Making and Laying Home-Made Pipe for Water Mains

Plymouth, Mass., has the practically unique distinction of manufacturing all the pipe which has been used for its water mains. The policy of using exclusively sheet-iron or sheet-steel cement-lined pipe was adopted many years ago (in 1855) and has been followed consistently ever since. In 1900 the town water department built a specially designed plant for making this pipe as a part of its water-works routine.

Plymouth has a comparatively small population (about 12,000), and the water pressures are not high—from 30 to 70 lb. per sq.in. While the water-works superintendent does not by any means recommend the universal use of cement-lined, sheet-steel water-mains, there seems to be no question of its satisfactory service and economy in Plymouth. It is not unlikely that in many localities where freight rates on cast-iron pipe make it almost prohibitive, home-made cement-lined pipe would be a simple and economical solution of the distribution-system problem.

The original pipe, of which there is still a large amount in use, consisted of a sheet-iron shell about 9 ft. long, lined on the inside with about ½ in. of cement mortar mixed 1:1. The pipe was laid on a bed of mortar in the trench with the ends simply butted together and covered with a steel sleeve, or collar, afterward incased in mortar. The top and sides of the pipe were then covered with 2 in. or more of mortar, all of the same proportions as the lining—1:1 cement and sand. A part of one of these mains which had been in continuous use for 60 yr. was dug up Oct. 4, 1915, in the presence of one of the editors. It was in perfect condition inside and out.

Method of Manufacturing Cement-Lined Pipe

The water-works shop built in 1900 is equipped with machinery and facilities for making pipe according to the Phipps patented method. Since then, mains up to 30 in. in diameter have been manufactured. This new pipe consists of a shell, a jacket, male and female end rings and sleeves. The shells and jackets are made of rectangular plates of soft steel, the gage depending on the diameter of the pipe. For 24-in. pipe the gage is 12; 18-in. pipe, 13; 16-in., 13; 12-in., 15; 10-in., 17; 8-in., 18; 6-in. 19; 4-in., 20. The jackets are all of 26-gage wrought iron.

