بسم الله الرحمن الرحيم

السلام عليكم ورحمة الله

South valley University
Faculty of Engineering
Mechanical Power Engineering Dep.

Flow-Network Design

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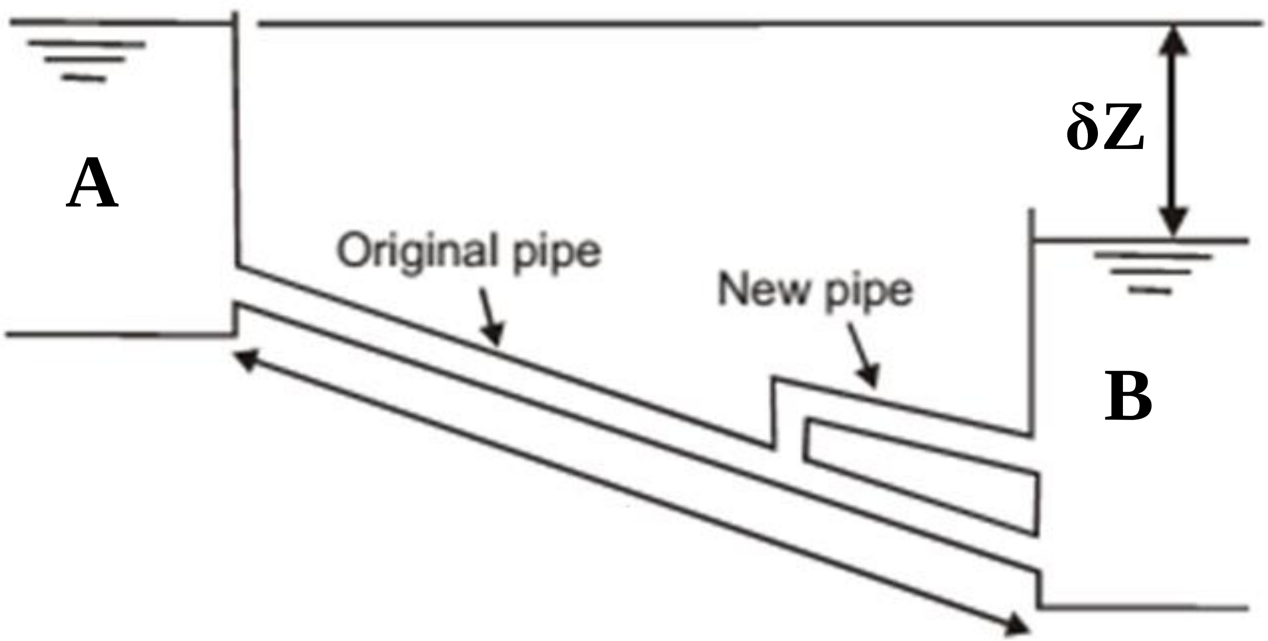
Lecture 4

Branching Pipes

A simple branching-pipe system

Adding a parallel pipe to the original pipe



Example

A pipe joins two reservoirs whose head difference is 10m. The pipe is 0.2 m diameter, 1000 m in length and has a f value of 0.008. a) What is the flow in the pipeline? b) It is required to increase the flow to the downstream reservoir by 30%. This is to be done adding a second pipe of the same diameter that connects at some point along the old pipe and runs down to the lower reservoir. Assuming the diameter and the friction factor are the same as the old pipe, how long should the new pipe be?

