sheds in the vicinity, as to the rise in a given length of time after a heavy rainfall, so as to determine the lapse of time between either the beginning or the maximum rainfall and the maximum crest rise. Rainfall data show that a maximum rainfall of 4 in. in one hour may be looked for, and from 8 in. to 10 in. in twenty-four hours. On this basis there would fall for each square mile in the first hour, 9,288,800 cu. ft. (1 in. equals 2,322,200 cu. ft.). Then the question would arise as to what part of

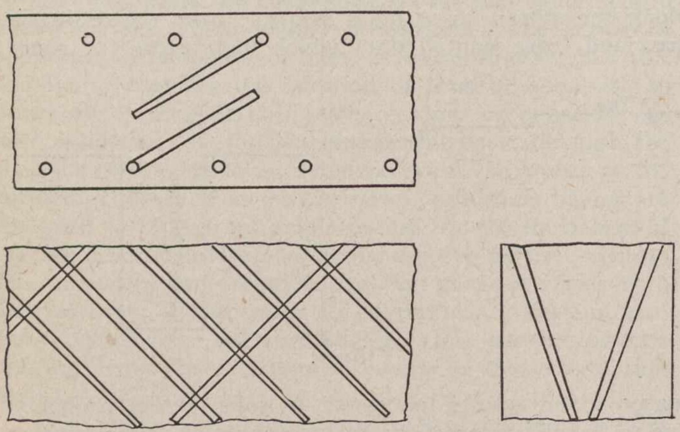

Fig. 3.—Method of Drilling.

this reaches the dam the first hour, and each succeeding hour until the maximum crest height is reached, and the effect the condition of the soil and the ground water content has on this. From J. B. Francis' records, the indication would seem to be that a depth of rainfall varying from 6 in. to 11 in. or more, with rates about as follows, may be looked for: 4 in. in two hours, 6 in. in about twenty hours, and 9 in. to 10 in. in thirty hours, etc.

For the rainfall and flood conditions, Fanning's formula has been much used, as well as others, but must be applied with care for the particular location, the period of the year in which the rainfall occurs, as on frozen ground or with a light fluffy snowfall it requires 15 in. or 20 in. to equal 1 in. of rainfall. While assuming 4 in. to 5 in. of wet soggy snow to equal 1 in. of rainfall, the rainfall combined with the water from the melting snow with the frozen ground underneath will give quite sudden changes in the flood conditions, which will exceed any rainfall obtained from hourly rainfall records; recording gauges at dam, however, would show this.

The effect of impoundings or pondage in reducing flood conditions, if the area is sufficient, where there is one or more dams above the one to be designed, should be considered. The crest of the dam under design should be proportioned to care for the failure of at least one, or more, of these dams in addition to that of flood conditions, depending on the location of towns and villages below, and the property value and loss of life likely to occur in case of such failure.

In the design of a dam of the mass or solid section type, as shown by section, Fig. 1, the dam may be considered as a beam fixed at one end and having an uniform load, and as such may have shear at the joints, tension in the upper face and at the heel, with compression at the toes, etc.

Then to care for tension in the upper face, steel may be provided, but its calculation would be to some extent theoretical. In any event, if securely anchored to the rock formation in drilled holes, and the steel provided with split ends and wedges, and afterward grouted in carefully, this method would certainly add to the stability of the dam, especially when the dimensions were properly proportioned to care for shear. Steel bars may be embedded at an angle of about 30 degrees, as shown in Fig. 4, or some other angle, with the horizontal so that the steel will take tension as far as it is possible to make it do so under these conditions.

In preparing the foundation, care must be taken to remove surface rock that has deteriorated, to a depth that test holes show to be safe, and then the surface under the dam should be roughed, either toothed or sawtoothed, or in a similar fashion, so that pressure will tend to force the dam downstream and against the toothed or roughed surface, as shown.

This work should be carefully performed, either by the use of dynamite or steel points and wedges. But dynamite should be used in the hands of an experienced man, who understands placing shots. Especially is this true of the cut-off wall at the heel, for if such placing is done it should be carried out in the manner described.

Care should be taken to so set the upper drill holes to line for a narrower cut than is required, then removing the shattered stone by wedges and points, as it is necessary that the cut-off wall should not be shaken to such an extent that there will be liability of leakage to the downstream side.

A careful note should be taken to see if seams run at right angles with the stream, or partially with the stream; also the character of the stone and of any change in the composition, as there are cases where there are one or two different rock formations in the same river bed.

One or two test holes should be exploded with various charges, at some other point, to determine the proper charge to be used, but vertical holes should not be used, unless absolutely necessary. In this respect it might be said also that a regular 500-volt current will explode twenty holes, and such a number of holes exploded simultaneously will do better work than three or four holes ex-

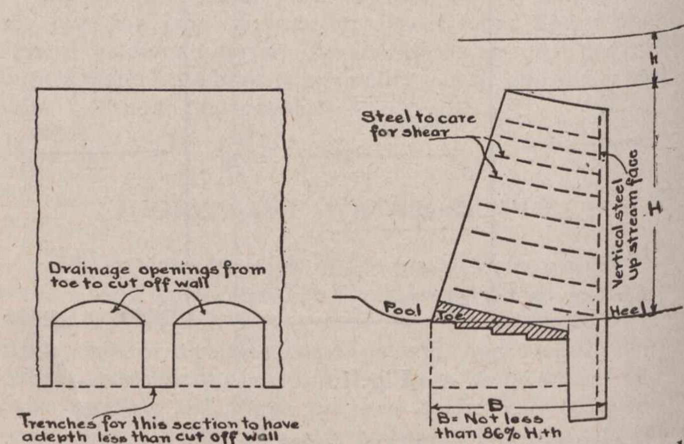

Fig. 4.—Solution of Solid Dam Showing How the Arch Can be Used for Drainage from Cut-off Wall to the Toe.

ploded at a time. Holes may be placed as described below:—

Holes running with trench on each side, about 4 ft. apart and at an angle of 45 degrees, with extra holes at each end at same angle, looking the other way. The depth of these holes will depend on the depth of trench required and the width of the same. In addition to this, holes may be drilled from side to centre as shown in the end section, Fig. 3.

The writer has seen trenches cut in this manner, by men who understood tunneling and channeling, that would meet the conditions required in every respect.