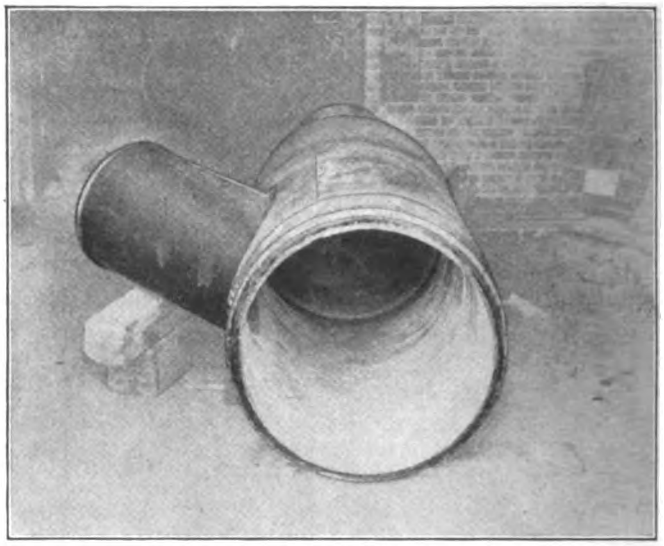


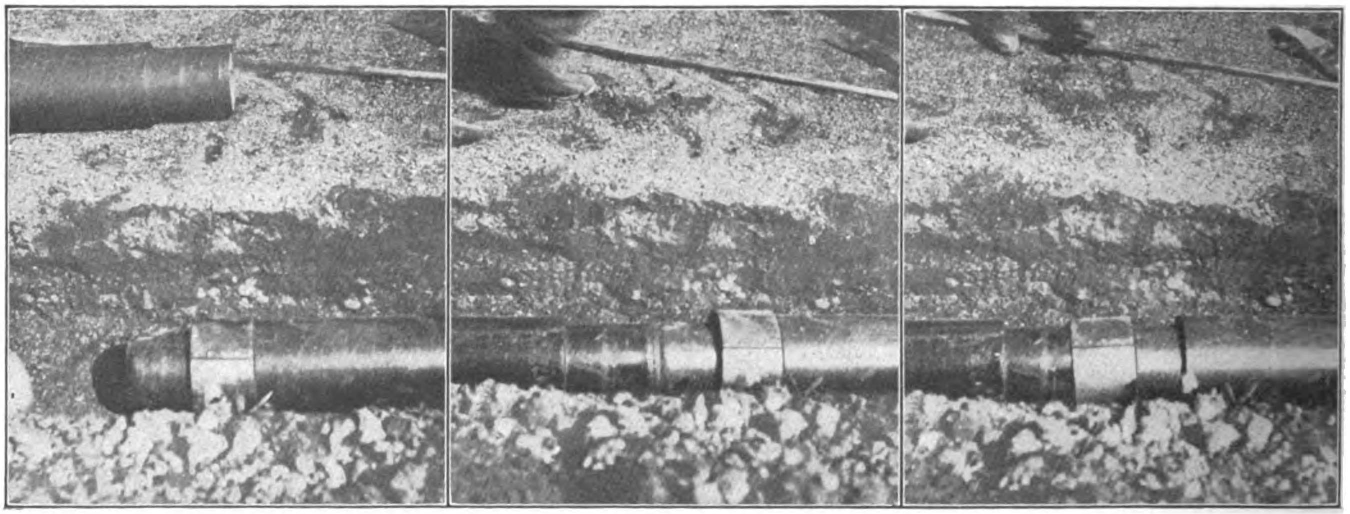
FIG. 1. A "SPECIAL" OF CEMENT-LINED SHEET-STEEL WATER PIPE

The plates for the shell are punched in a machine which makes the two rows of holes simultaneously. The holes are spaced ¾ in. c. to c., the edge of the holes being ⅝ in. from the edge of the plate. When the punching is completed, the plate or plates (two for the larger sizes of pipe) are bent to the approximate radius required, by running them through steel rolls. The plates are then riveted together by hand on a bench, or "stake," the top of which is shaped to approximately the curve of the interior of the pipe. The jacket plates are handled in the same manner, making cylinders 1½ in. larger in diameter than the shells.

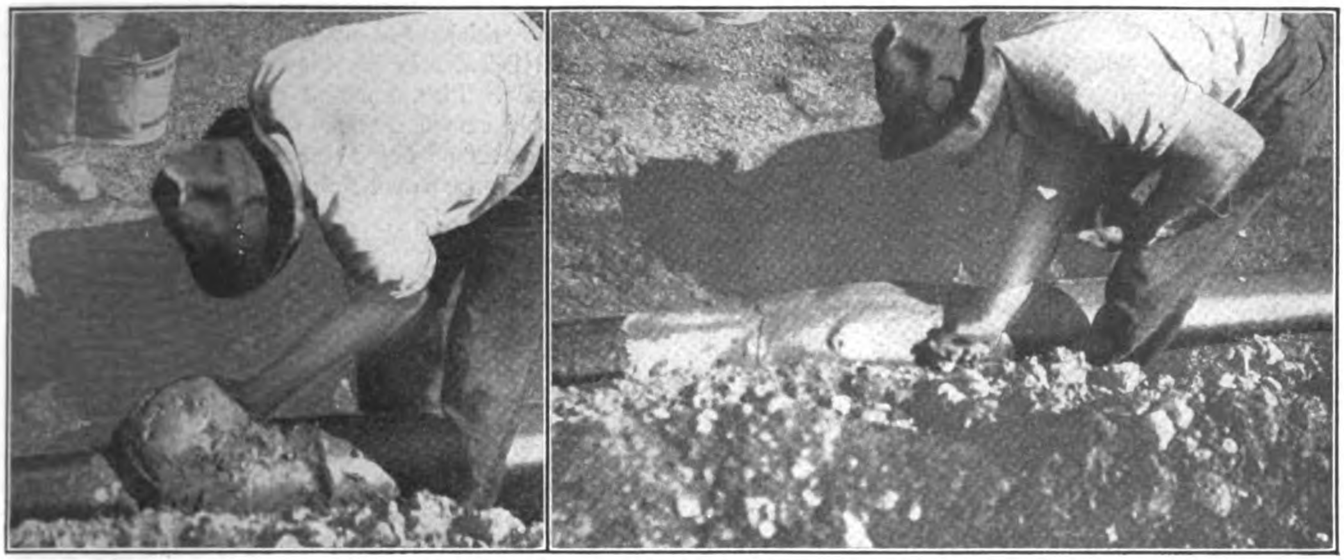
The end rings are of the best grade of cast iron; a male, or convex, ring is driven into one end of the shell and a concave, or female, ring into the other end. The thickness of the ring castings on the inside of the pipe is the same as that of the cement lining.

