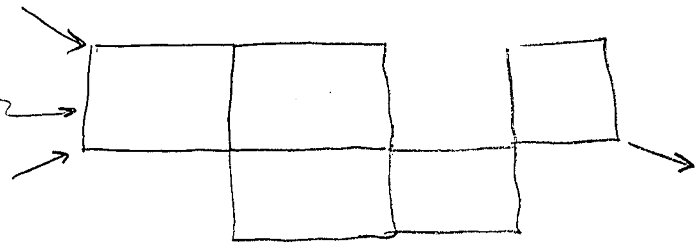
I. INTRO

A. MOST PIPING SYSTEMS ARE COMPLEX

1. CITY WATER DISTRIBUTION
2. OIL REFINERIES

B. CONTAIN MULTIPLE LOOPS

EACH LINE IS A PIPE



PLAN VIEW

C. USUALLY NEED TO DETERMINE Q_i, WHERE i = PIPE NO.

II SOLUTION TECHNIQUES

A. DARCY WEISBACH

1. $h_f = f \frac{L}{D} \frac{V^2}{2g}$
2. TYPE II PROBLEM: ITERATIVE!
   a. guess f_1
   b. iterate for pipe 1 until you know Q
   c. but you guess an initial Q for each pipe
3. DOUBLE "DO-LOOP"

B. HAZEN - WILLIAMS

1. EMPIRICAL
2. VELOCITY
   a. ENGLISH UNITS: $V = 1.318\, C_H R^{0.63} S_E^{0.54}$
   b. SI : $V = 0.85\, C_H R^{0.63} S_E^{0.54}$

where

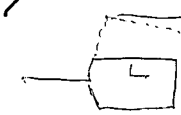
$V =$ mean fluid velocity in pipe, LT^{-1}

$R =$ hydraulic radius $= \frac{A}{P}$ where

$A = \pi D^2/4$

$P =$ "wetted perimeter," πD

$$R = \frac{\pi D^2/4}{\pi D} = \frac{D}{4}$$



$S_E =$ slope of EGL $= h_L/L$

$C_H =$ Hagen-Williams resistance coefficient
. see page 4/7 for valves

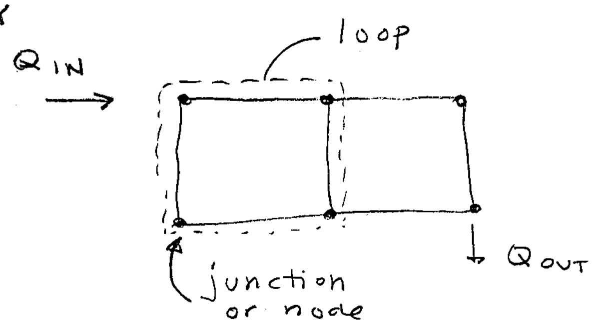
3. NOTES:

? a. USED FOR WATER ONLY!

b. $C_H = \phi$ (roughness only); $\neq \phi(\mathrm{Re})$

III. SOLUTION STRATEGY

A. TRUTHS



? 1. Σh_L for any given loop $= 0$

2. $\Sigma Q_{IN} = \Sigma Q_{OUT}$ at each junction

B. PROCEDURE

1. GUESS Q IN EACH PIPE

   a. remember TRUTH 2 ABOVE
   b. this is initial flow distribution
   c. you will correct it with

$$Q = Q_0 + \delta \quad \text{where}$$

$\delta =$ correction
$Q =$ true flow in pipe (calculated)
$Q_0 =$ assumed flow

2. EXPRESS $h_L = KQ^x$ where

e.g. $h_L = f\frac{L}{D}\frac{V^2}{2g} = f\frac{L}{D}\frac{Q^2}{A^2 2g}$

$h_L =$ head loss in each pipe (usually neglect minor losses) $= KQ^2$ with $K = f\frac{L}{D}\frac{1}{A^2 2g}$

