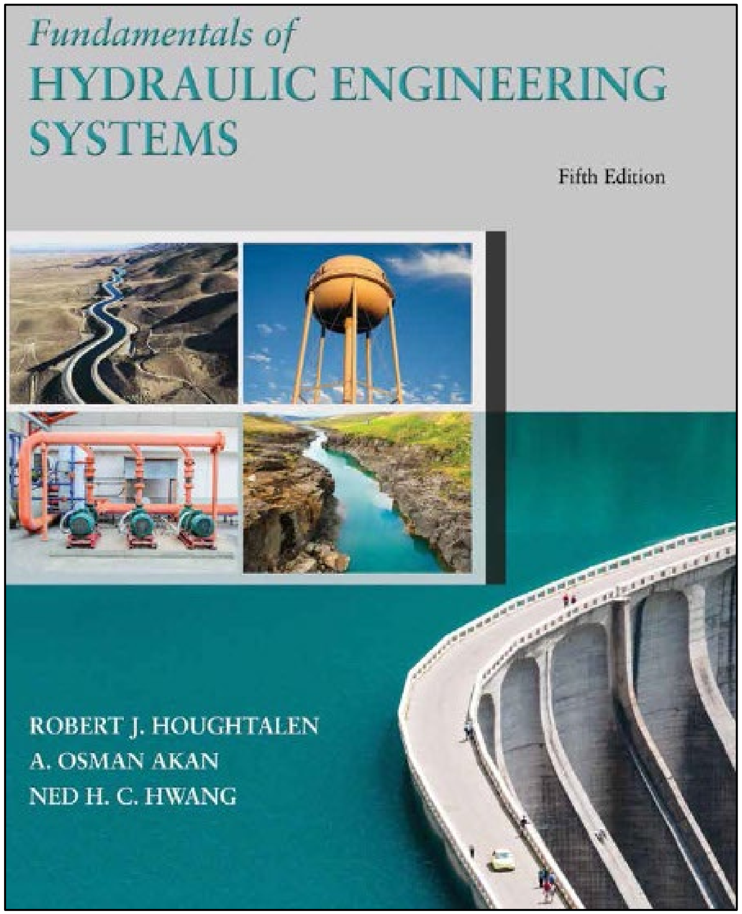
Fundamentals of Hydraulic Engineering Systems

Fifth Edition



Chapter 4b

Pipelines and Pipe Networks

Pearson

Branching Pipe Systems (1 of 2)

Definitions and Concepts

Branching Pipe System: a pipe network containing one junction which usually connects a number of reservoirs.

The Classic Three Reservoir Problem: (see figure below)
Given: Water elevations, pipe mat'ls, sizes, and lengths
Find: Q_1, Q_2, and Q_3

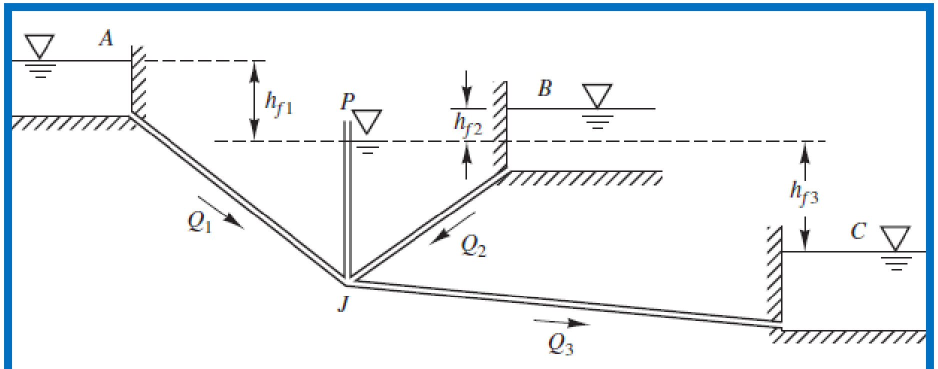


Figure 4.4 Branching pipes connecting three reservoirs

Branching Pipe Systems (2 of 2)

Active Learning Exercise

Q: What equations would you use to solve for the 3 Qs.
A1: Balance Energy. Yes, but between what points?

A2: Between the 3 reservoirs and the junction. However, this introduces another unknown (P/γ) at the junction (J).

Q: What additional equation can be used in the solution?

A: Continuity: $Q_1 + Q_2(\text{or } -Q_2) = Q_3$

Note: Velocity head is ignored at the junction and minor losses are ignored in pipes.

