3. If the radius can be made very long, the least resistance will evidently be from the bend of greatest radius.

4. For small pipes, at least, with long radii the loss of head will be less than it would be in straight pipe of a length equal to the tangents of the curve. This occurs when the saving in friction head due to shorter line becomes greater than the excess loss due to the bend.

In order to show the loss of head for bends in ordinary use, Table I. has been prepared on the same basis as Fig. 4, giving the excess loss for bends made according to the New England Waterworks Association standard.

Table I.—Loss of Head Due to Ninety Degree Bends of the New England Waterworks Association Standard.

Size of pipe. Inches.	Radius bend. Feet.	Excess loss over loss in straight pipe of length equal to tangents. $v = 3$ ft.	$v = 5$ ft.	$v = 10$ ft.
4	1.33	0.021	0.073	0.37
6	1.33	0.025	0.082	0.40
8	1.33	0.026	0.086	0.41
10	1.33	0.027	0.089	0.42
12	1.33	0.028	0.090	0.43
16	2.0	0.026	0.085	0.41
20	2.0	0.027	0.086	0.41
24	2.5	0.026	0.085	0.41
30	3.0	0.026	0.083	0.41
36	4.0	0.026	0.083	0.40

Necessity for Considering Loss in Bends.—For most lines of small pipe, consideration of economy or convenience in laying will govern the selection of the bend or curve to use. Generally, of course, the use of very sharp bends should be avoided. In designing pipe systems about pumping stations, filter plants, and elsewhere, where many specials are necessary, a thorough understanding of the loss is important to avoid unnecessary loss of head.

For large pipes the losses in bends assume a far greater importance. The loss is more important for several reasons. First, the actual loss is greater for the larger pipes than for small pipes. Second, for the same velocity the frictional loss is less for large pipe than for small pipe, so that the loss in bends is a greater proportion of the total loss. Third, the amount of money involved is greater in the case of large pipe, and a greater expenditure is justified to avoid losses of head.

The importance of losses of head which occur on large pipe lines at bends and at other specials and at entrances and outlets of the pipe to structures is not as generally realized as it should be. It is not uncommon to find losses from such causes, in large and comparatively short pipe lines, a large percentage of the total loss. In many cases much greater capacity of the line could have been obtained by proper consideration of the losses in the design of these works, and in some cases the capacity could have been nearly if not quite doubled. Instances of this may be found in intake and suction pipes. The importance of these losses may be understood when it is realized that in 1,000 ft. of 72-in. pipe a single 90° bend poorly designed may readily reduce the capacity of the line by 5 per cent., and a poorly designed inlet or outlet of the pipe to a structure may reduce the capacity by fully 10 per cent. It is not uncommon to find structures on pipe lines in which the velocity is suddenly reduced to a small amount, after which it is again increased. Such structures are extremely wasteful in head. A careful design to secure gradual changes in velocity and to prevent eddies at specials is very essential in order to secure the proper capacity of large lines and to prevent the waste of capital in building larger pipe lines than are needed.

Loss of Head in Other Than 90° Bends.—There are but little data on losses in curves of radii other than 90° curves. Even with bends of small curvature the flow is disturbed, eddies are started, and considerable loss of head may result. It seems certain that the loss in 45° bends is greater than one-half that in 90° bends. Until more information is obtained, the writer suggests the use of the following values for losses of head:

For loss of head due to 45° bends, use three-fourths that due to 90° bends of the same radius.

For loss of head due to 22.5° bends, use one-half that due to 90° bends of the same radius.

For loss of head due to a Y-branch, use three-fourths that due to a tee.

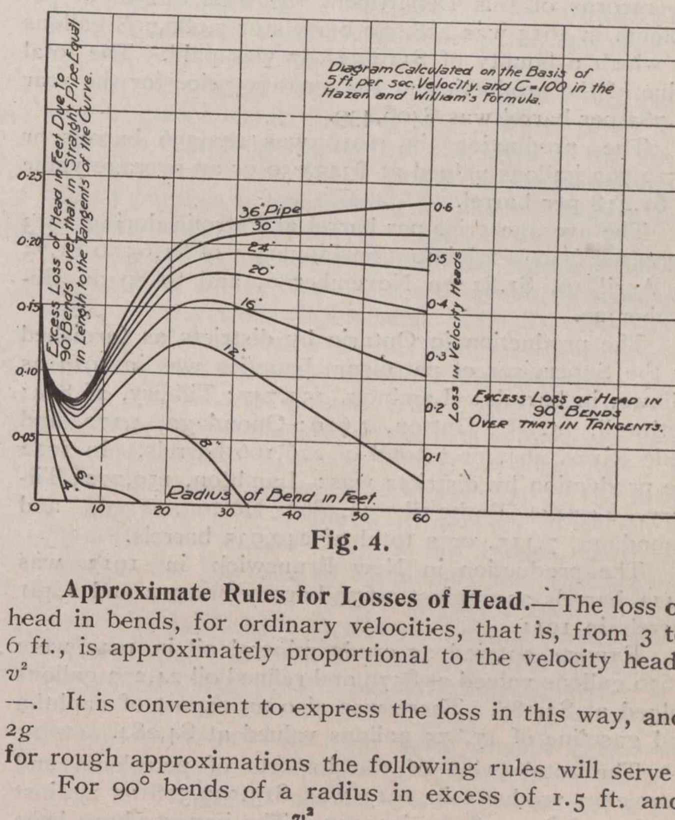

Fig. 4.

Approximate Rules for Losses of Head.—The loss of head in bends, for ordinary velocities, that is, from 3 to 6 ft., is approximately proportional to the velocity head, $\frac{v^2}{2g}$. It is convenient to express the loss in this way, and for rough approximations the following rules will serve:

For 90° bends of a radius in excess of 1.5 ft. and less than 10 ft., $h_b = \frac{1}{4}\frac{v^2}{2g}$.

For tees (bends of zero radii), $h_b = 1\frac{1}{4}\frac{v^2}{2g}$.

For sharp 90° bends of 6-in. radii, $h_b = \frac{1}{2}\frac{v^2}{2g}$.

Only further experimental work can satisfactorily settle some points involved in the loss of head in bends. Experiments which would add to the data on the loss of head in bends of large diameter would prove of the greatest service. It is for such bends that the matter is of the greater importance and the data more limited.

Messrs. Cammell, Laird and Company, of Birkenhead, England, have supplied the turbines for the Canadian Pacific steamer St. George, the installation being made at the Robins drydock at New York under the superintendence of engineers from Birkenhead.