LOSS OF HEAD DUE TO BENDS IN WATER PIPES.

THERE has been much argument as to the loss of head due to bends or curves in pipe lines. Many theories have been advanced and many attempts to determine the laws which govern it have been made, but after great care, different experimenters have arrived at quite different conclusions. The result is an abundance of experimental data on the subject with small means of determining what are most feasible and most reliable.

A good deal of accurate information, derived from the data already at hand, is contained in a paper on the subject by Mr. W. E. Fuller, read by him before the New England Waterworks Association last September. It is in such a form as to admit of ready determination of the probable loss of head in bends and curves under the conditions that are ordinarily met with in waterworks practice.

It is known that water passing around curves and bends loses a greater amount of head than when passing through an equal length of straight pipe. When the direction of the flow of water is changed, the distribution of velocity and pressures in the pipe is also changed, eddies are set up, and probably other actions take place which cause this excess loss.

It is more convenient, in comparing different bends, to divide the total loss of head due to the bend into two parts: (1) that which occurs in an equal length of straight pipe; (2) the excess loss due to the curve. If this is done it is necessary to assume that the effect of roughness of pipe, condition of joints, and other matters which affect the flow in straight pipe have the same effect on the flow in curved pipes. Quite probably this is not exactly true, in which case bends of the same dimensions with different hydraulic conditions would give different excess losses of head. The experimental data are insufficient to decide this matter, but they indicate that the effect of roughness, etc., is not greatly different in the two cases. Loss of head due to bends will be considered as that portion of the total loss in excess of the loss which would occur in an equal length of straight pipe.

It is known that the disturbance caused by the bend is continued for some distance in the straight pipe beyond the bend and that the loss due to the bend continues in this straight pipe. It is also probable that the pipe preceding the bend, causing more or less eddies, according to its condition, may affect the loss due to the bend. The fact that some of the loss due to the bend takes place in the straight pipe makes it necessary in experimental work to measure the head at some distance beyond the bend itself. The loss due to pipe friction must then be eliminated before the loss due to the bend can be obtained. This pipe friction represents a large proportion of the total loss, so that errors in obtaining it materially affect the loss due to the curve. With all these difficulties to overcome it is not surprising that the different experiments should not agree closely.

Main Points at Issue.—For practical purposes it is essential to know the effect of both the radius of the bend and the velocity upon the loss of head for pipes of different sizes.

Until recent years Weisbach's formula, based upon experiments made on small pipes, was generally accepted. This formula is:

h_b (additional loss of head due to 90° bend) = $0.13 + 1.85 \frac{D^3}{2r^2} \frac{v^2}{2g}$,

in which D is diameter of pipe, r the radius of the centre line of the bend, and v the average velocity in the pipe. On this basis the greatest loss of head would be from a bend of the smallest radius, and the longer the radius the less the loss would be.

Experiments made at Detroit on pipes of 12, 16, and 30 in. in diameter, indicated losses quite different from those given by the Weisbach formula. From these experiments it was concluded that the loss of head was a minimum for bends with radii of about two and one-half times the diameter of the pipe. These experiments also indicated that the loss did not in all cases vary as the square of the velocity.

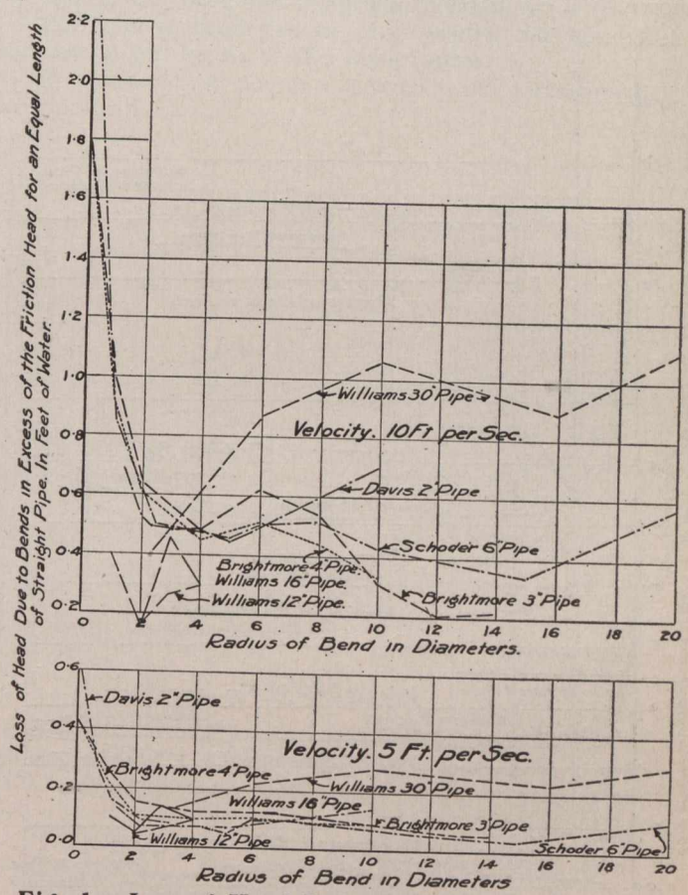

Fig. 1.—Loss of Head Due to 90° Bends. Radius in Diameters.

Further experiments made on 2, 3, 4 and 6-in. pipe showed that the Weisbach formula did not hold for larger pipes under ordinary conditions of service. These later experiments, however, did not confirm the Detroit experiments as to the minimum loss occurring with bends of a radius of 2½ pipe diameters. These different experiments indicated quite different variations of loss in relation to the velocity. Some of the experiments showed this relation as high as $v^{2.75}$, while others showed it as low as $v^{1.5}$.

These experiments give the best basis that we have of obtaining the loss of head in bends.

The experiments were all carefully made, every effort being made to eliminate errors. The conditions existing for the different experiments were nea enough alike to justify the expectation of at least an approximate agreement.

In the discussion of the question resulting from these experiments it seems to have been assumed that the loss of head in bends on different sizes of pipe should be the same when the radius of the bend in terms of the di-