Lining the Shells with Cement Mortar

The lining of the pipe is accomplished by a simple machine, the essentials of which are an elevator and a revolving cylinder, or since it is slightly tapered, a "cone." The shell is placed on the elevator platform over the pit containing the cone, the top of which ex-



FIGS. 2 TO 4. STEPS IN MAKING THE JOINT IN CEMENT-LINED SHEET-STEEL WATER MAIN



FIGS. 5 AND 6. COVERING THE JOINT WITH NEAT CEMENT MORTAR

tends into the shell far enough to prevent the mortar lining from falling through. The mortar is mixed on the floor above by machine. It is made of neat Rosendale cement and water. The cone is started revolving, and the batch of mortar is dumped into the top of the pipe shell, which is then lowered on the elevator over the revolving cone. The elevator is raised again, the pipe removed and the rough places and final finish given by hand tools.

When the cement lining has properly set, the shells are stood on end alongside an elevated platform and the jackets placed over them. A special clamp is used to hold the bottom of the jacket, and four wedges hold its top in place. The space between the jacket and the shell is filled with a very wet grout of neat cement. The mixing is done on the same machine as for the lining, and the grout is conveyed in a traveling steel bucket. The pipe is then allowed to stand for 24 hr.

Making Joints—Tests of Old and New Joints

When properly cured, no difficulty is experienced in handling the pipe. It can be rolled off a wagon without injury. In laying the pipe the end rings are wedged together as tightly as possible. The joint is then plastered over with mortar, and a sleeve of the same gage iron as the shell is pushed over the connection. The whole connection is then plastered over with two or more inches of neat cement mortar (see accompanying illustrations, especially Figs. 5 and 6.)

