RESULTS OF INSPECTION OF WATER-DEVELOPMENT WORKS AT
THE KRASNOYARSK HYDROELECTRIC POWER PLANT

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The water-development works at the Krasnoyarsk hydroelectric power plant were inspected during the period from 12-16 April 1999 in conformity with the "Inspection schedule for water-development works at electric power stations, branches, and subsidiaries of the joint-stock company "EES Rossii" in 1999," and the organization of the inspection of their condition was verified in accordance with the volume of requirements regulated by the "Position on the branch inspection system for the safety of water-development works at electric power stations." The inspection was conducted by a commission composed of leading specialists from the publicly owned joint-stock companies Lengidroproekt and VNIIG im. B. E. Vedeneeva, the Saint Petersburg Design and Technology Office "Lengidrostal'," the Krasnoyarsk Architectural and Construction Academy, and the publicly owned joint-stock company SibVNIIG, as well operational and power-inspection services.

General Information on the Hydroelectric Plant and a Brief Characterization of the Water-Development Works. The Leningrad Division of the S. Ya. Zhuk Design-Survey and Scientific-Research Institute "Gidroproekt" was the general designer for the hydroelectric power plant. The Krasnoyarsk hydroelectric plant was placed in commercial service on 26 July 1972. The reservoir behind the plant is regulated on a seasonal basis. The elevation of the normal support level is 243 m, the actual flood level is 245 m, and the low-water level is 225 m. The following are component parts of the water-development works: concrete gravity dam; powerhouse; inclined canal lift; and, high-head hydraulics laboratory (not currently in operation). All structures are referred to as Class I. The water-passing structures of the hydroproject (spillway dam and water conduits) provide for the passage of a 100-year storm with a flow rate of 20,600 m³.

The water-retaining structure of the hydroproject - the concrete gravity dam - is situated on durable jointed granites, which include individual veins of porphyrites and syenites. Both insignificant tectonic cracks, and also large-scale displacements, which may be accompanied by crushing zones, exist within the bounds of the granites. The largest crack (principal tectonic zone) with an opening from several centimeters to 2.5-3 m intersects the thrust front at an angle of 25-30°. Two other smaller cracks are situated in a section of the spillway dam.

The dam with its triangular profile and vertical thrust face stands 124 m high and is 1,065 m long at the crest. The slope of the lower face is 0.76-0.80. Over its length, the dam is divided into 15-m wide sections by expansion-deformation joints, and consists of channel, plant, and blind sections.

The following are characteristic features of the dam's design: recesses 4 m wide in the foundation bed of the structure; a water supply to each generating set provided by two steel-reinforced-concrete pipelines 7.5 m in diameter, which are carried onto the downstream face of the dam; rejection of the installation of compensators at the point where the pipelines meet the powerhouse, and their replacement by a closed member assembled and concreted prior to start-up of the generating set; and, use of a new type of seal for the expansion joints, which consists of a system of metallic sheets with subsequent grouting of the joint. A flexible anti-filtration curtain and flexible bed drainage were constructed beneath the dam. A grout curtain up to 65-70 m deep was built in two tiers, and is reinforced by additional rows of grout holes in an area of tectonic faults. At the contact between the concrete and rock, the grout curtain is reinforced by a mating grouting, which consists of three-five rows of holes 15-30 m deep. In zones of increased jointing and tectonic faults, through stabilizing grouting has been carried out beneath the entire lower surface at a depth of 30 m.

The near-dam-type powerhouse, which is 62.3 m high, 872.6 m long, and 82.6 m wide is situated on granites. Section grouting has been conducted at depths of 20-25 m over the entire area of the powerhouse. Drainage holes 7-12 m deep have been drilled from the draft tubes to relieve the counterpressure in the foundation bed of the powerhouse. A basic characteristic feature of the design is the fact that the mass of the block housing the generating sets in the powerhouse functions with the dam in shear.
Water flows are delivered to each generating set through two conduits, which are unified into a single pipe by a fork in advance of the spiral case. The reinforced-concrete jacket of the penstock was designed for a stage of failure in the case of the emergency malfunction of the metallic jacket under the total external water pressure with a water hammer, and with allowance for temperature effects with a safety factor of 1.1 in the reinforcement.