Solution

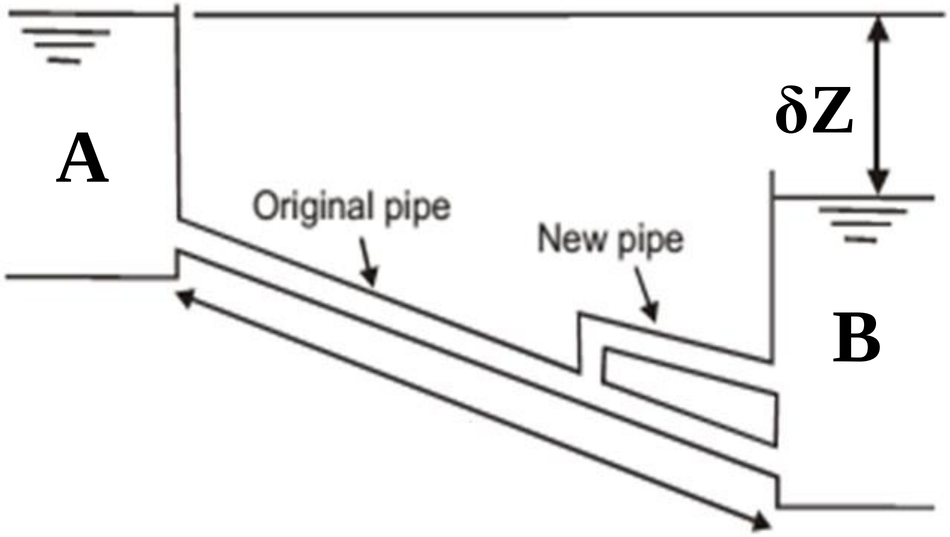
Case 1:

$$h_f = \frac{fLQ^2}{3d^5}$$

$$10 = \frac{0.008 \times 1000 Q^2}{3 \times 0.2^5}$$

$$Q = 0.0346\, m^3 / s$$

$$Q = 34.6\, litres / s$$



Case 2:

$$H = 10 = h_{f1} + h_{f2} = h_{f1} + h_{f3}$$

$$\therefore$$

$$h_{f2} = h_{f3}$$

$$\frac{f_2 L_2 Q_2^{\ 2}}{3 d_2^{\ 5}} = \frac{f_3 L_3 Q_3^{\ 2}}{3 d_3^{\ 5}}$$

Solution

as the pipes 2 and 3 are the same f, same length and the same diameter then $Q_2 = Q_3$.

By continuity $Q_1 = Q_2 + Q_3 = 2Q_2 = 2Q_3$

So

$$Q_2 = \frac{Q_1}{2}$$

and

$$L_2 = 1000 - L_1$$

Then

$$10 = h_{f1} + h_{f2}$$

$$10 = \frac{f_1 L_1 Q_1^2}{2d_1^2} + \frac{f_2 L_2 Q_2^2}{2d_2^2}$$

$$10 = \frac{f_1 L_1 Q_1^2}{2d_1^2} + \frac{f_2 (1000 - L_1)(Q_1 / 2)^2}{2d_2^2}$$

Solution

As $f_1 = f_2$, $d_1 = d_2$

$$10 = \frac{f_1 Q_1^2}{2 d_1^2}\left(L_1 + \frac{(1000 - L_1)}{4} \right)$$

The new Q_1 is to be 30% greater than before so $Q_1 = 1.3 \times 0.034 = 0.442\ m^3/s$

Solve for L to give

$$L_1 = 455.6m$$

$$L_2 = 1000 - 455.6 = 544.4\ m$$

Flow Between Reservoirs

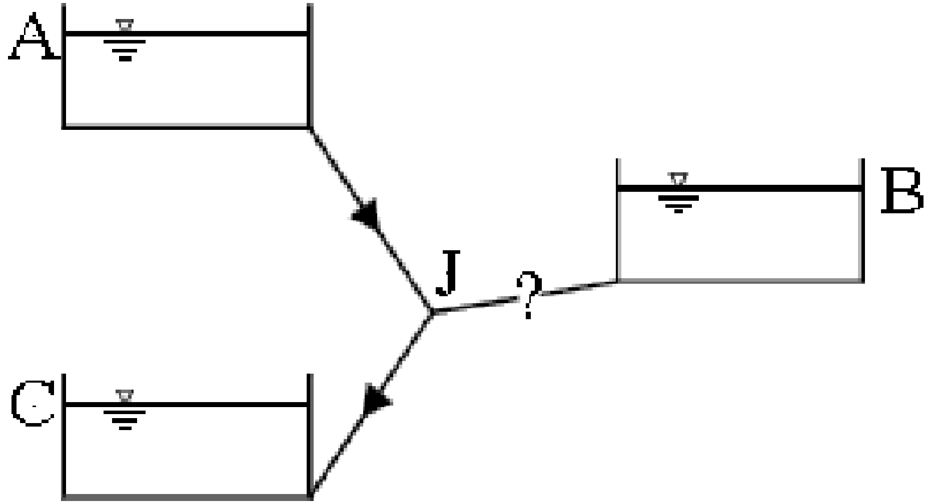
Problem Description:

Given:

Reservoir elevations, sizes of pipes ,friction factor, minor loss coefficients and fluid properties

Required: Flow through each pipe and head losses

Expect the flow direction in the flowing figure?



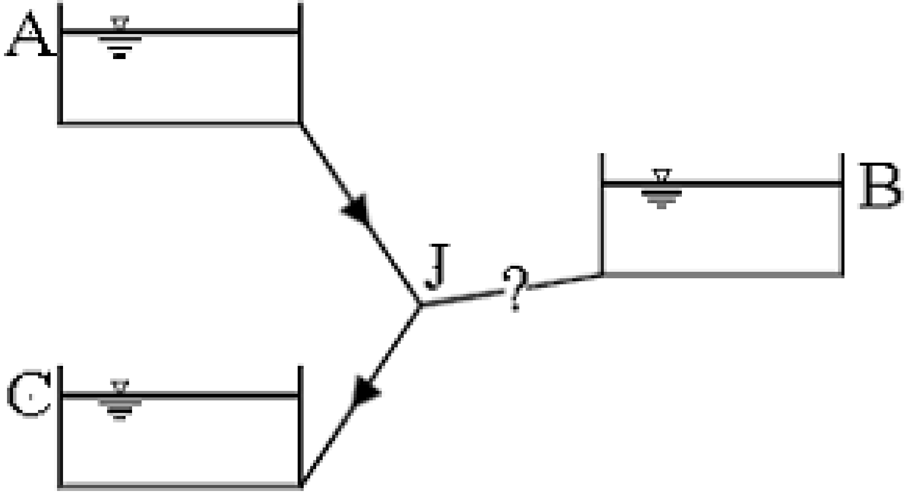
Step analysis:

a) *Apply the loss equation for each pipe* : $(h_L = KQ^2)$

$$|H_J - H_A| = K_{JA}Q_{JA}^2$$

$$|H_J - H_B| = K_{JB}Q_{JB}^2$$

$$|H_J - H_C| = K_{JC}Q_{JC}^2$$



b) *Continuity equation at junction J*

net flow out of junction $J = 0$

$$Q_{JA} + Q_{JB} + Q_{JC} = 0$$

- **Note** the sign convention: Q_{JA} is the flow from J to A; it will be negative if the flow actually goes from A to J.

- **The direction of flow in any pipe is always from high head to low head.**

- **The problem and its solution method can be generalized to any number of reservoirs.**

Solution Procedure:

1. Establish the head loss vs discharge equations for each pipe.

2. Guess an initial head at the junction, H_J.

3. Calculate flow rates in all pipes (from the head differences)

4. Calculate net flow out of J.

5. If necessary, adjust H_J to reduce any flow imbalance and repeat from (3)

Important Note

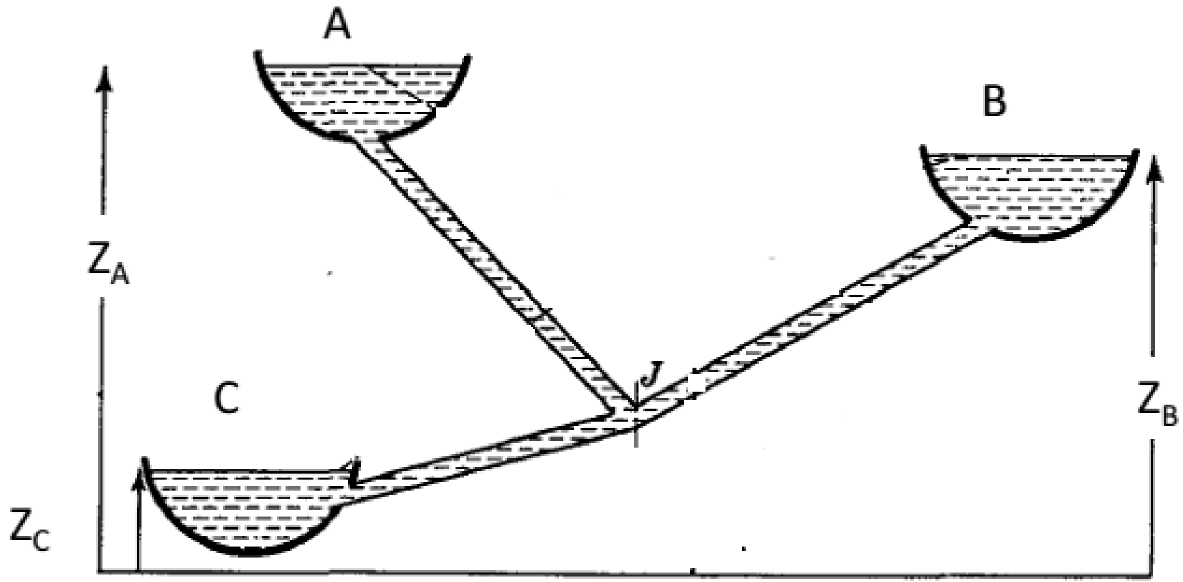
If the direction of flow in a pipe, say J_B, is not obvious then a good initial guess is to set $H_J = H_B$ so that there is initially no flow in this pipe. The first flow-rate calculation will then establish whether H J should be lowered or raised and hence the direction of flow in this pipe.

Example 1

Reservoirs A, B and C have constant water levels of 150, 120 and 90 m respectively above datum and are connected by pipes to a single junction J at unknown elevation. The length (L), diameter (D), friction factor (f) and minor-loss coefficient (K) of each pipe are given below. Calculate:

(a) Calculate the flow in each pipe.
(b) Calculate the pressure at the junction J.

Pipe	L(m)	D(m)	f	K
JA	1600	0.3	0.015	40
JB	1600	0.2	0.015	25
JC	2400	0.25	0.025	50



Solution

Prepare head loss vs discharge relations for each pipe

$$h_L = \left(\frac{fL}{D} + K\right)\frac{V^2}{2g} \quad where\ V = \frac{4Q}{\pi D^2}$$

$$h_L = \left(\frac{fL}{D} + K\right)\frac{8Q^2}{\pi^2 D^4 g}$$

$$Pipe\ AJ: \left|H_J - H_A\right| = 1224\, Q_{AJ}^2 \qquad Q_{AJ} = \pm\sqrt{\frac{\left|H_J - 150\right|}{1224}}$$

$$Pipe\ JB: \left|H_J - H_B\right| = 7488\, Q_{AJ}^2 \qquad Q_{JB} = \pm\sqrt{\frac{\left|H_J - 120\right|}{7488}}$$

$$Pipe\ JC: \left|H_J - H_C\right| = 6134\, Q_{AJ}^2 \qquad Q_{JC} = \pm\sqrt{\frac{\left|H_J - 90\right|}{6134}}$$

The value of H_J is varied until the net flow out of J is 0 ·

•If there is net flow into the junction then H_J needs to be raised.

•If there is net flow out of the junction then H_J needs to be lowered.

After the first two guesses at H_J, subsequent iterations are guided by interpolation.

