That the upper end of Curve No. 6 turns in an up-stream direction, the same as on Curves Nos. 2, 3 and 4, is only logical. All dams—and this is no exception—are provided with an excess of material at the crest, and therefore the stresses and the resulting deformation must be less in this than in lower zones; besides, for Curves Nos. 4 and 6, the outside temperature, and therefore, also, the temperature of the dam body, especially at the crest, was higher than that of the water on May 18th and on June 25th.

This higher temperature of the crest portion tends to accentuate the pointing of the upper portion of Curves Nos. 4 and 6 in an up-stream direction. Curve No. 7 (October 27th, 1915) indicates the effect of lower temperatures of the crest portion, than that of the water and of lower portions of the dam body.

The horizontal scale of these curves is exaggerated 1,200 times, in order to show the results more plainly. In reality, the curves are smooth, although the irregularities, as shown, are present.

In the foregoing description, some of the actions and behaviors of arch dams have been explained in detail. In the following the method of eliminating some of the undesirable features and making the structure act more like a theoretical arch, than otherwise possible, will be outlined.

By a simple system of iron pipes (shown in Figs. 5 to 8), distributed on the face of the contraction joints, and provided with slots at certain intervals, it is possible to deliver cement grout under pressure into the space (from ¼ to ⅜ in. wide) between adjacent walls of the contraction joints, and put initial axial compression into the whole structure, thereby making it act like a solid arch.

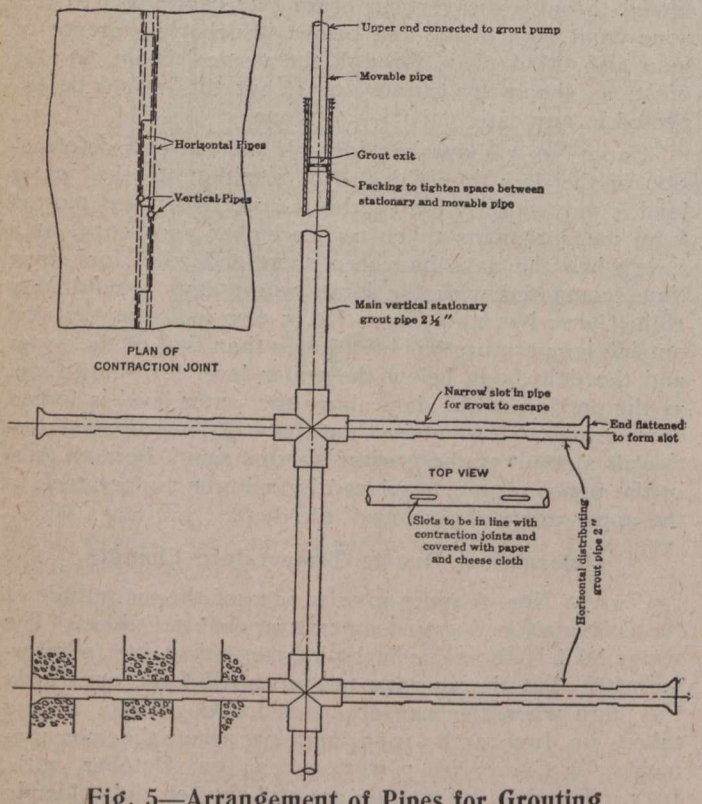

Fig. 5—Arrangement of Pipes for Grouting

At the same time, this grouting will greatly improve the watertightness of the dam.

It is well known that contraction joints, even of the most efficient design, cannot be expected to be entirely watertight. The leakage through such joints on large structures may easily amount to from 10,000 to 20,000 gallons daily, and has amounted to as much as 450,000 gallons daily. This can be eliminated by grouting the joints under pressure; still, the main purpose of this grouting is to compel the arch dam to act as an arch from the very moment the water begins to fill the reservoir.

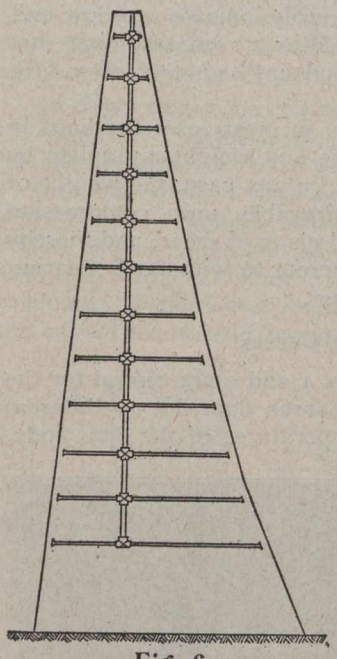

Fig. 6

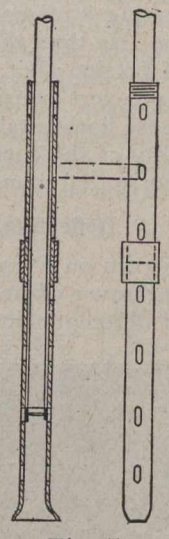

Fig. 7

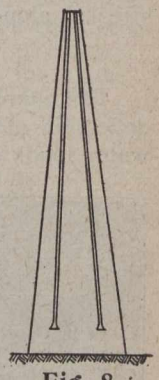

Fig. 8

Forcing the grout into the contraction joints, and keeping it there under pressure until it has set, presses the crown of the arch in an up-stream direction, and puts shear on the foundation in the opposite direction to that due to the water load. It seems logical, therefore, to use such a grout pressure as will force the crown up stream half the total amount of the deflection resulting from a full reservoir. In this way the maximum shearing stresses are reduced by one-half (reservoir full), the maximum cantilever stresses are reduced by one-half, and, when fully loaded, the arch compression should then be as nearly as possible in accordance with the values obtained from the simple formula:

$$\text{Unit compression} = \frac{\text{Unit water pressure} \times \text{upstream radius}}{\text{Thickness of section}}$$

A check on the necessary grout pressure can be obtained by sighting across the crown of the arch with a transit, after first establishing the necessary bench-marks.

Great refinement in choice of final grout pressure, however, cannot be counted on, and is not essential. Considering the great influence of the temperature on the total deflection of the arch structure, as can be seen from the curves, especially Curves Nos. 6 and 7, it is necessary to use some judgment as to what the grout pressure should be in each case.

As a general rule, it can be stated that the grouting ought to be accomplished at a time when the structure is cold, and when the joints, therefore, have opened to their maximum extent, permitting easy access for the flow of all parts of thin grout (1 cement to 7 water to start with and thicker to finish). A large dam will generally have the least volume during March, and, therefore, the contraction joints will have opened up a maximum during this time, if the reservoir is empty.

When applying the grout pressure at such a time, it should be kept in mind that the dam body is larger at any other time, due to an increase in temperature, and that, with the cracks closed, the compression per square inch