final analysis, the engineer will be called upon to make decisions based on his experience and judgment quite apart from correct mathematical applications.

SIMPLIFICATION OF HYDRAULIC COMPUTATIONS

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The solution of some of the hydraulic problems that the city engineer meets has been facilitated by various methods recently developed. I am going to mention two of these. The first is the computation of flow or pressure drop in a pipe network. Methods are now available which enable the engineer to reduce certain apparently complicated systems to a single equivalent pipe of definite length. One pipe may be said to be equivalent to another or to a system of others when it can carry the same total flows at the same over-all pressure losses. When once this equivalent length has been found, then the answer to any one of a number of questions may be read directly from pipe-flow tables or charts, which are readily available.

In solving such problems it is usually desirable, first, to reduce all pipes in any given system to individual, equivalent single pipes of a single size. This may be done by the use of Table 1. This table shows, for example, that one foot of 6-inch pipe is equivalent to 4.06 feet of 8-inch pipe. Hence, if in a given system there were 1,000 feet of 6-inch pipe, this could be replaced by 4,060 feet of 8-inch pipe.

The next step in the solution of a network problem is to combine the pipes in pairs whenever possible and then to find the equivalent lengths of these pairs. This may be done by means of Fig. 1. First find the ratio of the lengths of the two pipes (now converted into equivalent lengths of the same size of pipe). This ratio will be called L_2/L_1. L_2 will be the smaller of the two lengths. From the righthand side of one of the lines in Fig. 1, locate this value; then read the corresponding value on the lefthand side of the line. This is the value of the ratio of the equivalent length of the pair, L_x, to the length of the stated one, L_2. Finally, multiply the smaller length L_2 by this Ratio L_x/L_2 to find the length of the pair, L_x. This will be illustrated by Example No. 1.

TABLE 1

Equivalent Length of Pipes of Various Sizes Having Same Loss of Head as One Foot of Smaller Size

$$\left(\frac{D_1}{D}\right)^{4.8704}$$

	4 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.	18 in.	20 in.	22 in.	24 in.	30 in.	D_1
	1.000												4
	7.205	1.000											6
	29.25	4.060	1.000										8
	86.72	12.04	2.965	1.000									10
	210.7	29.25	7.205	2.430	1.000								12
	446.5	61.97	15.26	5.149	2.119	1.000							14
	855.6	118.7	29.25	9.866	4.060	1.916	1.000						16
	1518.	210.7	51.91	17.51	7.205	3.401	1.775	1.000					18
	2537.	352.1	86.72	29.25	12.04	5.681	2.965	1.671	1.000				20
	4035.	560.0	137.9	46.53	19.15	9.037	4.716	2.657	1.591	1.000			22
	6164.	855.6	210.7	71.08	29.25	13.81	7.205	4.060	2.430	1.528	1.000		24
		2537.	624.8	210.7	86.72	40.93	21.36	12.04	7.205	4.529	2.965	1.000	30
		6164.	1518.	512.2	210.7	99.47	51.91	29.25	17.51	11.01	7.205	2.430	36