$K =$ coefficient

Q = flow

x = exponent

C. NEED TO EXPRESS HAZEN-WILLIAMS IN THIS FORM. USING THE <u>ENGLISH</u> UNITS EQN,

$$Q = AV = \frac{\pi D^2}{4}\left(1.318\, C_H \left(\frac{D}{4}\right)^{0.63} S_E^{\,0.54}\right) \quad \text{OR}$$

$$\Longrightarrow \quad Q = 0.432\, C_H\, D^{2.63}\, S_E^{\,0.54}$$

but $h_L = S_E \cdot L$, so $S_E = \frac{h_L}{L}$

$$Q = 0.432\, C_H\, D^{2.63} \left(\frac{h_L}{L}\right)^{0.54}$$

solving for h_L yields

$$\boxed{h_L = 4.73\, L\, D^{-4.87}\, C_H^{\,-1.85}\, Q^{1.85}}$$ ENGLISH UNITS ONLY

so in $h_L = K Q^x$,

$$K = 4.72\, L\, D^{-4.87}\, C_H^{\,-1.85}$$

$$x = 1.85 \qquad (\text{D-W } x = 2)$$

D. NEED TO KNOW VALUE OF CORRECTION, δ

1. WE WANT $\sum h_{L_{\text{LOOP}}} = \sum_{i=1}^{n} K_i Q_i^{2} = 0$

approximate 1.85 with 2 for expansion <u>only</u>

2. USING $Q = Q_o + \delta$,

$$\sum_{i=1}^{n} K Q_i^{2} = \sum_{i=1}^{n} K_i (Q_{o_i} + \delta)^2 = 0$$

$$0 = \sum_{i=1}^{n} K_i \left(Q_{o_i}^{2} + 2 Q_{o_i}\delta + \cancel{\delta^2}\right)$$

neglect - small

$$0 = \sum_{i=1}^{n} K_i Q_{o_i}^{2} + 2\delta \sum_{i=1}^{n} K_i Q_{o_i}$$

solving for δ yields

$$\delta = -\frac{\sum K_i (Q_{oi})^2}{1.85 \sum K_i Q_{oi}}$$

change 2 back to 1.85 now

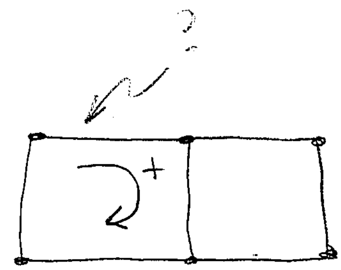
but since $h_L = \sum K_i (Q_{oi})^2$

$$\delta = \frac{-\sum h_{L\,\text{Loop}}}{1.85 \sum |h_L/Q|}$$

preserves "sign"

