HYDRAULIC MODEL INVESTIGATIONS OF SPILLWAY STRUCTURES FOR THE CHIRKEY HYDROELECTRIC STATION

G. L. Rubinshtein, G. K. Deryugin, and V. F. Tsilikin

UDC 627.83.001.57

A considerable part of the investigations performed by the B. E. Vedeneev All-Union Scientific-Research Institute of Hydraulic Engineering (VNIIG) to substantiate the design of the Chirkey hydroelectric station [1] consisted of work in the laboratory, designing the main spillway structures—the dam (Figs. 1 and 2) and tunnel (Figs. 1 and 3) variants of the operating spillway and the temporary level II spillway (Fig. 1d)—on a three-dimensional model (scale 1:50).

It was necessary to solve the complex problem of providing satisfactory conditions for connecting the pools in the case of discharges from 50 to 2900 m³/sec passing the high-head hydrodevelopment located in a narrow, tortuous canyon with steep slopes up to 300 m high. In this case the design of the spillway had to be such as to eliminate intense scouring of the bottom in the immediate vicinity of the structure, which was dangerous for the stability of the dam, and to keep a considerable part of the spillway discharge from striking the canyon slopes, which were composed of Cretaceous fractured limestones [2]. In the latter case undermining of the slopes and their collapse would almost certainly obstruct the channel and cause the groundwater to rise under the powerhouse.

Another important problem was to work out the design of spillways which would provide their sufficiently reliable use under different discharge conditions, to determine the optimal parameters for a number of elements of these designs, and to establish the hydraulic characteristics of the flow within those limits. These problems were solved for the dam variant of the spillway, consisting of three pressure pipes and chutes on a special supporting structure (Figs. 1 and 2). However, this variant was rejected since it was impossible to construct the powerhouse and spillway simultaneously. We will examine only the results of investigations that were used for the further development of the elements of the adopted tunnel variant of the spillway.

For the conditions at the Chirkey station the scheme of connecting the pools by an ejected nappe was considered the most rational; however, it proved to be quite complex to develop a design for the end of the spillway such that it would eject the flow a considerable (up to 180-200 m) distance from the structure with practically no expansion in plan. Investigations carried out for the dam variant of the spillway showed that not only the most frequently used modifications of the usual cylindrical ski-jumps but also special types of these structures [3] forming a narrow, elongated nappe proved to be unacceptable. In all cases the flow at the place of falling expanded so much that the peripheral parts of the nappe carrying an appreciable portion of the discharge struck the canyon slopes. In the case of a relatively small width of the ski-jump, average depth of the flow of 7-8 m at the takeoff, and Froude numbers of the order of Fr = 60-70 it was impossible, on the basis of the recommendations [3], to select such an outline of its bottom surface which would provide the prescribed form of the ejected nappe; the limits of using the proposed ski-jump designs indicated in [3] should apparently be considered insufficient.

Thus for the variant with a dam spillway, despite the large number of investigated variants of frontal ski-jumps, it was impossible to select a design that did not necessitate clearing away the slopes in the lower pool of the hydrodevelopment. It was possible to solve the problem only by means of the specially developed modification of a ski-jump without a side wall proposed by M. E. Faktorovich [4]. This ski-jump over a wide range of heads and discharges distributes the discharge over a length of 150 m and the flow falls practically exactly along the channel axis.

As will be shown below, the conditions of connecting the pools is considerably facilitated by the use of an analogous type of the construction in the case of the tunnel variant of the spillway as well. Quite complex was

Translated from Gidrotekhnicheskoe Stroitel'stvo, No. 9, pp. 28-31, September, 1976.
Fig. 1. Variants of the operating spillway layout. a) Frontal ski-jump; b) ski-jump with lateral overflow; c) open stretch of spillway; d) temporary level II tunnel. 1) Dam spillway; 2) variant I of tunnel route; 2) variant II of tunnel route.

Fig. 2. Section through dam spillway.

Fig. 3. Distribution of average hydrodynamic pressures along bottom axis of the operating tunnel.

the regime of connecting the pools in the case of routing the tunnel according to variant I (Fig. 1) due to the fact that the dimensions of the rectilinear stretch of the channel used for distributing the discharge were insufficient for dissipating the excess flow energy. In the lower pool there was a considerable decrease in the water levels, an unsubmerged hydraulic jump practically occurred, and intense wave action and ejection of considerable masses of water onto the banks to a height as much as 20 m above the natural level of the discharge was observed. Under these conditions considerable special clearing of the river bed (up to 75,000 m³ on the left-bank slope and about 25,000 m³ on the right-bank slope of the canyon) was required to eliminate these phenomena, in connection with which the laboratory recommended, and the design organization adopted, variant II of the route (Fig. 1), which permitted using for energy dissipation a longer and wider rectilinear stretch of the channel and facilitated the conditions of connecting the pools.