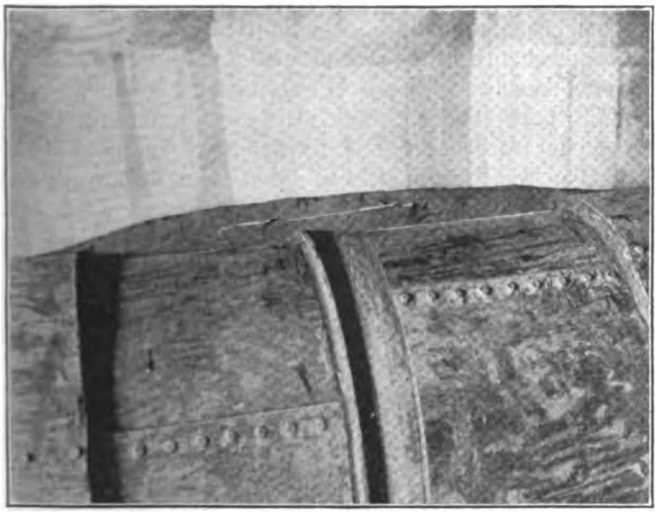


FIG. 7. COMPLETED JOINT IN CEMENT-LINED MAIN WITH CONCRETE COATING REMOVED

Tests of a 50-yr.-old 10-in. main 7,500 ft. long have shown a leakage of 9,550 gal. daily, or 4.4 gal. per lin.ft. of joint per day. Tests of a 25-yr.-old main 9,300 ft. long, half of it 16 in. and the other half 14 in. in diameter, have shown a leakage of 2.3 gal. per lin.ft. of joint per day. The joints are undoubtedly the weakest part of the old-style pipe, but tests of new joints in the new type of pipe show very little leakage under testing pressures of 150 lb. per sq.in.

Cost Data on Cement-Lined Pipe

The cost of making this pipe does not differ greatly from the cost of cast-iron pipe delivered at Plymouth under the prevailing prices. There are times, however, when there has been considerable economy in the cement-lined mains. The soil of Plymouth is dry and sandy, and there is no corrosion from the outside. On the inside of the mains there is never any trouble from tubercles or other incrustations, and the pipe maintains its maximum carrying capacity indefinitely. The loss of head from friction is of course more than in new iron pipe.

The cost of making 16-in. pipe in 1907 was $1.24 per lin.ft., including the joint sleeves. In 1908 the cost of making 7,424 ft. of 18-in. pipe was $10,714.78, or $1.44 per lin.ft. In 1910 the cost of making 8-in. pipe was 52½c. per lin.ft.; 6-in., 38.2c. per ft.; and 4-in., 27.6c. These costs do not include the cost of sleeves for the 4- and 6-in. sizes. The cement-lined pipe is lighter than cast-iron pipe, and the cost of handling and laying is less, if anything, than that for cast-iron pipe.

Records of Maintenance Costs—Making Taps

A record of the mains since 1905 is as follows: There were then 46¾ mi. in use (2- to 20-in.), the number of leaks per mile was 0.87, and the cost of repairs per mile was $11.02. In 1906 there were 47¼ mi. in use, 0.53 leak per mile, and the cost of repairs per mile was $6.67. In 1907 there were 49½ mi. in use, 0.52 leak per mile, and the cost of repairs per mile was $12.56. In 1908 there were 51½ mi. in use, 0.64 leak per mile, and the cost of repairs was \$7.71 per mile. In 1909 there were 52¼ mi. in use, 0.96 leak per mile, and the cost of repairs per mile was \$12.43. In 1910 there were 53¼ mi. in use, 0.43 leak per mile, and the cost of repairs per mile was \$3.71. In 1911 there were 53½ mi. (2- to 30-in.) in use, 0.03 leak per mile, and the cost of repairs per mile was \$3.50. In 1912 there were 54 mi. in use, 0.44 leak per mile, and the cost of repairs per mile was \$4.37. In 1913 there were 54½ mi. in use, 0.28 leak per mile, and the cost of repairs per mile was \$4.47. In 1914 there were 55¼ mi., 0.25 leak per mile, and the cost of repairs was \$2.20 per mile. These figures show a decreasing number of leaks and a decreased cost of maintenance, as much of the older pipe was replaced. The average number of leaks per mile for the whole 10-yr. period is 0.495, and the average cost of repairs per mile is \$6.86.

No difficulty is experienced in making taps in this type of water main. The jacket is cut away with a cold chisel, and the intervening cement down to the shell is chipped away in the same manner. Tapping through the shell and lining and the placing of the corporation cock are then performed in the usual way.

The superintendent of the Plymouth water-works is Arthur E. Blackmer.

