the quality and content of the design documents with respect to MMIs as well as suggestions on improving their quality and organizational measures to provide safety and reliability of hydraulic structures.

The experience of realizing the layout of MMIs at the construction of the Kolyma hydrostation showed that the main problem is preservation of the MMIs and cable lines during construction and temporary operation. The long time of building the structures with division into phases and start-up complexes were not taken into account and were not reflected in the layout of the MMIs. The layout of the MMIs was worked out in the usual way. The leading research organization issues
suggestions (recommendations) on the selection, number, and arrangement of the MMIs in the structures. The design organization conscientiously displays these recommendations in the drawings-layouts of the MMIs; the specifications for the instruments, cables, and additional materials are drawn up and on this the development of the design ends. The sketchy character of the design documents leads to mass loss of MMIs. We will give several examples.

Transducers measuring stresses in the reinforcement were installed in the reinforced-concrete roof of the draft tubes. According to the construction plan the bulk of the rock in the tubes was mined after concreting the roof. As a result of blasting to loosen the rock below the roof, the transducers and cable lines were put out of commission. The cable lines from the MMIs in the gate room and headrace tunnel of the first phase of the hydrostation were also destroyed by blasting. If the technology and sequence of construction and installation works and organization of construction and works performance plan determined by the design were taken into account when developing the working drawings of the layout of the MMIs, it would have made no sense to install MMIs in the roof of the draft tubes and other structures. During filling of the reservoir of the second phase, which occurred at a high rate (up to 3 m/day), the rock fill of the upstream shoulder received considerable deformations, as a result of which all MMIs embedded in the upstream shoulder failed. This probably occurred due to breaking the electrical cables.

Another example. The cable lines from the temperature transducers installed in the sides and bottom of the temporary outlet were brought out to the open surface and wound into a coil, where they should have been stored for many months without any protection and guarding until it was possible to lay them along a permanent route. Preservation of this cable was possible only with the organization of a 24-hour guard post in the open air in the zone of dangerous conduction of blasting operations or construction of some protective guard structures (devices). The plans of the MMIs did not provide for any protective measures, designs, and means to ensure preservation of the MMIs.

Underestimation of the importance of the problem of preservation when working out the layout of MMIs leads to large losses. Instead of a serious analysis, determination, and elimination of the true reasons why a considerable part of the installed instruments is lost, the customer and design organization take the easiest but hopeless path: in all instances they write streams of letters with complaints to the general contractor.

The solution of the problem is seen mainly in a radical and qualitative improvement of the layout of the MMIs and in the development and refinement of organizational and legal provisions regulating matters of the safe and reliable operation of dams.

The quality of the layout of MMIs can be improved, in our opinion, by developing a standard "Guide to the Design of Systems Monitoring the Safety and Reliability of Hydraulic Structures of Hydroelectric Stations" mandatory for all participants of the investment process.

All experience gained in the design, construction, and operation of hydraulic structures with respect to providing reliable and safe operation should be generalized in the Guide. The requirements imposed on the design documents with respect to the layout of MMIs as the primary source of information for diagnosing the state of structures should be clearly defined and presented.

The layout of MMIs should be worked out with consideration of the technological sequence, time of constructing individual members of the structures, and methods of performing the construction and assembly works.

Main attention must be devoted to problems of the reliability and preservation of the MMIs. Cable lines should be laid along safe routes: in special galleries, shafts, reinforced-concrete flumes, pipes, and other structures making it possible to preserve the instruments and cables from possible damages during their entire service life.

Temporary and permanent observation panels should be located in places convenient for servicing and should be proved with convenient approaches. Laying of bundles of cables in a loam facing or core along the flow from the upper to the lower pool can serve as a source of dangerous concentrated seepage of water. The Guide should give reliable design techniques precluding such possibility and confirmed by practice.

The aforementioned methods will require certain expenditures, but they will be justified. It is better to install fewer instruments but provide their reliability and preservation than to lose irretrievably tens of kilometers of electrical cable and hundreds of instruments.