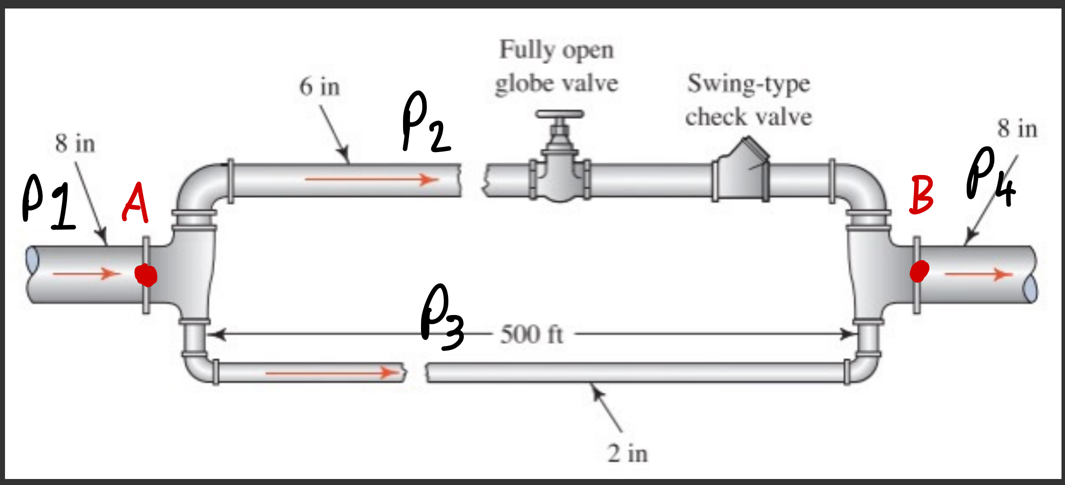
12.4 In the branched-pipe system shown in the figure below, 1350 gal/ min of benzene (sg = 0.87) at 140 °F is flowing in the 8-in pipe. Calculate the volume flow rate in the 6-in and the 2-in pipes. All pipes are standard Schedule 40 steel pipes.



given:

$Q_1 = 3.0067\ ft^3/s$

$D_1 = 0.6651\ ft$

$D_2 = 0.5064\ ft$

$D_3 = 0.1723\ ft$

$Sg = 0.87$

$\gamma = 53.418\ lbf/ft^3$

$\nu = 4.93 \times 10^{-6}\ ft^2/s$

$$\frac{P_2}{\gamma} = \frac{P_1}{\gamma} + h_L$$

$$\frac{P_a - P_B}{\gamma} = h_L$$

Losses in 2:

2·T-junction (Q_1):

Reducer:

2·elbow:

pipe$_2$:

globe valve:

check valve:

expansion.

$$\left(\frac{8 Q_1^2}{g \pi^2 D_1^4}\right)(2KT) +$$

$$\left(\frac{8}{g\pi^2 D_2^4}\right)\left(K_{R_2} + 2K_{ELB} + f_2 \cdot \frac{L_2}{D_2} + K_{GV} + K_{CV} + K_{ExP_2}\right)$$

Losses in 3:

2·T-junction (Q_1):

Reducer:

2·elbow:

pipe$_2$:

expansion.

$$\left(\frac{8 Q_1^2}{g \pi^2 D_1^4}\right)(2KT) +$$

$$\left(\frac{8}{g\pi^2 D_3^4}\right)\left(K_{R_3} + 2K_{ELB} + f_2 \cdot \frac{L_2}{D_3} + K_{ExP_3}\right)$$

$$Q = V \cdot A \qquad V = Q/A$$

$$Re = \frac{4\,Q \cdot \pi D}{\nu}$$

$$A = \frac{\pi \cdot D^2}{4}$$

$$V = Q / \pi D^2/4$$

$$Q_1 = Q_2 + Q_3$$

$$Q_2 = \sqrt{\frac{\frac{\Delta P}{\gamma} - (2\,K_T)\,\frac{8\,Q_1^2}{g\,\pi^2 D_1^4}}{\left(\frac{8}{g\pi^2 D_2^4}\right)\left(K_{R_2} + 2K_{ELB} + f_2 \cdot \frac{L_2}{D_2} + K_{GV} + K_{CV} + K_{EXP_2}\right)}}$$