H_J (m)	Q_{JA} (m^3/s)	Q_{JB} (m^3/s)	Q_{JC} (m^3/s)	$Q_{JA}+Q_{JB}+Q_{JC}$
120	−0.1566	0.0000	0.0699	−0.0867
140	−0.0904	0.0517	0.0903	0.0516
132.5	−0.1196	0.0409	0.0832	0.0045
131.8	**−0.1219**	**0.0397**	**0.0825**	**0.0003**

The quantity of flow in each pipe is given in the bottom row of the table, with the direction implied by the sign.

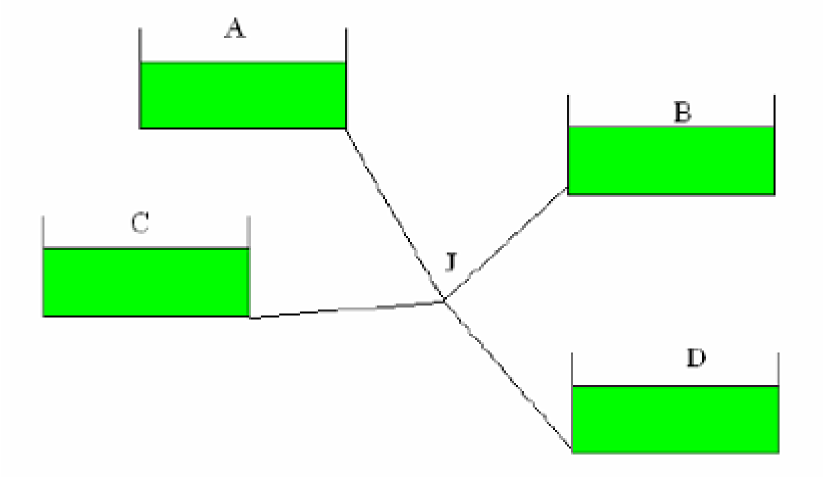
$$H_J = \frac{p_J}{\gamma} + Z_J$$

$$p_J = \rho g (H_J - Z_J) = 67000\ Pa = 67\ kPa$$

Examples 2

The table shows the data for the network of pipes shown connecting four reservoirs to a common junction.

Reservoir	Water Level (m) above a datum	K for Pipe connecting to J (s^2/m^5)
A	50	4.0
B	45	3.0
C	40	2.0
D	30	2.0



Calculate the flow in each pipe using iteration with flow accuracy less than 0.1 m^3 /s

Solution

Prepare head loss vs discharge relations for each pipe

$$h_L = \left(\frac{fL}{D} + K\right)\frac{V^2}{2g} \quad \textit{where } V = \frac{4Q}{\pi D^2}$$

$$h_L = \left(\frac{fL}{D} + K\right)\frac{8Q^2}{\pi^2 D^4 g} = K_t Q^2$$

$$\textit{Pipe AJ}: |H_J - H_A| = 4\,Q_{AJ}^2 \qquad Q_{AJ} = \pm\sqrt{\frac{|H_J - 50|}{4}}$$

$$\textit{Pipe JB}: |H_J - H_B| = 3\,Q_{AJ}^2 \qquad Q_{JB} = \pm\sqrt{\frac{|H_J - 45|}{3}}$$

$$\textit{Pipe JC}: |H_J - H_C| = 2\,Q_{AJ}^2 \qquad Q_{JC} = \pm\sqrt{\frac{|H_J - 40|}{2}}$$

$$\textit{Pipe JC}: |H_J - H_D| = 2\,Q_{AJ}^2 \qquad Q_{JC} = \pm\sqrt{\frac{|H_J - 30|}{2}}$$

Solution

Assume $H_J=(50+45+40+30)/4=41.25$ m

H_J (m)	Q_{JA} (m^3/s)	Q_{JB} (m^3/s)	Q_{JC} (m^3/s)	Q_{JD} (m^3/s)	$Q_{JA}+Q_{JB}+Q_{JC}+Q_{JD}$ (m^3/s)
41.25	-1.479	-1.118	0.791	3.354	1.548
40	-1.581	-1.291	0	2.236	-0.636
40.4	-1.549	-1.238	0.447	2.28	0.06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Thank You
For Your Attention