IV. HOW TO SOLVE

A. ASSIGN SIGNS
  1. CLOCKWISE = +
  2. COUNTERCLOCKWISE = −



B. ASSIGN Q_o TO ALL PIPES
  1. $\sum Q_{oj} = 0$
  2. USE PIPE DIAMETERS & LENGTHS TO HELP

C. COMPUTE h_L FOR EACH PIPE

D. CORRECT THE Q BY FINDING δ

E. APPLY TO EACH PIPE AND REPEAT

TABLE OF C_H VALUES

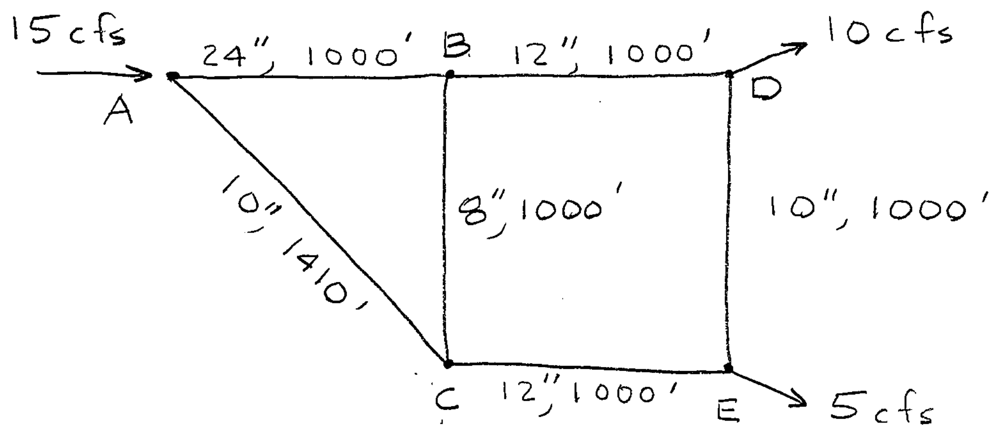
C	CONDITION
140	Extremely smooth, straight pipes; asbestos cement
130	Very smooth pipes; concrete; new cast iron
120	New welded steel
110	Vitrified clay; riveted steel
100	Cast iron after years of use
95	Riveted steel after years of use
60-80	Old pipes in bad condition

plastic ?

Ref: Streeter, V.L. and E.B. Wylie. 1985. Fluid Mechanics, 8th Edition. NY, NY: McGraw-Hill Book Co.

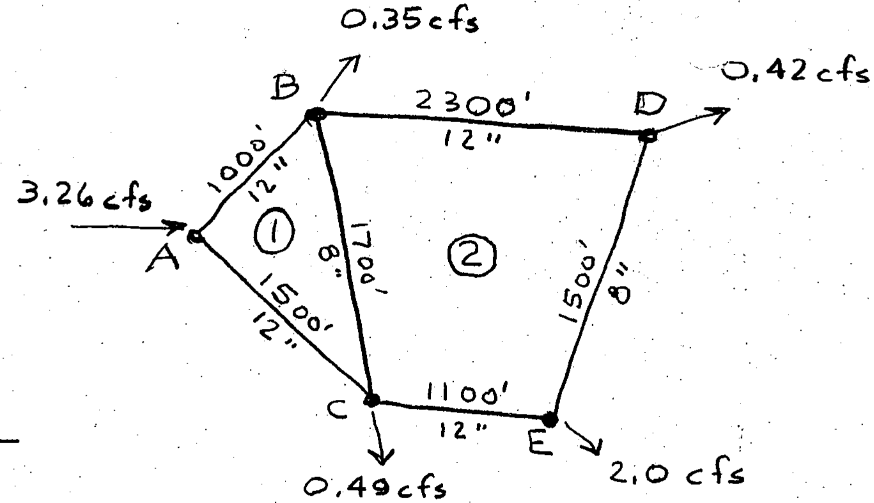
GIVEN: WELDED STEEL PIPE NETWORK AS SHOWN