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Lost-Head Diagrams for Bends in Water Pipe

By Ben Moreell*

Numerous formulas for the determination of the hydraulic head lost in a circular bend in a water pipe have been proposed from time to time. These formulas are based either upon a theoretical consideration of the mechanics of the problem or upon the author's "judgment," the latter of which may be classed as mere arbitrary assumptions. The desirability of establishing a uniform standard of practice which shall conform as closely as possible with all of the known facts led the writer into an investigation of this subject. The resulting conclusion was that theoretically there is no loss of head in water flowing around a bend and that any compensation for the loss which is known to occur should be based upon the results of actual experiments.

The first reliable recorded experiments are those of Williams, Hubbell and Fenkell on 12-, 16- and 30-in. water mains of Detroit, Mich., with velocities up to 5.8 ft. per sec. Later, experiments were made by Saph and Schoder at the Cornell hydraulic laboratory, G. J. Davis at the Wisconsin hydraulic laboratory, C. W. Alexander at the University of Birmingham and W. A. Brightmore. These later experiments were performed on 2- to 6-in. pipes, with velocities up to 16 ft. per sec.

We have also a table of constants established by Weisbach, based on the results of his own experiments and those of Dubuat. These constants are to be substituted in the equation

$$\textit{lost head} = C\frac{v^2}{2g}$$

and vary with the radius of curvature of the pipe.

Before entering upon a discussion of the results obtained, it might be well to investigate the "character" of the loss which takes place at a bend. The work of Saph and Schoder at the Cornell laboratory shows this quite clearly. Figs. 1 and 3 show velocity contours in straight and curved portions of a 2-in. brass pipe. Although the average velocity in all cross-sections of a pipe line of the same diameter throughout must be the same $\left(v=\frac{Q}{A}\right)$, it is evident from an examination of Figs. 1 and 3 that the average velocity next to the sides of the pipe in curve-distorted flow is greater than in normal flow, causing a greater loss in head due to friction on the pipe wall. This consideration leads us to the conclusion that the loss of head due to curvature is caused (1) by the resistances produced by distortion in the interior of the stream, causing boils and counter-currents even in a perfectly smooth pipe, and (2) by the increased frictional resistance on the sides of the conduit, due to the shifting of the maximum velocity from the center toward the outside of the curve.

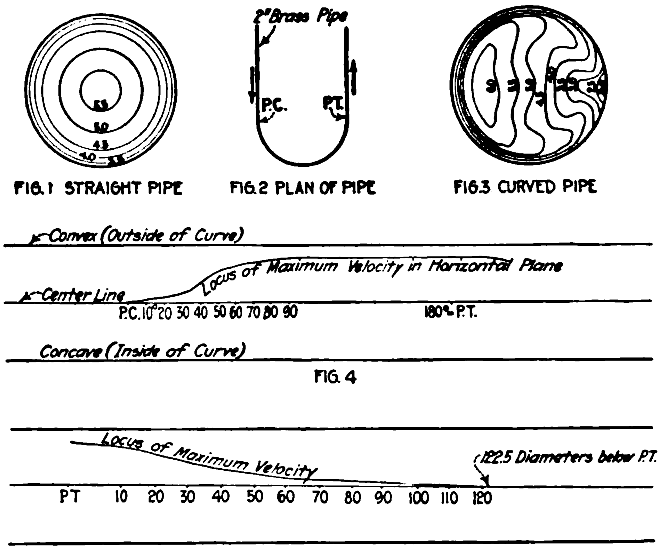

FIG. 1 STRAIGHT PIPE FIG. 2 PLAN OF PIPE FIG. 3 CURVED PIPE

FIG. 4

FIG 5

FIGS. 1 TO 5. EFFECT OF CIRCULAR BENDS ON FLOW OF WATER IN PIPE

Figs. 4 and 5 show the locus of the positions of the maximum velocity in the plane of the horizontal diameter of the pipe. As the water strikes the P. C., the position of the maximum velocity begins to move toward the outside. At 50° from the P. C. it is found that the distortion has practically been completed. There is no appreciable change in the second quadrant, the water having thoroughly adjusted itself to curvilinear motion.

