CONSTRUCTION AND OPERATING PROPERTIES
OF EXPERIMENTAL DIAGONAL TURBINE AT
BUKHTARMINSK HYDROELECTRIC PLANT

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The first Soviet diagonal turbine [1] was put into operation on August 5, 1965 at the Bukhtarminsk hydroelectric plant. During a period of one and a half years, this experimental turbine was subjected to comprehensive hydraulic strength tests, and in March 1967 it was placed in normal operation. By the time of the planned major maintenance, in December 1969, the turbine had operated for 15,190 h; by December 1971, it had operated 22,552 h. Thus, there are sufficient data for evaluating its operation.

According to the technical specifications, the experimental turbine [2, Fig. 54] should have a guaranteed capacity of 77,000 kW under a design head of 61 m, and a short-duration capacity of 90,000 kW under a maximum head of 66 m. These indices were ensured by a 4.35-m diameter runner at a speed of 150 rpm (Fig. 1).

The turbine is equipped with a conical guide-vane device and a welded steel scroll case connected to a conical stator; the guide vanes (24) have spherical end surfaces and are connected to the regulating ring by means of hinged levers and links.

Fig. 1. Cross section of diagonal turbine at Bukhtarminsk hydroelectric plant (see Fig. 54 in [2]).

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According to the published data [3], the weight of the experimental diagonal turbine was 20% greater than that of the Francis turbines installed at the Bukhtarminsk plant (370 and 312 tons, respectively), and the labor required for their manufacture increased by 50% (65,000 man-hours and 36,000 man-hours, respectively). The above increase in the weight and labor-consumption of the experimental turbine is not a characteristic feature of diagonal turbines in general, it was due to different circumstances relating to the novelty of these machines, as described below. The weight of the experimental turbine increased because of the change-over from a radial to a conical guide-vane device, since it was necessary, on the one hand, to increase the rigidity of the stator by making its upper and lower rings not in the form of flat disks, but in the form of box-like elements in order that they could resist the additional forces arising as a result of the inclined position of the stator columns; on the other hand, it was necessary to line with steel plates the lower part of the turbine pit in order to strengthen the excessively thin concrete layer which covered the scroll case from above. The weight of the experimental turbine was increased also by the use of a wing servomotor in the runner. As shown by subsequent investigations carried out by the TsKTI and the MEI, the use of conventional servomotors with translational pistons permits reducing the weight of the runners by about 15-20%. The shaft diameter was increased and, consequently, the weight of the supporting parts and of the entire turbine were also increased in connection with the reduction of the speed from 166.7 to 150 rpm. This was done at the request of the manufacturer, who did not have at that time sufficient elements for the manufacture of a generator operating at a speed of 166.7 rpm. The length of the shaft in the experimental turbine was increased in order to install the attached generator at the same level of the generators for the eight permanent units. If all the units at the plant had been equipped with diagonal turbines, then the shafts could have been made shorter, and, consequently, the weight of the turbine and the volume of concrete in the block could have been reduced. An influencing factor in the increase of the turbine weight was the fact that this was the first turbine of its type and, in the design of its parts, the manufacturers used a factor of safety which was higher than that generally adopted for other turbines.

The 50% increase in the amount of labor required for manufacturing the experimental diagonal turbine, in comparison with the permanent Francis turbines used at the Bukhtarminsk hydroelectric plant [3], was essentially a result of the use of a more complex guide-vane device. A substantial effect also was the fact that the cost of the special technical installations developed and constructed was assigned to the experimental turbine alone. In [2],