Dismantling of the platforms of levels 7, 6, and 5 is analogous to the preceding.

The containers of the air curtain of level 4 are assembled.

Anchors, stairs, and platforms are installed from the bottom up from additional stairs installed on the platform at an elevation of 101.2 m, or from the top down from floating devices as the reservoir is drawn down.

After installing the containers, all stairs and platforms are dismantled in the opposite order.

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TUNNEL SPILLWAY FOR A HIGH-HEAD HYDRODEVELOPMENT

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Design studies for underground spillways with energy dissipation inside the structure were carried out at the feasibility study stage at the Central Asian branch of the All-Union Planning, Surveying, and Scientific-Research Institute (Sredazgidroproekt) as applied to a hydro development with a head of more than 200 m and discharge through the tunnel spillway of 4000 m³/sec. The department of hydraulic research of Gidroproekt performed hydraulic calculations of the most complex elements of the spillway and issued an expert conclusion concerning the hydraulic part of the feasibility study of the spillway.

The experience of Sredazgidroproekt gained when designing the spillway structures of the Rogun, Nurek, Charvak, Kambarata, and Sangtuda hydrostations and the Teri hydrocomplex in India was used in the feasibility study.

When designing a tunnel spillway for a hydro development, main attention was devoted to solving the following problems: cavitation and dynamic effect of the flow on elements of the water passage part of the structure, transition horizontally and vertically of sections of the spillway channel, transition with the lower pool.

Cavitation and Dynamic Effect of the Flow. According to the data of laboratory investigations and experience of operating existing high-head spillways, water velocities of 40 m/sec are the maximum allowable for surfaces of the flow parts made of ordinary hydrotechnical concrete in the absence of special anticavitation measures. The surfaces being washed by the flow should be practically free of local and general asperities, which with the current constructions of formwork is practically impossible to realize. There are several methods of protecting structures from cavitation. The experience of operating high-head spillways showed that the most effective, cheapest, and most technologically efficient method of protection from cavitation is to deliver air to zones of its possible occurrence. In this case, the physical and mechanical properties of the fluid change markedly, the cavitation effect of the flow on elements of the flow part of the structure is practically eliminated and the dynamic effect is substantially reduced. However, this method of protection from cavitation is applicable only in free-flow spillways.

Transition horizontally and vertically of sections of the spillway channel has traditionally been solved by streamlined transitions, observing in so doing the requirements of providing a positive pressure of the flow on the convex side of turns and not allowing swinging of the flow, which can lead to "choking" of closed conduits. Subsequently, with development of the theory and designs of controlling rapid flows, suggestions appeared for transitions of the elements of spillway structures on local sections (deflection of a horizontal flow onto the ceiling of an inclined conduit, use of shaft stilling basins and swirl units with drainage of water from them at lower elevations in the necessary direction, etc.).

The transition with the lower pool is an independent complex set of problems. Transition of pools in the case of tunnel spillways is realized mainly by deflecting the flow from the structure by ski-jump buckets, more rarely stilling basins, and end structures with side drainage are constructed in the lower pool of such spillways. The following negative phenomena occur in the case of joining pools by deflecting the jet:

- The considerable volume of scouring of the channel in the lower pool in the case of insufficient deflection of the jet can cause undercutting of the end structure of the spillway or another structure, and in a narrow canyon can threaten also the stability of the bank slope.

- Bars form as a result of scouring of the channel, which can lead to backwater of the hydrostation;

Aeration of the flow being discharged into the lower pool leads to the formation of water spray, which rises to a considerable height and is carried away by the wind to great distances. This can complicate the operation of outdoor electrical equipment and disturb the stability of steep banks adjacent to the structure owing to saturation with water;

The water spray lowers the air temperature and enriches the water in oxygen, which can disturb the natural sanitary-biological state of the environment, especially on cascades of reservoirs;

The scoured banks and channel of the river disturb the natural landscape of the locality.

