The great responsibility placed on the structures and equipment for the Sayano-Shushenskoe hydroelectric station predetermined the need for a reliable scientific substantiation of all main design decisions. The B. E. Vedeneev All-Union Scientific-Research Institute of Hydraulic Engineering (VNIIG) is the principal organization for research related to the equipment of the structure and construction technology of the hydrostation. A considerable part of the research was devoted to the selection of a rational layout of station structures, study of the hydraulics of the seepage, and substantiation of the discharge schemes during the construction and temporary and permanent operating periods. To substantiate selection of the type and designs of the main structures for the hydrostation, their operation under loads was studied thoroughly and concrete was selected for different parts of the structure. Full-scale observations of the state of the structures are being carried out.

**TYPES OF INVESTIGATIONS**

**Hydraulic Research**

About 10 variants of overflow works differing in the distribution of the spillways along the front of the dam and designs of the spillway passages were studied on three-dimensional models at scale of 1:120, 1:100, and 1:50. However, even the best of these variants required constructing in the lower pool an artificial scour pit and separating the powerhouse into several sections. The search for the optimal solution led to consideration of the advisability of constructing a stilling basin, the need for which was determined also by the conditions of passing the discharges during the second constructional phase. It became possible to locate a stilling basin in the lower pool after increasing the power of each unit to 640 MW, reducing the number to 10, and eliminating the double-conduit spiral casing.

The advisability of using a stilling basin, intended for dissipating the energy in a 25 million-kW overflow, was substantiated by comprehensive investigations performed by the laboratories of the hydraulic, structural mechanics, and dynamics of structures with the participation of the departments of measurement techniques and mathematics. The characteristics of the hydrodynamic effects, modes and frequencies of natural vibrations of the dam and structural elements of the stilling basin, and dynamic components of stresses in the concrete of the dam, the maximum value of which was less than 0.5 MPa, were determined.

In subsequent investigations the main parameters of the stilling basin and waterway of the service spillways were substantiated on three-dimensional models (scale 1:120) and on partial models (1:60 and 1:50) and in the design work carried out in close relation with them. The characteristics of the hydrodynamic effects were also established.

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†A number of variants were examined also in the Department of Hydraulic Research of the research division of the All-Union Planning, Surveying, and Scientific-Research Institute (Gidroproekt).

‡The Department of Hydraulic Research of Gidroproekt also participated in solving these problems and also in substantiating the measures on protecting from cavitation the service spillways of the hydrostation.

The trapezoidal stilling basin has a retaining wall on the bank side. The channel wall is, in turn, a dividing abutment separating the basin from the tailrace of the powerhouse and the longitudinal cofferdam for the second-phase cut. The baffle wall is a 19-m-high spillway with a standard crest shape operating at a difference in pool elevations of more than 20 m, specific discharge of 130 m$^3$/sec-m, and crest velocities of 15-25 m/sec. It is being constructed in several phases corresponding to the stages of reservoir filling. The 2.5-m-thick concrete slabs for bed protection are anchored to the foundation. The construction of a baffle wall with a crest elevation exceeding the tailwater level during discharge of the hydrostation makes it possible to conduct regular inspections and, if necessary, to repair the stilling basin. Below the baffle wall the rocky channel is protected by a 2-m-thick baffle platform.

Quite intense transformation of the velocity field in the flow occurs within the stilling basin: At a maximum discharge of 13,500 m$^3$/sec the bottom velocities on the first third of its length already have decreased from 52-50 to 30 m/sec, and to 15 m/sec before the baffle wall.

Considerable attention was devoted to the pressure and fluctuating components of the loads. The distribution of the average pressure is considerably nonuniform; expressed as "full-scale," it varies from 0.5 MPa in the stretch adjacent to the spillways to 0.1 MPa in the wake beyond the piers. The maximum value of the standard deviation of the pressure fluctuation is 0.12 MPa at the start of the basin, decreasing to 0.03 MPa at its end. The highest fluctuation frequencies are recorded at the start of the basin, but even here the most power-consuming frequencies are equal to about 1.5 Hz at the lowest natural frequencies of the 12 x 15 m protective slabs of about 25 Hz. These slabs were designed with consideration of the fluctuating component of the load.

The design of the service spillways was worked out on the basis of investigations of numerous variants at VNIIG on sectional models at a scale of 1:50 and at the research division of Gidroproyekt on models at a scale of 1:25 and 1:13.

The service spillways are curved pressure pipes. At the site of the grooves of the emergency gate their dimensions are 5 x 10.5 m, and at the outlet of the pressure section 5 x 6 m. The elliptical surfaces of the inlet bulkheads eliminate cavitation. The pressure sections of the spillways on the downstream face of the dam pass into open chutes. The surfaces of the chutes are protected from cavitation erosion by using high-strength frost-resistant concrete (M400, Mrz-500, V-12) and aeration of the boundary layer of the flow through special air ducts.

Investigations of the conditions of passage of the temporary (construction period) discharges, designs of the temporary spillways and their mechanical equipment began at even earlier stages of development of the contract design and are continuing to the present, since this is necessary for operative correction of the detail plans. Experiments were conducted on a model at a scale of 1:100 and on a number of sectional models at scales of 1:30-1:50. Experiments were performed on a vacuum-cavitation stand for developing measures to protect the temporary spillways. As a result of these investigations VNIIG together with Lengidroproekt developed a rational design for the first-phase earth-rock cofferdam, which provided reliable protection of the cut at current velocities to 10 m/sec. Experiments also substantiated the channel damming project.

In order to pass temporary discharges without impeding construction work the spillways are located at various levels of the dam, including the main and flushing spillways, emergency spillways in the dividing abutment, spillway chutes on the crest, and spillways at the second level. On the basis of calculations and model investigations rational designs of these spillways were developed, the conditions of their trouble-free operation were determined, the flow characteristics were established, and the scheme for delivering air to the boundary layers for protecting the concrete from cavitation was worked out. With consideration of the wide range of variation of the heads (20-160 m), the heights of the baffle wall necessary to ensure energy dissipation and safety of the concrete-buggy trestle at intermediate construction stages were determined for the period of operation of the temporary spillways.

To substantiate the design of the mechanical equipment for the second level spillways, vertical lift gates (main and emergency) were investigated, the average fluctuating compo-