THE HALLIGAN DAM.

The Halligan dam, a structure which has attracted much attention in Colorado, is the subject of a paper by Mr. G. N. Houston which will be presented before the American Society of Civil Engineers on Dec. 20. The full paper will be found under the title of "The Halligan Dam" in the Society's "Proceedings," volume 37, page 1143, from which the following notes are taken:

The dam is 16 miles from the nearest railroad siding. It forms a reservoir of 6,408 acre-feet, owned by the North Poudre Irrigation Company, of Ft. Collins.

Before Mr. Houston was retained as consulting engineer, plans had been prepared for an arched cyclopean masonry dam, with a gravity section, to store water to a depth of 55.5 ft. above the outlet tube, and a contract had been let for its construction at cost plus 20 per cent. Work was commenced, but, after building to a point slightly above the lower outlet

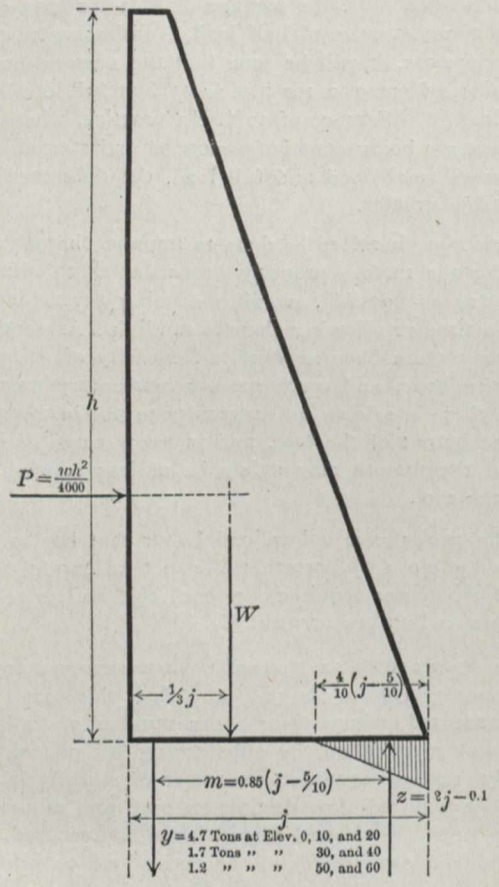

Fig. 1.

tube, the available funds were exhausted and the work was temporarily abandoned. The foundations remained in this condition for about eighteen months, and then the work was to obtain as much storage capacity as possible for a limited sum of money.

New plans and specifications were prepared for a cyclopean masonry dam, reinforced with steel rods, to be built on the foundations already constructed. This dam is of lighter cross-section than the original gravity type designed, and 14.3 ft. higher. This additional height increased the storage capacity by at least 2500 acre-feet, which, at the usual price of $40 per acre-foot, is worth $100,000. The dam was built for $7,000 less than if it had been constructed according to the original plan. In other words, the company saved $107,000 by the use of this design instead of the usual gravity section.

There are about 3,500 cu. yd. of masonry in the old work, and 12,134 cu. yd. in the new structure, making a total of about 15,634 cu. yd. in the whole dam. The cost of the old work was more than $100,000, that of the new work was about $80,000. Work was begun under Mr. Houston's supervision in July, 1909, and completed on May 1, 1910.

Construction.—The foundations, as left by the first contractor, were very uneven, and, before beginning the new structure, it was necessary to use about 1,400 cu. yd. of masonry to bring them up to zero elevation.

For 35 ft. above this point the dam contains irregular masses of rock, varying from 1 cu. ft. to 2 cu. yd., bedded in a 1:3:5 concrete, mixed wet. Smaller rocks were used to fill in between the large masses, 6 in. being the minimum distance between the stones. The quantity of cement used in the concrete for this part of the work was about 1.20 bbl. per cubic yard. The rock content averaged 27 per cent. of the total mass.

After the construction had reached approximately El. 35, the character of the large rock became so poor that it was decided to build the remainder of the dam entirely of 1:3:6 concrete. The projecting lip of the spillway, however, was built of a mixture of about 1:2½:4. The crushed rock varied from a small percentage of pieces having a greatest dimension of 6 in. to pieces ½ in. in diameter. All material finer than ½ in. was excluded on account of the large percentage of mica which it contained. The sand used was very coarse although it varied somewhat.

Concrete was laid during the day through all but the severest winter weather. The water was heated, and varied in temperature from 130 to 160 deg. Fahr. An attempt was made to heat the sand, but was abandoned as not necessary. The temperature of the concrete as deposited in the dam varied from 35 to 60 deg. Fahr. Before bedding the large rocks they were cleaned with a jet of steam. During the night the new work was covered with tarpaulins, under which lighted lanterns were placed. Concrete was not mixed when the temperature was lower than 20 deg. Fahr.

The bulk of the reinforcement was of high-carbon steel. A small quantity of twisted steel was also used in the upper part of the dam. Where the elevation of the old foundation was —3, or lower, the reinforcement was bent and built into the work. Where the foundations were higher than this holes 1 in. larger in diameter than the bars were drilledfrom 3 to 5 ft. deep and the bars were set in neat cement grout.

Spillway.—Mr. Houston originally contemplated a spillway wholly within the cross-section of the dam, but his attention was called to the fact that a discharge over it having a depth of from 2 to 3 ft. would probably leave the face of the dam. As there was a possibility of discharges of much greater depth, it was necessary to widen the crest of the spillway in some way, hence the projecting lip. The surface of the spillway is a compound curve, formed by the arcs of three circles, and following as nearly as possible the curve of discharge of a sharp-edged weir, as determined by Bazin's experiments. The capacity of the spillway is about 14,000 sec.-ft., and that of the two outlet tubes is about 1,400 sec.-ft.

Stresses.—The following analysis of the stresses in the dam is based on the following assumptions.

First: That the high-water level is 9.7 ft. above the spillway, that is, to the top of the dam.

Second: That the dam resists the water pressure partly as a cantilever beam and partly as an arch.

Third: That the center of gravity of the compressive forces is at a point distant from the down-stream face 0.15 of the effective thickness of the dam.

Fourth: That the dam section is a complete triangle, thus making the perpendicular line through the center of