CAST IRON PIPE

CAST IRON PIPE RESEARCH ASSOCIATION
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cipra

An Association of Quality Producers
Dedicated to Highest Pipe Standards
Through Continuing Research

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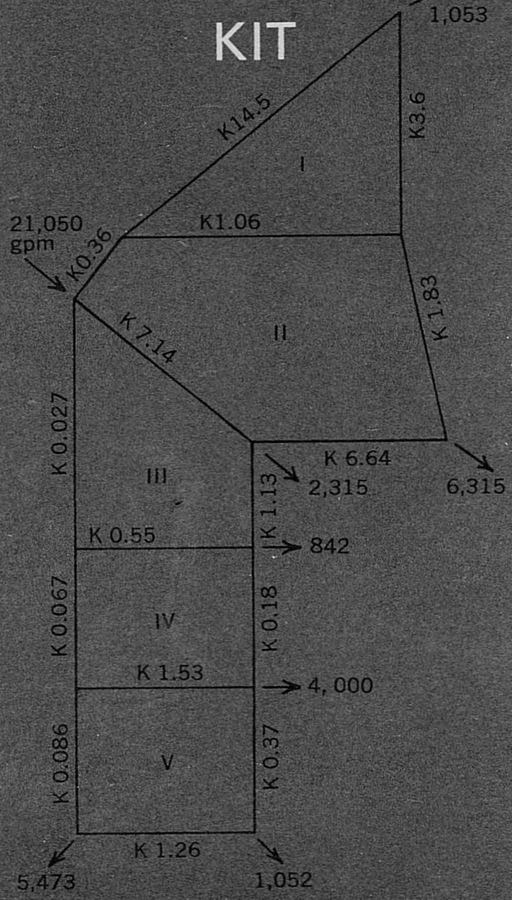
P 119

CIPRA PIPE NETWORK CALCULATOR KIT



CAST IRON PIPE

THE MARK OF PIPE THAT LASTS OVER 100 YEARS

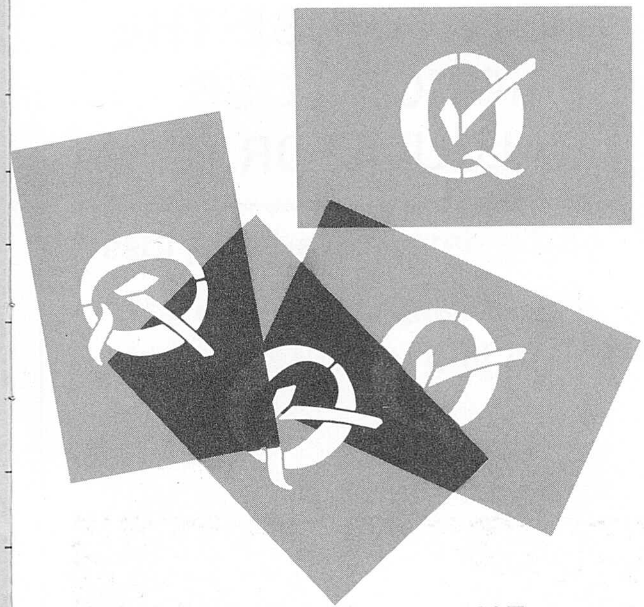
Dale T. Carlson

Keep your CIPRA calculator always handy

Keep it in this special pocket folder

A new aid in determining Water Pipeline Flow and Friction Loss

This new slide chart marks the first time aid in initial estimating of pipeline flows has been provided in this convenient form. You will find your CIPRA calculator valuable in analyzing your pipeline network problems and arriving at speedier answers through quicker repetitions. Use it for all your water distribution network analysis work. It can even aid you in saving costs when utilizing computer services by providing more accurate assumed flows and thereby reducing the number of machine iterations required to arrive at predetermined accuracy.



THE MARK OF PIPE THAT LASTS OVER 100 YEARS

More than 60 water utilities have cast iron pipe installations at least a century old—proof that for longest, lowest cost-waterline service, cast iron pipe is your wisest choice.