Figure 4.4 Branching pipes connecting three reservoirs

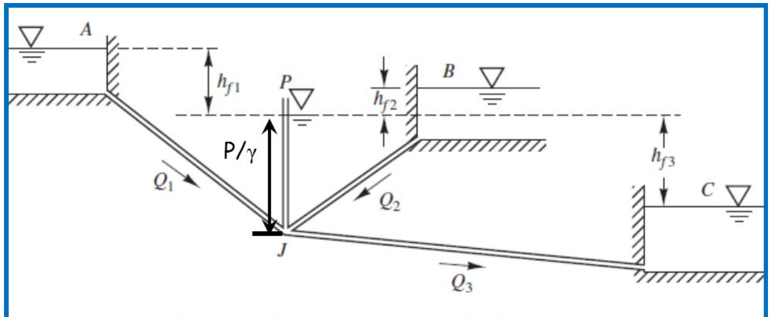


Figure 4.4 Branching pipes connecting three reservoirs

Pipe Networks (1 of 4)

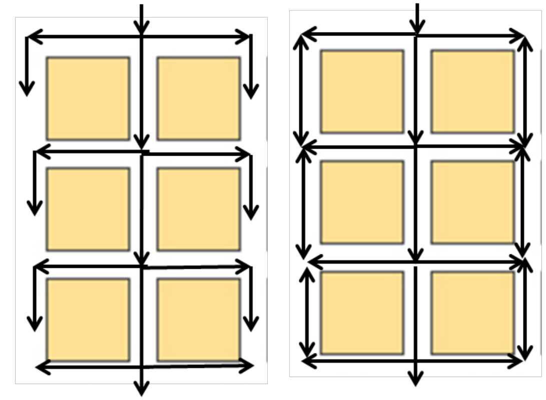
Municipal Water Delivery

Q: Which system is better for delivering water to customers?

A: Dendritic – a little less pipe

A: Grid – less disruptive for service repairs; water less likely to sit in dead spots (THMs)

Water Distribution – City Blocks



Dendritic System (tree structure) | Grid System (loop structure)

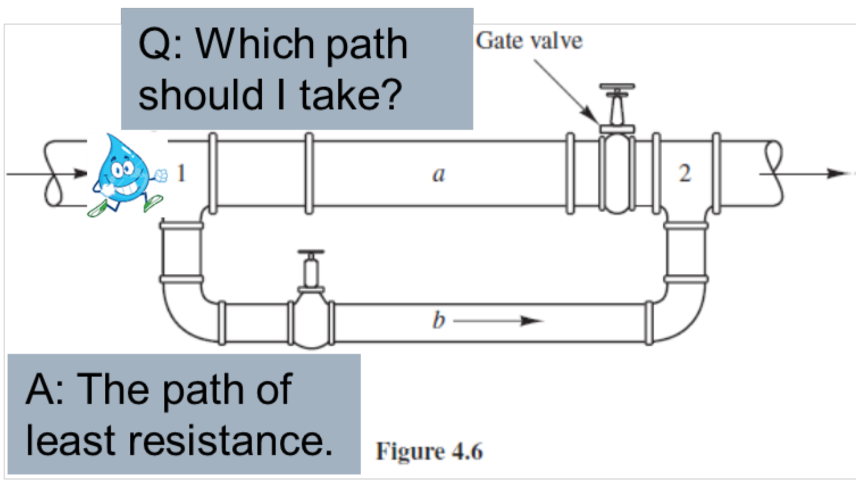


Figure 4.6

Q: What principles (equations.) are available to find Q_a & Q_b?

A: Continuity: $Q_a + Q_b = Q_{total}$

Pressure drops (losses) from “1” to “2” must be identical regardless of the path taken.

Pipe Networks (2 of 4)

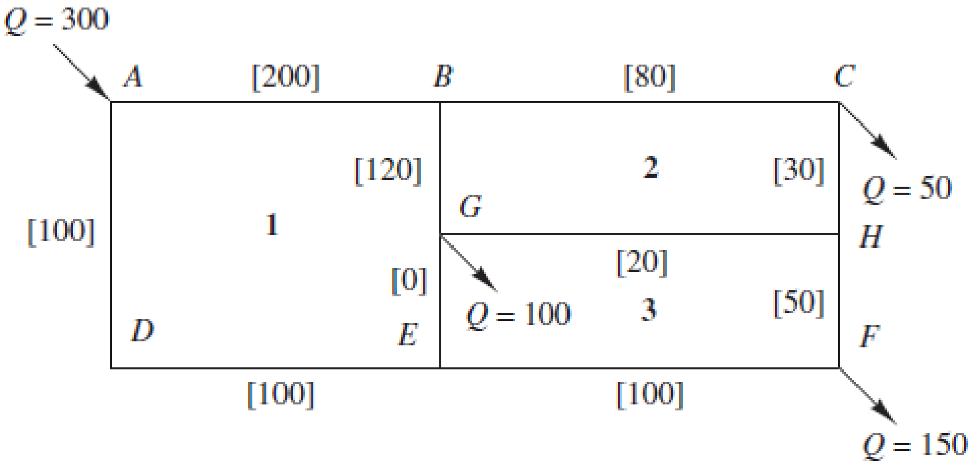
Initiation of the Hardy Cross Method

Q: Starting with the Darcy-Weisbach equation, determine the value of K for friction loss expressed as $h_f = KQ^2$.

$$\mathbf{A:}\ h_f = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right) = f\left(\frac{L}{D}\right)\left(\frac{Q^2}{2gA^2}\right);\ \text{so}\ K = \frac{fL}{\left(2gDA^2\right)}$$

Q: Estimate all Q's in the pipe network depicted below.