**Monitoring the Condition of the Water-Development Works.** Monitoring is carried out using complex field observations conducted with monitoring-measuring equipment (MME) designed for different purposes. The commission noted that the quantity, nomenclature, and condition of the MME corresponds to design requirements and existing standards, and provides the proper level of condition monitoring for the water-development works. Focusing attention on processes occurring in the foundation bed of the dam, which are related to its aging, it is recommended, at the same time, to establish additional MME primarily in the area of the tectonic zones.

Information from remote MME is acquired using an automated information-collection system developed in due time by the All-Russian Scientific-Research Institute of Hydraulic Engineering. The development and fabrication of a measuring system on a modern element base with measurement results input to a personal computer are being completed at the present time. The first phase of the automated observation system based on direct and inverted plum lines is in the debugging stage, and work has begun on the organization of seismic observations.

The water-development works are operated by the Hydraulic-Engineering Department, which employs 103 persons. The condition of the water-development works is monitored by the MME section of the Hydraulic-Engineering Department at the power plant with a staff of 15 persons, 10 of which are engineering-technical personnel with a special high- and medium-level technical education. The condition and operation of mechanical equipment in the hydraulic structures is monitored by the repair section of the turbine shop, which employs 22 persons.

Noting that on the whole, the structure, and the numerical composition and qualification of the workers monitoring the condition and operation of the water-development works and their mechanical equipment satisfy the requirements that have been set forth, the commission considered it expedient to recommend an increase in the number of persons employed by the MME section by creating an analytical group of from two three persons to perform in-depth analyses of the condition of the water-development works that have seen extended service.

The requirements of guideline materials and methodical instructions regarding the volume and dates of observations are fulfilled by the personnel; required instruction, regulatory documents, methodical instructions, and manuals are available in the Hydraulics Department. As the commission has pointed out, regulatory-methodical documents should, at the same time, be included in the latest issues of the Construction Rules and Regulations.

**Condition of the Water-Development Works and Hydromechanical Equipment.** Based on results of field observations on the overall displacements (settlements, horizontal displacements, inclines), joint openings, stresses, and deformations, as well as the results of the commission's inspection, the condition of the structures has been assessed as satisfactory. It was pointed out at the same time that analysis of data derived from multiyear observations revealed certain signs of slowly developing processes characteristic of aging "dam/foundation-bed" systems, the disregard of which may lead to a reduction in the operational reliability of the structure. These signs encompass the zone of contact between the dam and foundation bed, and are manifested in the condition of the underground perimeter (curtains, drains). The following serve to confirm this: a continuing, even though slow, increase in counterpressure in the foundation of the shore sections; local anomalies of the filtration regime in the foundation bed of the channel sections; and, water levels close to the upper-pool level in the shore piezometers located along the drainage line. The latter may suggest the unsatisfactory performance of the anti-filtration curtain and drainage. In this connection, the commission recommended to ascertain the causes of the progressive increase in counterpressure in the foundation of the shore sections, and the anomalies of the filtration regime under a portion of the channel sections, and to evaluate the performance of the underground perimeter of the dam (curtains, drains).

The overall condition of the concrete surfaces of the structures was assessed as satisfactory. It was noted simultaneously that individual sections of the surface have negligible failures that do not affect the normal operation of the design. The concrete of the divided abutment and bulwarks of the bottom openings in the zone of variable water level possesses surface failures up to 10 cm deep. The concrete of the thrust front of the spillway face and lip – springboard – is in satisfactory condition. Spalling to a depth of 2-4 cm and traces of cavitation failures exist in the region of the intersectional joints. Some of these defects have been eliminated by repair with the use of polymer compositions.

The commission also pointed out that a significant number of cracks through which the filtration of water is observed into the conduit for the eighth generating set exists in the lining of the reinforced- concrete conduits. It is recommended that special inspections of the conduits be conducted, their performance investigated, and that recommendations be made for continued service. It was pointed out simultaneously that the inclined sections of the penstocks have not been inspected since the start of service due to lack of technical facilities required to transport people into these zones.

Inspection of the hydromechanical equipment of the water-development works by the commission has indi-