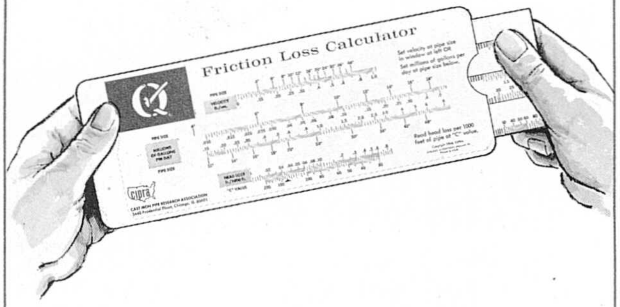
Another service to engineers by

cipra

Cast Iron Pipe Research Association has over half a century of close working relationship with consulting engineers—providing technical and test data on pipe, as well as on standards, through the services of CIPRA field engineers and its Chicago headquarters staff. Call on this experienced counsel for help in all matters of waterline pipe usage.

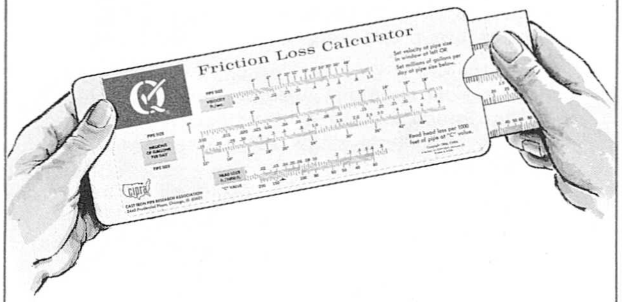
HOW TO USE THE FRICTION LOSS CALCULATOR...

1. To determine head loss for given flow or pipe line velocity:



Set the flow or velocity in the pipe over the pipe size and read the head loss on the bottom scale over the known or assumed "C" value.* Thus for a 24-inch Cement Lined Cast Iron Pipe (C=140) delivering 4 mgd, the head loss will be 0.5 ft./1000 ft. and the velocity will be 1.97 ft./sec.

2. To determine pipe size for given flow and allowable head loss:



Set the allowable head loss over the "C" value* on the bottom scale and select the size of pipe to deliver the desired quantity on the middle scale. For example, if it is desired to deliver 300,000 gpd (0.3 mgd) with a head loss not exceeding 1.0 ft./1000 ft., the head loss would be set over C=140 and an 8-inch Cement Lined Cast Iron Pipe would be selected as the size nearest the desired delivery of 0.3 mgd.

*Many flow tests have been conducted on Cement Lined Cast Iron Pipe which justifies the use of a "C" value equal to 140. Actual tests by competent engineers on new pipe and on installations after many years of service show "C" values as high as 150. In the table below are listed "C" values as determined by actual tests from various cities over the country.

Flow Tests of Cement-Lined Cast-Iron Pipe After Extended Periods of Service

Location	Size in.	Test Age years	C Value
Birmingham, Ala.	6	1	148
		6	141
		12	138
		17	133
Catskill, N.Y.	16	25	136
Champaign, Ill.	16	13	137
		22	139
		28	145
		36	130
Charleston, S.C.	5.78	new	145
		12	146
		16	143
	12	15	145
		25	136
Chicago, Ill.	36	1	147
		12	151
Concord, N.H.	12	13	143
		29	140
		36	140

Flow Tests of Cement-Lined Cast-Iron Pipe After Extended Periods of Service

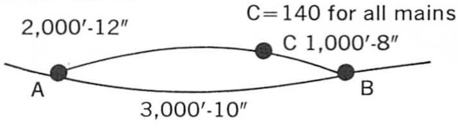
Location	Size in.	Test Age years	C Value
Danvers, Mass.	20	31	135
		38	133
Greenville, S.C.	30	13	148
		20	146
	30	19	148
		25	146
Greenville, Tenn.	12	13	134
		29	137
		36	146
Knoxville, Tenn.	10	16	134
		32	135
		39	138
Manchester, N.H.	12	5	151
		19	132
		26	140
Safford, Ariz.	10	16	144

*Journal AWWA v. 57, no. 6, June, 1965

EQUIVALENT PIPES

In the design of parallel (reinforcing) mains, it is often convenient to employ the technique of hydraulic equivalents. This same technique can be used to simplify complex distribution networks before proceeding with a Hardy Cross analysis.

As a typical example, assume that it is desired to reduce the piping complex shown below to an equivalent single 12″ main between points A and B.