Principle:
Conservation of Mass (i.e., mass balance of flows at all nodes)



Pipe Networks (3 of 4)

Analysis by the Hardy Cross Method

Q: Determine the total friction loss (clockwise and counter clockwise) for loop 1 based on $h_f = KQ^2$ (Darcy-Weisbach)

Q: The clockwise and counter-clockwise head losses do not balance. What does this mean and what should be done?

A: Flows in the loop should be adjusted to balance losses.

Principle:
Conservation of Energy (head loss balance in all of the loops)

Pipe	Q (m^3/sec)	K (sec^2/m^5)	h_f (m)
AB	0.200	194	7.76
BG	0.120	678	9.76
GE	0.000	2,990	0.00
AD	(0.100)	423	(4.23)
DE	(0.100)	1,630	(16.3)

Pipe Networks (4 of 4)

Flow Corrections

Hardy-Cross Method: If $\sum K_c Q_c{}^2 \neq \sum K_{cc} Q_{cc}{}^2$ around a loop (subscripts refer to clockwise and counterclockwise flow), losses are equalized by adjusting the flow rates by ΔQ, then $\sum K_c (Q_c - \Delta Q)^2 = \sum K_{cc} (Q_{cc} + \Delta Q)^2$

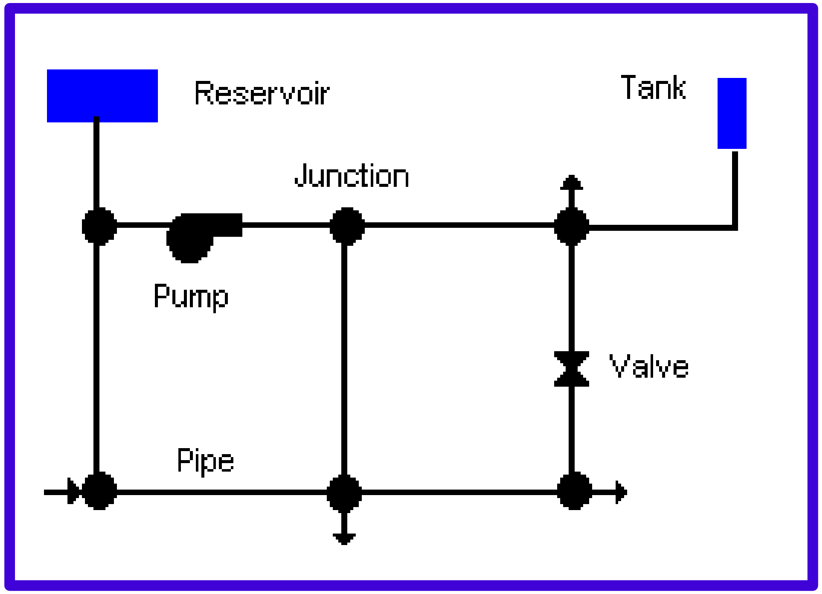
Based on mathematics, the flow correction ΔQ is $\rightarrow \Delta Q = \dfrac{(\sum h_{fc} - \sum h_{fcc})}{2\left(\sum \dfrac{h_{fc}}{Q_c} + \sum \dfrac{h_{fcc}}{Q_{cc}}\right)}$

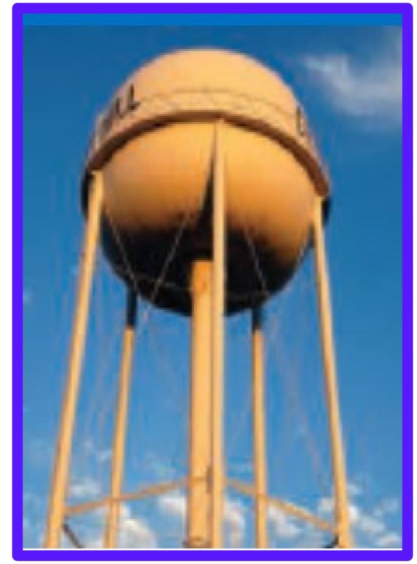
A second iteration uses this correction to determine a new flow distribution. A successive computation procedure is used until the entire network is balanced (mass and energy).