Problems related to the operation of high-head spillways led to the need to develop and investigate new types of spillway structures satisfying a broad range of requirements, the most important of which are operating reliability, high technical and economic indices, and ecological purity, which is determined primarily by the degree of effect of the discharge on the state of the channel below the site of the hydro development and on the microclimate in the river valley [1]. These requirements are maximally fulfilled by underground spillways, in which, with expenditures less than in open spillways, the excess kinetic energy of the flow can be dissipated inside the structure and the flow velocity can be reduced at the outlet to the lower pool to values such that the flow being discharged does not cause noticeable deformations of the channel in the lower pool and complications related to spray. In such spillways the problem of protection from cavitation is solved rather reliably, and an independent mutual orientation of elements of the spillway is also provided, which simplifies its layout.

With consideration of the aforesaid, five variants were examined at Sredazgidroproek for establishing the optimal solution in the feasibility study of the tunnel spillway: 1) two-lane spillway with a deep water intake and vertical shaft; 2) shaft spillway with two portals, shafts, and common outlet tunnel; 3 and 4) two-lane spillways with a front intake and vertical or inclined shafts; 5) two-lane spillway with a deep intake and shaft stilling basins.

All examined variants of spillways realize the idea of intermediate energy dissipation by creating swirl units (variants 1, 2, 3, 4) or by means of shaft stilling basins (variant 5).

In variants with swirling of the flow, the formation of a swirled flow occurs due to a change in the corresponding forms of the flow channel of the spillway or by means of swirlers of a relatively simple and compact design with tangential delivery of water to the outlet channel. As the swirled flow moves, gradual dissipation of energy occurs in the entire range of variation of discharges over the length of the outlet channel due to an abrupt increase of losses due to friction and changes in the structure of the flow, gradual transition of the flow from a rotational motion to an axial translational motion with flow velocities at the outlet not exceeding 20 m/sec. The centrifugal forces during swirling create an additional pressure on the walls of the outlet channel, which reduces the danger of cavitation erosion and enables doing away with special measures on protecting the surface of the tunnels and shafts.

A relatively stable water-air "cushion" forms in shafts (inclined or vertical), protecting the lower part of the shaft and swirl unit from the dynamic action of the falling flow.

In the variant with shaft stilling basins, intense dissipation of excess kinetic energy occurs in the shaft of the basin due to sudden expansion and turbulent mixing of the flow.

The following main principles and initial data were used when designing a bank tunnel spillway: the spillway is intended for reducing maximum discharges through the existing spillway of the dam and stilling basin; the seismicity of the region is intensity 7; the maximum discharge of the tunnel spillway is 4000 m³/sec at the elevation of the normal pool level (NPL) of the reservoir of 240 m; the spillway is located in the mass of the right wall of the canyon in slightly fractured, poorly permeable rocks characterized by a high mechanical strength; the excess energy of the flow is dissipated inside the spillway by swirlers or shaft stilling basins; construction of the spillway is carried out with the hydro development operating with annual drawdown of the reservoir from the elevation of the NPL of 240 m to the elevation of the dead storage level (DSL) of 200 m; works on constructing the inlet portals of the spillway are carried out only with the reservoir drawn down below their sill; the layout of the spillway provides preservation of the grout curtain of the dam and existing transport and other communications.

Layout and Designs of the Examined Spillway Variants

1. Two-Lane Spillway with a Deep Intake and Vertical Shafts. The spillway was developed as part of two independent lanes, each for a discharge of 2000 m³/sec located in plan about 50 m apart and having a length of 1100 and 1220 m. The layout and design of both lanes of the spillway are identical. The structures include: inlet portals, guard and service gates, inlet tunnels, vertical shafts, outlet tunnels, and end structures. The vertical shafts are joined with the inlet and outlet tunnels by vertical and horizontal tangential swirlers, which make it possible to join elements of the spillways on local sections, to provide cavitation-