First reduce the series pipes, ACB, to a single equivalent main by assuming any convenient flow such as 0.50 mgd.

head loss in AC = 0.32 × 2 =	0.6 ft.
head loss in CB =	2.3
head loss in AB =	2.9 ft.

Hence, the series pipes ACB may be replaced by (2.9 ÷ 2.3) 1,000 = 1,260 ft. of 8″ pipe (or any other convenient pipe size by similar calculation).

In reducing the parallel mains to a single equivalent main, assume any convenient head loss between points A and B such as 3 ft. then,

in the 10″ pipe,
h/L = 3/3,000 = 1 ft. per 1,000′ and
Q = 0.57 mgd
in the 8″ pipe,
h/L = 3/1,260 = 2.38 ft. per 1,000′ and
Q = 0.51

The *total flow* between A and B, for the assumed head loss, is 1.08 mgd.

A 12″ pipe (C = 140) would discharge 1.08 mgd with a head loss of 1.33 ft. per 1,000 ft. Hence, the system shown could be considered hydraulically equivalent to a 12″ pipe (3 ÷ 1.33) 1,000 = 2,250 ft. long.

HOW TO USE THE PIPE NETWORK CALCULATOR...

The Hardy Cross Method

(Head loss calculations of the CIPRA calculator are based on the Hardy Cross Method of analysis)

The analysis of the flow of water in the pipes of a distribution system is complicated. A method of analysis developed by Prof. Hardy Cross* leads to a satisfactory solution of flow in pipe networks.

There are two fundamental conditions which must prevail in any network: (1) The total flow reaching any junction equals the total flow leaving it; and (2) the total change in head along any *closed* path is zero.

The loss of head in a length of pipe may be represented by $h = KQ^n$, where K is a coefficient of resistance and Q is the delivery. When the Hazen-Williams formula is used, $h = KQ^{1.85}$. If the distribution of flow in the network assumed initially were correct, the change of head around any *closed* circuit would be zero.

Considering for the moment a single circuit, write for each pipe

$$Q = Q_o + \Delta$$

where Q is the corrected flow, Q_o is the assumed flow and Δ is the flow correction. Then

$$KQ^n = K(Q_o + \Delta)^n = K(Q_o^n + nQ_o^{n-1}\Delta + \ldots.)$$

If Δ is small compared with Q_o, the remaining terms in the expansion may be neglected.

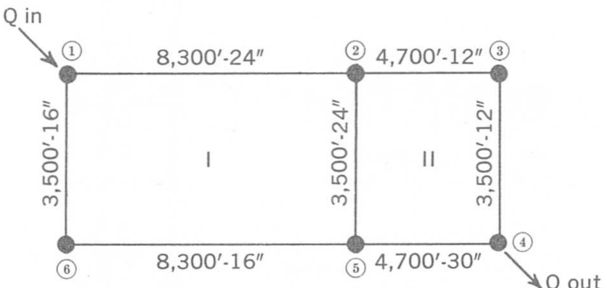
For the assumption that $\Sigma KQ^n = 0$,

$$\Sigma KQ_o^n = -\Delta\Sigma nKQ_o^{n-1}$$

$$\Delta = \text{Correction} = -\frac{\Sigma KQ_o^n}{\Sigma nKQ_o^{n-1}} = -\frac{\Sigma A}{\Sigma B}$$

*Cross, Hardy. "Analysis of Flow in Networks of Conduit or Conductors." Bul. 286, Engineering Experiment Station, University of Illinois, Urbana, Illinois—November, 1936.

SOLVING NETWORK PROBLEMS



C=140 for all pipes

STEP 1—Sketch layout of the distribution system, showing all put-in and take-off points. Indicate size and length of each pipe and its known or assumed Hazen-Williams C factor. Number each junction point, and each circuit.

STEP 2—Prepare table similar to that shown below, and enter physical data in columns 1 thru 6. The "K per 1,000 ft." value is read directly from the "K" value scale after setting the pipe size under the known or assumed C value. The "K" value for each pipe in the network (column 7) is next computed.

STEP 3—Assume any flow distribution, each flow being expressed as a percentage of the total flow and enter in column 8.

