CHIRKEY HYDROELECTRIC STATION: DESIGN, CONSTRUCTION, OPERATION

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Located in Dagestan on the Sulak River, the Chirkey hydroelectric station with an installed capacity of 1 million kW is the largest hydrostation in the North Caucasus interconnected power system. The first unit of the hydrostation was put into operation on December 22, 1974 and the last, the fourth, in June 1976 (Fig. 1).

The Sulak River originates on the northeast slope of the Main Caucasian Range at a height of 3500 m, flows northeastward, and, overcoming a series of canyonlike gorges and basins, exits into piedmont regions and then empties into the Caspian Sea. The length of the river (with tributary) is 347 km, the normal runoff is 5.62 km$^3$, the normal discharge is 180 m$^3$/sec. The runoff regime is characterized by a prolonged flood (April-October), when melting of snow and glaciers coincides with rain showers. The presence of easily eroded rocks and intense showers cause the development of erosion processes, the occurrence of mudflows, and a large content of sediments in the river — about 21-million tons annually, of which 99% pass during freshets.

The dam raises the river 205 m versus the natural low-flow level, as a result of which a reservoir with a length of 40 km, maximum width of 5 km, and useful storage of 2.78 km$^3$ is formed. On drawing down the level by 40 m the useful storage of the reservoir is 1.32 km$^3$. The design head on the hydrostation turbines is equal to 170 m. With an installed capacity of 1 million kW the average annual electric power production is 2.43 billion kWh.

The dam site is located in a deep canyonlike gorge, the width of which at the water's edge was 12-15 m and at the elevation of the dam's crest 300 m. The walls and floor of the gorge are composed of platy limestones containing interlayers of marl and marly clays. In the lower part of the gorge there is a 12-m member of limestones with clay interlayers up to 10-cm thick. The limestone layers and clay interlayers dip toward the upper pool and right bank at an angle of 10-12°. The strength of the limestones varies from 700 to 1300 kg/cm$^2$.

The entire rock mass is broken by variously oriented tectonic fractures with dip angles 40-80° filled mainly with calcite and clay.

Wall expansion joints running parallel to the slope of the gorge are developed. These joints are especially developed on the left bank (shear fractures "A" and "B"). The wall incision of the pit for the abutments of the arch dam was made beyond the limits of the developed wall expansion joints and therefore reaches a depth of 50 m on the left bank and 30 m on the right.

The design seismicity of the region of constructing the hydrodevelopment is intensity 9. An intensity 8.5 earthquake occurred in 1970 during construction.

DESIGNING

The detail design of the Chirkey hydrostation (M. A. Mironov, chief project engineer), developed by the Leningrad branch of the State Planning, Surveying, and Research Institute (Lengidroproekt), was approved in 1967 by the USSR Ministry of Power and Electrification (Minénergo) as part of the following main structures: concrete arch dam, reservoir powerhouse, 330-kV outdoor electrical equipment, and Tishikla levee.

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The dam consists of a 48-m-high channel plug, 184.5-m-high arch part, and right-bank abutment. The maximum height of the dam is 232.5 m, crest length 338 m, volume of concrete 1.3 million m$^3$. The main technical indices of the dam are: ratio of crest length to height 1.45, volume of concrete per ton of hydrostatic pressure 0.28 m$^3$/ton. The 48-m-high dam plug dams the lower channel part of the gorge and serves as an artificial foundation for the arch. It has a trapezoidal cross section vertically and a V-shape horizontally. In the foundation of the plug is constructed a longitudinal elliptical cavity reducing the uplift pressure on the base and promoting pressing of the upstream face against the rock foundation.

The 184.5-m-high part of the arch dam is a double-curvature construction of almost symmetric outline elastically fixed in the foundation with a thickness gradually varying from 6 m at the crest to 30 m at the contact with the plug. The dam is divided by grouted radial joints of helicoidal form into 18 16.5-m-long sections. The 75-m-long central part of the dam (four sections) is used as the powerhouse part. Here are located the water intakes and penstocks of four turbine–generator units. The body of the dam is drained by pipe drainage. Longitudinal galleries are constructed at four levels over the height of the arch to observe the state of the concrete masonry and discharge of water from the drains.

The intake of each unit is a 64.5-m-high, 20-m-wide reinforced-concrete structure adjacent to the upstream face. In it are located the quick-drop service gates equipped with hydraulic hoists and guard gates with trash racks.

The 5.5-m-diameter penstocks with an average length of 250 m are located on the downstream face. They have a high-alloy steel shell with a thickness from 14 mm at the top to 46 mm in the lower part, and within the arch part are enclosed in a 1.5-m-thick reinforced-concrete casing rigidly connected to the downstream face.

The reservoir powerhouse is located directly at the downstream face of the dam plug and consists of underwater and above-water parts. In the underwater part are located four turbines, a part of the pressure conduits, steel scroll cases, draft tubes, and pumphouses. The turbines with 4.5-m-diameter runners are arranged successively in two rows: the first and third units on the downstream side and the second and fourth on the upstream side. The axes of the gate apparatus of all turbines are located at the same elevation, the draft-tube cones are located in two tiers. In this case elongation of the conical and diffusion parts of the draft tubes is characteristic for turbines of the upstream row.