L_x/L_2 PLOTTED ON THE LEFT. L_2/L_1 PLOTTED ON THE RIGHT.
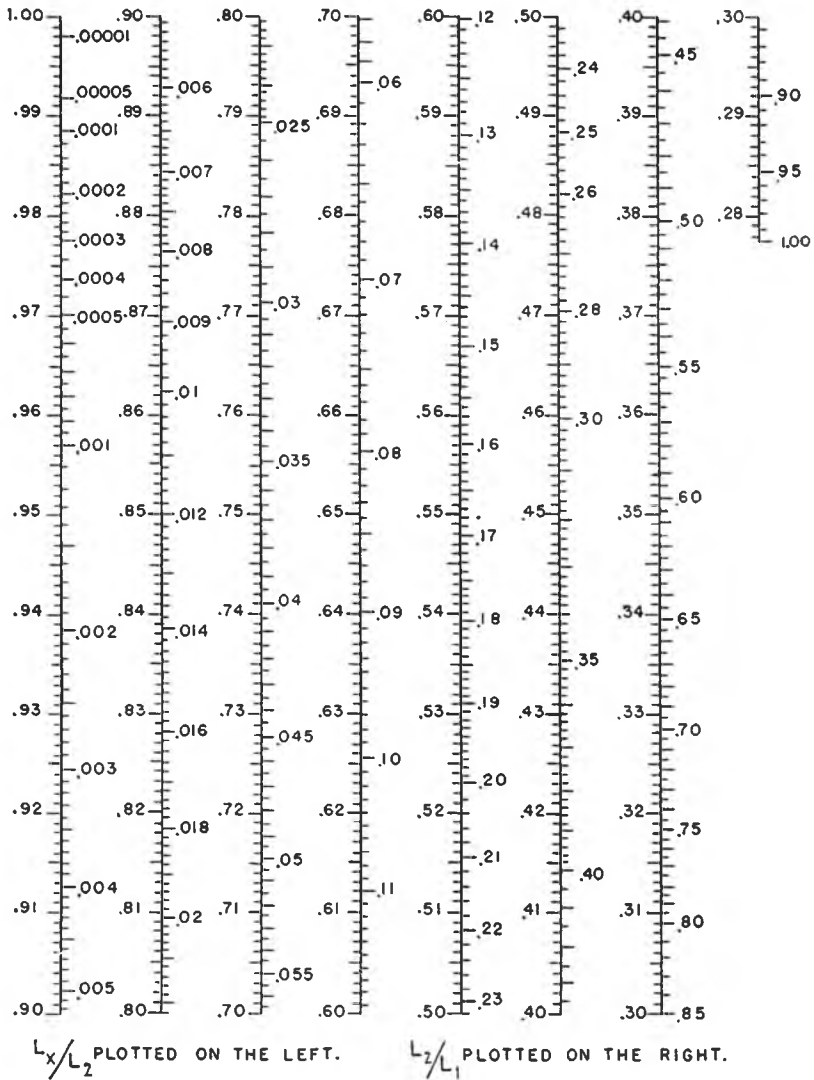
Fig. 1. Chart for determination of equivalent lengths of parallel pipes.

EXAMPLE 1

What length of 12-inch pipe is equivalent to a pair of parallel pipes of equal roughness, one a 10-inch pipe, 1,500 ft. long, and the other a 12-inch pipe 1,000 ft. long?

Solution:

The 10-inch pipe is equivalent to $1,500 \times 2.430$ (from Table 1) $=$ 3,645 ft. of 12-inch pipe. Call this L_1.

$L_2/L_1 = 1,000/3,645 = 0.274$; $L_x/L_2 = 0.474$ (from Fig. 1).

Then $L_x = 0.474 \times 1,000 = 474$ ft. of 12-inch pipe (same roughness as original pipes).

A more complicated problem is worked out in Example No. 2. This computation also shows the additional correction that must be made when the pipes have different roughness factors, as will be noted in examining the solution. The equivalent length of AG_1 (624 feet) has been corrected by applying a factor equal to the ratio of the two C's to 1.85 power to find 446 feet, the equivalent length of this portion of the pipe system in terms of a pipe with roughness factor 100. Fig. 2 is the system dealt with in this example.

EXAMPLE 2

Find the equivalent length in 8-inch pipe, $C = 100$, of the pipe network shown in Fig. 2.

Method:

Find the equivalent length of the loop BD in 8-inch and add to AB and to DFG to get the equivalent length of the line $ABDFG$.

Find the equivalent length of the loop KN in 8-inch and add to AJK and to NG to get the equivalent length of the line $AJKNG$.

Find the equivalent length AG_1, of $AJKNG$ and of $AIHG$ (change first to 8-inch) and change to length of $C = 100$; then find the equivalent length of this and of $ABDFG$ which is the answer AG.

Solution:

BED in 8-inch pipe $= 2,000 \times 4.060$ (from Table 1) $= 8,120$ ft.
$BCD/BED = 2,000/8,120 = 0.246$; (from Fig. 2) $BD/BCD = 0.491$
$BD = 0.491 \times 2,000 = 982$ ft. of 8-inch
$ABDFG = 982 + 4,000 = 4,982$ ft. of 8-inch, $C = 100$
$KLN/KMN = 2,000/2,000 = 1.0$; (from Fig. 2) $KN/KMN = 0.2775$
$KN = 0.2775 \times 2,000 = 555$ ft. of 8-inch
$AJKNG = 555 + 4,000 = 4,555$ ft. of 8-inch, $C = 120$
$AIHG$ in 8-inch $= 4,000/2.965$ (from Table 1) $= 1,350$ ft., $C = 120$
$AIHG/AJKNG = 1,350/4,555 = 0.296$; (from Fig. 2) $AG_1/AIHG = 0.462$
$AG_1 = 0.462 \times 1,350 = 624$ ft. of 8-inch, $C = 120$
AG_1 for $C = 100$, $624 \times (100/120)^{1.85} = 446$ ft. of 8-inch
$AG_1/ABDFG = 446/4,982 = 0.0895$; (from Fig. 2) $AG/AG_1 = 0.641$
$AG = 0.641 \times 446 = 286$ ft. of 8-inch, $C = 100$ (answer).