FIND: FLOW IN EACH PIPE. QUIT WHEN $|\delta| \leq 0.02$ cfs



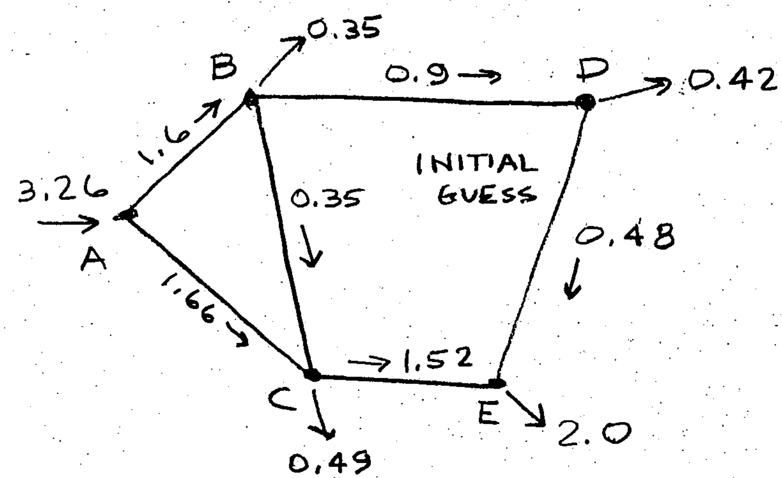
Example Using Hazen-Williams Equation

Welded Steel: Hazen-Williams C value is equal to 120



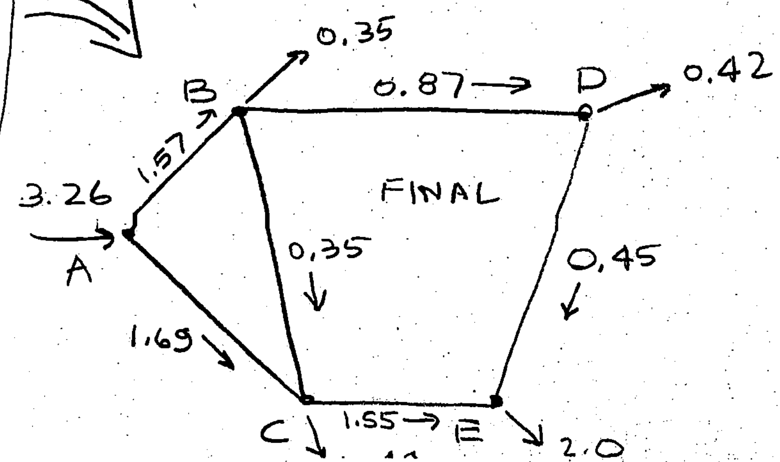
TRIAL 1

1 Loop	2 Pipeline	3 D, ft	4 L ft	5 Qa, cfs	6 hf ft	7 ABS|hf/Q| L^(-2)T	8 delta Q cfs	9 Qcorr cfs
1	AB	1	1000	1.6	1.61	1.00	-0.019	1.58
	BC	0.667	1700	0.35	1.18	3.37	-0.019	0.35
	CA	1	-1500	-1.66	-2.58	1.55	-0.019	-1.68
					0.21	5.93		
2	BD	1	2300	0.9	1.27	1.42	-0.020	0.88
	DE	0.667	1500	0.48	1.87	3.89	-0.020	0.46
	EC	1	-1100	-1.52	-1.61	1.06	-0.020	-1.54
	CB	0.667	-1700	-0.35	-1.18	3.37	-0.020	-0.35
					0.35	9.74		



TRIAL 2

1 Loop	2 Pipeline	3 D, ft	4 L ft	5 Qa, cfs	6 hf ft	7 ABS|hf/Q| L^(-2)T	8 delta Q cfs	9 Qcorr cfs
1	AB	1	1000	1.58	1.57	0.99	-0.009	1.57
	BC	0.667	1700	0.35	1.18	3.37	-0.009	0.35
	CA	1	-1500	-1.68	-2.64	1.57	-0.009	-1.69
					0.11	5.94		
2	BD	1	2300	0.88	1.23	1.39	-0.007	0.87
	DE	0.667	1500	0.46	1.74	3.76	-0.007	0.45
	EC	1	-1100	-1.54	-1.64	1.07	-0.007	-1.55
	CB	0.667	-1700	-0.35	-1.18	3.37	-0.007	-0.35
					0.14	9.59		



Notes: Col. 1 is the Loop - either 1 or 2

Col. 2 is the pipeline in each loop

Col. 3 is the diameter of each pipe

Col. 4 is the length of each pipe. I use a negative value if the flow is negative (see note for column 6).

Col. 5 in TRIAL 1 is the assumed flow in each pipe. Positive is in the clockwise direction

Note that the sum of Q's at each junction is zero.

Col. 6 is the head loss hl = 4.73*L*(D^ -4.87)*(120^ -1.85)*(Q^ 1.85). Since you can't raise Q to a negative power, I use a negative L instead

Col. 7 is the absolute value of the head loss divided by the Q to prepare for the error calculation

Col. 8 is the error computed as: delta = - SUM(hl)/(1.85*SUM(hl/Q))

Col. 9 is the corrected Q. For the pipe common to both loops,

Qcorr = Qa +(delta Q loop 1) - (delta Q loop 2)