The water, having traversed the curve, enters the downstream tangent under its fully distorted condition (Fig. 5). The equilibrium, however, has been destroyed, and the water gradually adjusts itself to the changed conditions until at 122.5 diameters downstream from the P. T. the condition of normal flow in a straight pipe has been attained. It is thus evident that a considerable portion of the loss due to a bend takes place in the straight portion of pipe downstream from the curve.

In all of the experiments performed, the results seem to indicate that for any given velocity, the lost head in a circular bend of a certain angle is proportional to the radius of curvature of the pipe, the ratio of radius of bend to diameter of pipe, $\frac{R}{D}$. The experiments have all been performed on bends of 90° with various radii.

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Although it seems reasonable to suppose that the excess loss in a bend would depend in some measure upon the nature of the material of which the conduit is made, the results obtained by the various investigators for the same material vary more than do those obtained by one investigator for different materials. With the limited data at hand it seems best to neglect for the time being any variation due to differences in the nature of the conduit surface.

The plan of the writer was to obtain curves from which, having given the ratio $\frac{R}{D}$ and the velocity, the designer could pick off the excess lost head due to the bend. The method employed was to plot for each velocity all of the results which could be obtained from the published data (Figs. 6 to 10).

No use was made of the data of Williams, Hubbell and Fenkell, or of Alexander. The Detroit experimenters found that for $\frac{R}{D}$ greater than 2½, as the ratio of $\frac{R}{D}$ increased, the loss increased instead of decreasing, as found by all of the other experimenters. In looking for the cause of the disagreement, the following facts may be noticed:

(1) The extreme smallness of the measured losses, combined with the comparatively low velocities available (the greatest about 3.5 ft. per sec. in the 30-in. pipe), would tend to magnify excess losses due to other effects than curvature.

(2) The upstream piezometers were placed where they would be affected by curves in the previous section.

(3) The downstream piezometers were placed too near to the P. T. of the curve to measure the total loss.

In the light of the foregoing observation, it was decided to omit these experiments from consideration, especially as they would aid in determining only the 3- and 5-ft. velocity curves (for which there are already good data), whereas our maximum is 16 ft. per sec.

In Alexander's experiments the curves were made of wood coated with shellac, while the adjacent tangents were made of cast-iron pipe of the same diameter. As he himself points out, the connection of the cast-iron pipe

