FULL-SCALE STRENGTH TESTS ON PENSTOCK OUTLETS
OF THE NUREK HYDROELECTRIC STATION

A. M. Shor

The downstream ends of the Nurek hydroelectric station penstocks are located in a foundation pit which is
bounded on its upstream side by a rock excavation and on its downstream by a wall of the power-station building.
Each outlet (Fig. 1) includes several straight barrels of the penstock, 6 m diameter, a bend with a deflection angle
of about 15° in plan and some 2.5° in the vertical plane, fastened to an anchored support; a conical reducer to 6 to
4.2 m diameter, and a bend 4.2 m diameter with a vertical deflection angle of about 5°. A penstock 2-m-diameter
manhole is provided in the straight portion of the penstock.

The penstocks for turbo-units Nos. 7 to 9 are included in the first stage of construction of the hydroelectric
station. The material used for their downstream ends is steel type 10G2S1 in accordance with All-Union Standard
(GOST) 5058-65, and for the manhole T-pieces, steel type 198IZ-2 according to National Economy Council Tech-
nical Regulations (STU) 30-458-64.

The penstocks are rigidly connected to spherical valves, whose expansion joints are located on the scroll case
side; therefore, with the valve closed, the axial load due to pressure on the valve is transmitted to the conduit.

In order to eliminate the transfer of the axial pressure on the valve to the power-station wall, it was decided
to provide a nonresistant interlayer around the conduit. It was proposed to backfill the whole of the conduit end
with soil to a depth of 25 m, the fill loading to be taken by a concrete lining built around the pipeline. However,
in view of the tight construction schedule it was decided to place the first conduit in temporary service at lowered
reservoir levels, with a lighter anchored support and without the concrete encasement and backfill.

Shortly afterward, circumferential cracks were discovered in the vicinity of the joint zone on the conical re-
ducer. The cracks appeared during welding of the assembly platform. It was considered that the cracks were the
result of a high degree of cold working during rolling. However, subsequent tests on specimens taken from the zone
of cracking did not indicate a noticeable diminution in impact strength from the standard. Inasmuch as there was
insufficient time for replacing the defective metal before commissioning the station, it was decided to place a pro-
tective reinforced-concrete encasement around the conduit, capable of withstanding the total internal pressure, with
a factor of safety of unity. No computations were made to check the composite action of this encasement and the
steel shell, owing to the indefinite nature of the design scheme. However, there was also no time for implement-
ing this decision. In order to be convinced of the possibility of safely operating the unencased turbine conduits, hy-
draulic tests of the downstream end of the penstock were included in the plan of commissioning operations. Press-
urizing was confined to the zone where the above-mentioned cracks had been disclosed. It was proposed that the
conduit which had manifested no cracks would be brought into service in accordance with the results of the tests.

For testing this limited zone of the conduit, a plugging installation made of two available conical blank flanges
was designed and fabricated at the base of the Central-Asia Trust for Design and Assembly of Hydraulic Structures
and Equipment (Gidromontazh); both of the cones had been designed for a pressure of 13 kg/cm². A working pres-
sure of 26 kg/cm² is secured by the second blank flange, with a pressure drop of 13 kg/cm² (Fig. 2). The full-scale
strength tests of the downstream ends of the Nurek station penstocks were carried out during the precommissioning
period, November 7 to 12, 1972. In the course of the tests, measurements were made of the stresses in the manhole
T-piece and the bend, which present certain complexities in strength design.*

*The strain-gauge investigations were carried out by E. N. Veretin, L. S. Kostenko, and L. M. Rozin, members of
the staff of the Special Design Bureau (SKB), Moscow State Institute of Steel Construction for Hydraulic Structures
(Mosgidrostal') under the author's supervision.

The opinion was expressed that, with an incomplete anchor support (Fig. 1), a general flexure of the conduit as a beam is possible, caused by the bend, which endangers its strength. Thus, during the tests the following problems were posed: a) to check the possibility of safely operating the unencased conduits at the commissioning pressure; b) to determine the stressed state of the manhole T-piece at the intersection zone of the shells; c) to determine the stressed state of the bend; d) to ascertain whether there is or is not a general flexure of the conduit as a beam.

Figure 3 shows the downstream part of the penstock (plan view) before commencement of the hydraulic tests; by that time the penstock had been concreted within the wall of the power-station building, using dry canvas as packing, and the lower part of the anchor support had been poured (Fig. 1). The limiting test pressure was 18 kg/cm², measured at the axis of the spherical valve. The pressure in the space between the conical blank flanges, created by a separate pump, was half the pressure in the conduit segment under test. Strain measurements were made at pressures of 10, 16, and 18 atm. Zero readings were taken before applying and after releasing the pressure. Readings which coincided with an accuracy to three divisions on the scale of an instrument ISD-3 were considered reliable. For the measurement of relative strains, use was made of resistor elements with a 20 mm base and a 200 Ω resistance, which were fastened to the external surface of the penstock with acetocelluloid glue and protected from moisture with plasticine.

Because of a lack of time for preparing for the tests, the number of gauges was reduced to a minimum. The strain gauges were installed at two sections of the manhole T-piece and at three sections of the bend (Fig. 4). Two strain gauges were attached at each section; one in the circumferential direction and the other in the axial (orthogonal rosette). The selected directions for gauge installation corresponded to the directions of the principal strains because the 19 points of measurement were located along one of the planes of symmetry of the conduit.