Team Activity: Review Ex. 4.8. Identify one or two points of confusion. How can the pressure at F be increased?

Homework Problems:

Municipal Water Distribution System Modeling



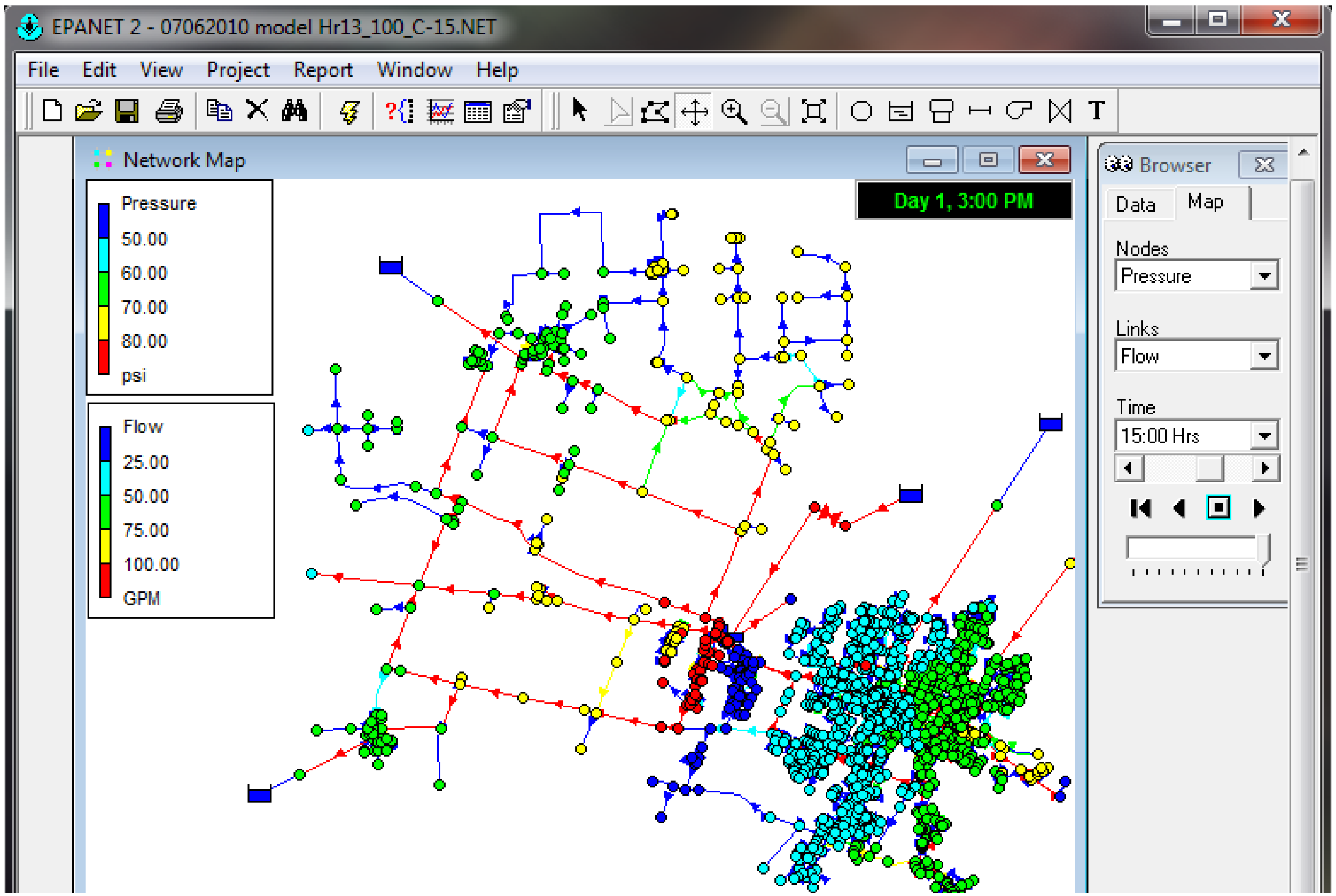


Network Table - Links

Link ID	Flow GPM	Velocity fps	Headloss ft/Kft	Status
Pipe 1	617.42	1.29	0.80	Open
Pipe 2	382.51	1.09	0.69	Open
Pipe 3	159.91	1.02	1.00	Open
Pipe 4	29.34	0.19	0.04	Open
Pipe 5	-90.09	0.57	0.34	Open
Pipe 6	292.42	1.19	1.03	Open
Pipe 7	55.58	0.63	0.57	Open
Pipe 8	-44.42	0.50	0.38	Open

U.S. EPA → EPANet
http://nepis.epa.gov/Adobe/PDF/P1007WWU.pdf

Pipe Network: Software Package Solutions



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