EXPERIENCE IN OPERATING HYDRO DEVELOPMENTS

TRANSFORMATION OF RELEASES IN THE LOWER POOL OF THE DNESTR HYDROELECTRIC STATION

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The Dnestr multipurpose hydro development is one of the largest hydropower facilities constructed in recent years in Ukraine. The main hydraulic structures of the hydro development is a high-head channel hydroelectric station equipped with six turbine-generator units and located 677.7 km from the river’s mouth. The normal pool level of the reservoir is 121 m, the lower pool level usually does not exceed 72 m. In connection with the peak-load operating regime of the hydrostation, an equalizing reservoir was constructed in the lower pool to smooth the fluctuations of the levels and discharges. Its length is 19.8 km and volume at the NPL of 72 m is 31 million m$^3$. At the lower levels characteristic during operation of the hydro development, the volume of the equalizing reservoir is: at 66 m, 4.29 million m$^3$; at 68 m, 11.5 million m$^3$; at 70 m, 20.2 million m$^3$ [2].

As a rule, in the absence of floods and freshets, the Dnestr hydroelectric stations operates in the morning and evening hours for 3-4 h each. The number of operating units is usually 2-4. During the remaining time of the day, when the demand for electricity decreases, discharge of water is stopped. That being the case, the discharges in the lower pool are determined by the seepage flow, amounting to 7.1 m$^3$/sec.

Five gauging stations were equipped for studying the transformation of releases on the stretch downstream from the hydrostation: in the lower pool of the hydrostation, at Ozhevo village (5.3 km downstream), upper pool of the equalizing dam, in the lower pool of the equalizing dam at a distance of 1.2 km from it (Nagoryany village), and in Molgilev-Podol’skii city (27.9 km downstream of the equalizing dam). At the first three stations the level was measured discretely: every 1-10 min depending on the rate of change and time of arrival of the peaks. At the Nagoryany and Molgilev-Podol’skii stations the level was recorded with the use of automatic recorders. At the two lower-downstream stations the discharges were measured along with a determination of the level.

The investigations showed that on the eve of releases, a virtually constant level of 68.90-68.92 is established in the lower pool of the hydrostation due to the seepage discharge. When the units are turned on, the rate of change in the level reaches 0.4-0.5 m/min. The maximum level is determined by the number of units turned on and the time of their operation. The range of fluctuations smooths out with distance from the hydrostation. For the equalizing reservoir, about half of the decrease of the range is confined to the stretch between the hydrostation and station Ozhevo. The main transformation of the releases occurs at the equalizing dam (Fig. 1).

Of greatest interest is a determination of the maximum water levels in the upper pool of the equalizing dam. A rise of the water level is determined by the number of units turned on at the hydrostations (by the maximum discharges), time of their operation, and number of gates opened on the equalizing dam. The effect of other factors — form of the hydrograph preceding the release for filling the reservoir — was insignificant. This is mainly due to the limited number of operating units.

Using the method of group consideration of arguments, we obtained a relation for determining the maximum water level in the upper level of the equalizing dam

$$H_{max} = 0.5116N + 0.00567 - 0.0094n + 65.86,$$

where $H_{max}$ is the unknown water level; $N$ is the maximum number of units operating at the hydrostation; $T$ is the time of their operation; $n$ is the number of gates opened on the equalizing dam; 65.86 is a free term.

It should be noted that the assumption made in the calculations about constancy of the discharges during releases cannot have any substantial effect on the accuracy of the calculations, since a rise of the water level in the lower pool insignificantly affects the head.
The travel time of the maximum level (wave crest) to the station nearest to the hydrostation, 5.3 km, is 12-15 min and the velocity is 6-8 m/sec. Such a considerable propagation velocity indicates pronounced wave motion of the releases and approximate correspondence of the velocity determined by the Lagrange or St. Venant formulas [1]. With operation of the units, when the depth of the equalizing reservoir is negligible, the propagation time of the wave front is twice greater and is 20-28 min, depending on the depth. In that case the channel roughness has a noticeable effect on the propagation time.

To calculate the transformation of releases in the lower pool of the equalizing dam and to monitor the discharges being released, we need data on its discharge capacity. To solve this problem, measurements of the discharge were taken at a distance of 1.2 km from the dam, where the function \( Q = f(H) \) is close to unique. In 1989-1990, when the channel in the stretch stabilized, we obtained: \( H = 64.5 \text{ m}, Q = 158 \text{ m}^3/\text{sec}; H = 65.0 \text{ m}, Q = 292 \text{ m}^3/\text{sec}; H = 65.5 \text{ m}, Q = 466 \text{ m}^3/\text{sec}; N = 66.0 \text{ m}, Q = 673 \text{ m}^3/\text{sec}; H = 66.5 \text{ m}, Q = 901 \text{ m}^3/\text{sec}. \)

Further investigations consisted in synchronous measurements of the level in the upper pool of the equalizing dam and at the gauging station. This makes it possible to establish the correspondence of the observed peaks. Knowing the number of open gates and corresponding water levels, we established the discharges passing through all and, consequently, one outlet from the rating curve at the gauging station. The results obtained made it possible to plot the graphic dependence of the discharges being released on the water level in the upper pool (Fig. 2), to which correspond the following values (Table 1).

The data presented indicate that at small and average heads (the elevation of the sill as a consequence of the spillway is 64.00-64.04 m), the actual discharge capacity of the equalizing dam exceeds by 20-30% the calculated one established at the stage of designing the hydro development. One of the causes of this was an improvement of the hydraulic conditions in the lower pool in comparison with the initial period, which increases the drowning ratio of the spillway.

Passing through the equalizing dam, the release hydrograph usually acquires a form close to a regular triangle. This prevents similarity of the process of transformation on the downstream stretch. The range of variations at station Mogilev—Podolskii is 0.89 of that observed at station Nagoryany. The lag of the arrival of the maxima for the 26.7-km-long stretch is 5 h and of the minima 3 h (Fig. 3).

There is a linear relation between the water levels in the lower pool of the equalizing dam at Mogilev—Podolskii (Fig. 4)

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H_{M-P} = 1.075H_{LP} - 9.75. \tag{2}
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The data obtained permit a short-range forecast of the level at station Mogilev—Podolskii, and in the case of undesirable deviations (particularly for navigation) they make it possible to provide the necessary conditions by regulating the gates on the equalizing dam. For this purpose, the discharge being released is determined from calculations of the water level in the upper pool of the equalizing reservoir and number of open gates. The water level at station Nagoryany is established from the curve \( Q = f(H) \) and the level at station Mogilev—Podolskii is determined by Eq. (2).