NOTE: I am indebted to the American Water Works Association for permission to include the table and figures referred to in this paper.
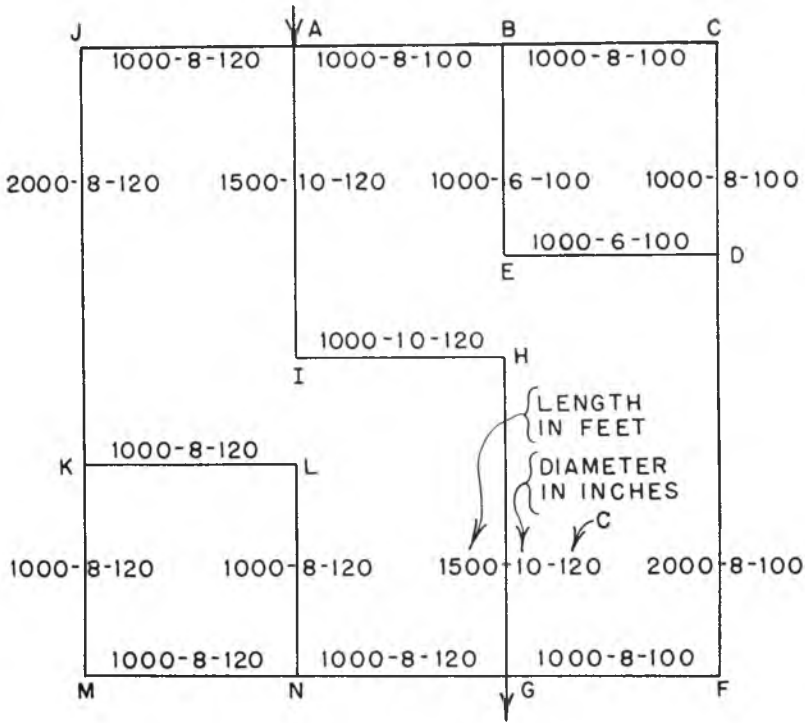
Fig. 2. System of pipes used in sample problem.

The other simplification of hydraulic computations which I wish to call to your attention is the use of so-called probability paper, designed by the late Allen Hazen, a noted sanitary engineer. This special variety of variably spaced cross-section paper greatly facilitates the estimation of probabilities or frequencies of occurrence of such important events as excessive storm flow in sewers, high flood stages in rivers, or low yields from surface water supplies, and other similar phenomena of interest to a city engineer. Such available data as relate to the problem may be plotted on this paper, and the resulting curve, when the proper type of paper is chosen, is frequently straight or nearly so. The extension of the curve within or even beyond the limits of the available data is thus greatly facilitated, and one may thus estimate the probable frequency of occurrence of storm intensity, gage heights, or yields, etc., of any desired magnitude, even of extreme magnitude. The paper to which I refer is made by the Codex Company of Norwood, Massachusetts, and I do not know of any other manufacturer who sells this. The complete explanation of the methods of using this paper is given in the book, *Flood*

Flows, by Allen Hazen, published by John Wiley & Sons, New York City.

You might find by writing to us that we could help clear up some points regarding the use of these methods that may not have been made clear in this short discussion.

VIEWS OF A RAILROAD ENGINEER ON ROAD AND DITCH ASSESSMENTS

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It is with some misgiving that I present this paper to a body of men empowered by law to levy such assessments.

You are all aware of the fact that often the railroad engineer does not agree with common practice in the levying of such assessments, as to either the principle or the application of the principle.

For this reason, I rather welcome the opportunity to come here, today, and discuss with you some of the major points on which our opinions as to the proper methods of procedure usually do not agree. Perhaps first we should define the term "special assessment".

SPECIAL ASSESSMENTS

A special assessment is not a tax levied against individuals or corporations, according to their income, their ability to pay, or their willingness or unwillingness to pay. It is not levied as a fine on account of any action or supposedly improper performance of the assessed, nor can its amount be determined in any way by the fact that the existence of the property of the assessed may not be welcomed in the community or may be considered to be a nuisance.

A special assessment is a special tax on real estate, and the courts have consistently held that a special assessment levied for the purpose of defraying the cost of a public improvement shall be levied against the land, or real estate, which will be benefited by the improvement, and that the amount assessed against each parcel of land shall bear the same ratio to the total cost of the improvement as the benefits derived by that parcel of land bear to the total benefits to all of the property affected.

Incidentally, it is generally held that the assessment in no instance shall exceed the amount of the benefits and, in most states, statutes provide that it shall not exceed some fixed