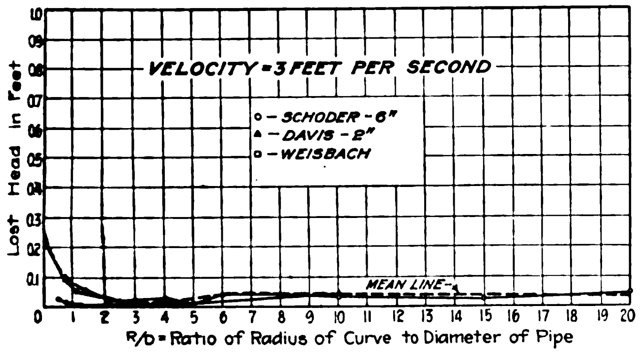

FIG. 6

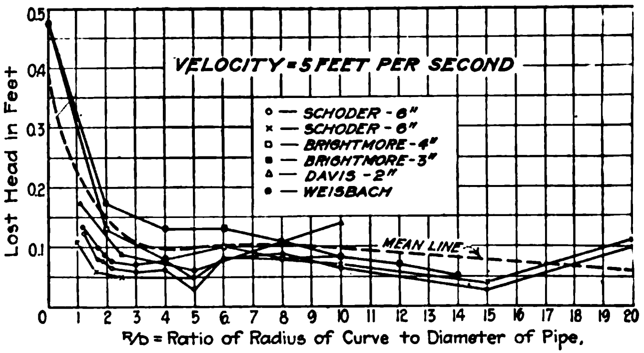

FIG. 7

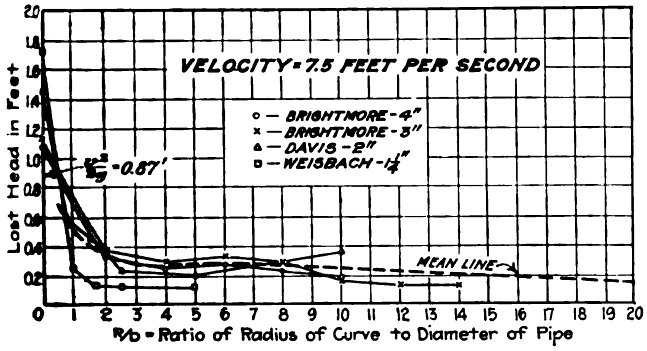

FIG. 8

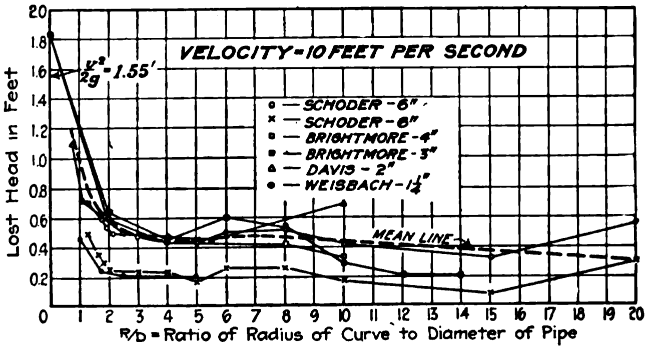

FIG. 9

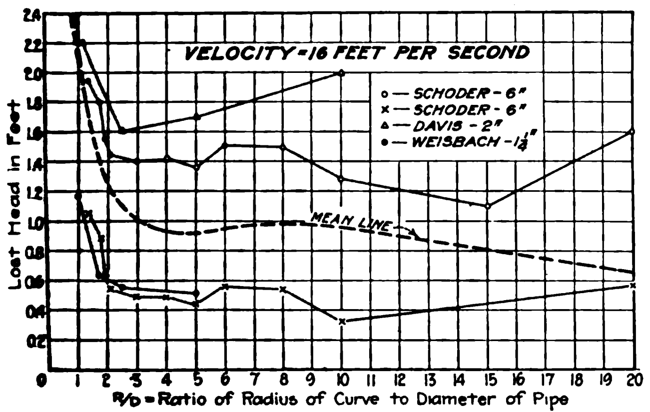

FIG. 10

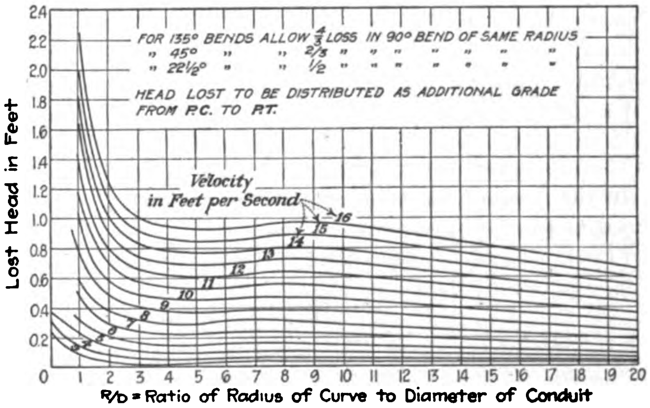

FIG. 11

FIGS. 6 TO 11. DIAGRAMS SHOWING LOSS OF HEAD DUE TO 900 BENDS IN WATER PIPE

In Fig. 6 the average values for "n" in Kutter's formula for "C" are: Schoder's 6-in. pipe, 0.009; Davis' 2-in., 0.008; Brightmore's 4-in., 0.0158; Brightmore's 3-in., 0.007