STEP 4—Select a closed circuit and enter the values of the "A" factor and "B" factor in columns 9 and 10. With the "K" value from column 7 set over the index mark, the "A" factor and "B" factor values can be read directly beneath the percentage of total flow. Values of the "A" factor are recorded with regard to this sign convention: head losses from clockwise flows are considered positive, from counterclockwise flows as negative. Values of the "B" factor are recorded without respect to sign.

STEP 5—The values of the "A" factors and "B" factors in each circuit are summed up with due regard to sign. A correction for each circuit, Δ, is calculated by dividing the sum of the "A" factor values by the sum of the "B" factor values.

STEP 6—Apply the correction, Δ (a percentage of the total flow), to each pipe in the circuit (column 11) to arrive at "first corrected flow values" (column 12). Note the pipes common to two circuits receive two corrections, one from each circuit.

The above steps are repeated, arriving at "second corrected flow values," and so on, until the corrections become negligible—indicating a hydraulic balance for the given conditions.

1	2	3	4	5	6	7	8	9	10	11	12
Circuit	Pipe	Dia.	C	K per 1000′	x L (1,000′)	=K	Q_0 (%)	A	B	Δ	Q_1 (%)
	1-2	24″	140	.022	8.3	0.183	+70	+470	13	+4	+74
I	*2-5	24″	140	.022	3.5	0.077	+65	+173	5	+4 −3	+66
	5-6	16″	140	.155	8.3	1.29	−30	−690	43	+4	−26
	6-1	16″	140	.155	3.5	0.54	−30	−290	18	+4	−26
							Σ =	−337	=79		
							Δ = −(−337/79) = +4.3				
	2-3	12″	140	.62	4.7	2.91	+5	+57	21	+3	+8
	3-4	12″	140	.62	3.5	2.17	+5	+42	16	+3	+8
II	4-5	30″	140	.0073	4.7	0.0343	−95	−157	31	+3	−92
	*5-2	24″	140	.022	3.5	0.077	−65	−173	5	+3 −4	−66
							Σ =	−231	=73		
							Δ = −(−231/73) = +3.2				

*Common to 2 circuits

EQUATION OF PIPE

It is frequently desired to know what numbers of pipe of a given size are equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipe of different sizes is proportional to the squares of their diameters; thus one 4-inch pipe will deliver the same volume as four 2-inch pipe. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies about as the square root of the fifth power. This table is calculated on this basis. The figures opposite the intersection of any two sizes is the number of the smaller-sized pipe required to equal one of the larger; thus one 4-inch equals 5.7 two-inch.

Diam. Inches	½	¾	1	2	3	4	5	6	8	10	12	14	16	18	20	24	30	36	42	48
2	32.0	11.7	5.7	1.0																
3	88.2	32.0	15.6	2.8	1.0															
4	181.	65.7	32.0	5.7	2.1	1.0														
5	316.	115.	55.9	9.9	3.6	1.7	1.0													
6	499.	181.	88.2	15.6	5.7	2.8	1.6	1.0												
8		372.	181.	32.0	11.7	5.7	3.2	2.1	1.0											
10		649.	316.	55.9	20.3	9.9	5.7	3.6	1.7	1.0										
12			499.	88.2	32.0	15.6	8.9	5.7	2.8	1.6	1.0									
14			733.	130.	47.1	22.9	13.1	8.3	4.1	2.3	1.5	1.0								
16				181.	65.7	32.0	18.3	11.7	5.7	3.2	2.1	1.4	1.0							
18				243.	88.2	43.0	24.6	15.6	7.6	4.3	2.8	1.9	1.3	1.0						
20				316.	115.	55.9	32.0	20.3	9.9	5.7	3.6	2.4	1.7	1.3	1.0					
24				499.	181.	88.2	50.5	32.0	15.6	8.9	5.7	3.8	2.8	2.1	1.6	1.0				
30									27.2	15.6	10.0	6.7	4.8	3.6	2.8	1.7	1.0			
36										24.6	15.6	10.6	7.6	5.7	4.3	2.8	1.6	1.0		
42										36.2	22.9	15.6	11.2	8.3	6.4	4.1	2.3	1.5	1.0	
48										50.5	32.0	21.8	15.6	11.7	8.9	5.7	3.2	2.1	1.4	1.0