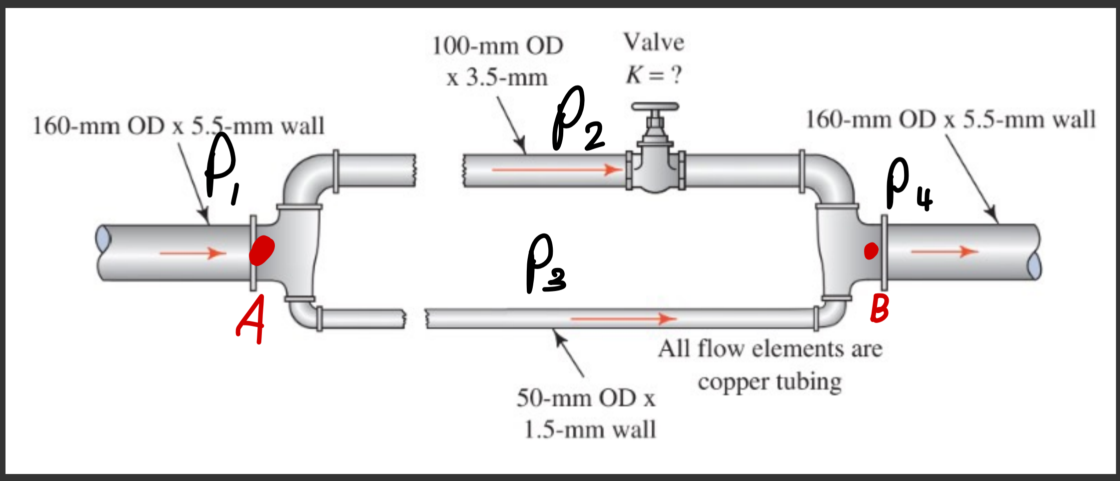
$$Q_3 = \sqrt{\frac{\frac{\Delta P}{\gamma} - (2\,K_T)\,\frac{8\,Q_1^2}{g\,\pi^2 D_1^4}}{\left(K_{R_3} + 2K_{ELB} + f_3 \cdot \frac{L_3}{D_3} + K_{EXP_3}\right)\frac{8}{g\pi^2 D_3^4}}}$$

Q_1 & 4	1350	gal/min	3.0067	ft^3/s					
sg	0.87								
p	52.19	lbm/ft^3							
g	32.2	ft/s^2							
T	140	°F							
y	53.418	lbf/ft^3							
v	4.93E-06	ft^2/s							
L	500	ft							
D_1	0.6651	ft							
D_2	0.5054	ft							
D_3	0.1723	ft							
e	0.00015				RHS1_Denom	RHS2_Denom			
D_1/e	4434				8.736212427	1286.094394			
D_2/e	3369.333								
D_3/e	1148.667								
f_1	0.014927			Iteration	Δ Pressure	RHS_Numerator	Q_2	Q_3	% Diff
fT_1	0.014			1	3000	54.2070869	2.49095821	0.205301259	-11.51%
fT_2	0.015			2	3700	67.31128399	2.775762758	0.228774447	-0.07%
fT_3	0.019			3	3710	67.4984868	2.779619985	0.229092355	0.07%
Re #	1.17E+06			4	3705	67.4048854	2.777692041	0.228933456	0.00%
K_T	60	fT							
K_R_2	20	fT		Δ Pressure	3705	lb/ft^2			
K_ELB	30	fT			25.7291665	psi			
K_EXP_2	5	fT							
K_T	60	fT							
K_R_3	25	fT							
K_EXP_3	5	fT							
K_Globe_Valve	340	fT							
K_Check_Valve	100	fT							

$Q_2 = 2.778\ ft^3/s$

$Q_3 = 0.2284\ ft^3/s$

12.5 A 160-mm pipe branches into a 100-mm and a 50-mm pipe as shown in the figure below. Both pipes are hydraulic copper tubing and 30 m long. (The fluid is water at 10°C.) Determine what the resistance coefficient K of the valve must be to obtain equal volume flow rates of 500 L/min in each branch.



given:

$Q_1 = 1{,}000$ L/min.

$Q_{2,3} = 500$ L/min.

$D_1 = 0.149$ m

$D_2 = 0.093$ m

$D_3 = 0.047$ m

$\gamma = 9.81$ kN/m³

$\nu = 1.3 \times 10^{-6}$ m²/s

$$\frac{P_2}{\gamma} = \frac{P_1}{\gamma} + h_L$$

$$\frac{P_a - P_B}{\gamma} = h_L$$

Losses in 2:

2·T-junction (Q_1):
Reducer:
2·elbow:
pipe$_2$:
globe valve:
expansion.

$$\left(\frac{8Q_1^2}{g\pi^2 D_1^4}\right)(2K_T) +$$

$$\left(\frac{8}{g\pi^2 D_2^4}\right)\left(K_{R_2} + 2K_{ELB} + f_2 \cdot \frac{L_2}{D_2} + K_{GV} + K_{ExP_2}\right)$$

Losses in 3:

2·T-junction (Q_1):
Reducer:
2·elbow:
pipe$_2$:
expansion.

$$\left(\frac{8Q_1^2}{g\pi^2 D_1^4}\right)(2K_T) +$$

$$\left(\frac{8}{g\pi^2 D_3^4}\right)\left(K_{R_3} + 2K_{ELB} + f_2 \cdot \frac{L_2}{D_3} + K_{ExP_3}\right)$$

$$Q_2 = \sqrt{\frac{\frac{\Delta P}{\gamma} - (2 K_T) \frac{8 Q_1^2}{g \pi^2 D_1^4}}{\left(\frac{8}{g \pi^2 D_2^4}\right)\left(K_{R_2} + 2 K_{ELB} + f_2 \cdot \frac{L_2}{D_2} + K_{GV} + K_{EXP_2}\right)}}$$

$$Q_3 = \sqrt{\frac{\frac{\Delta P}{\gamma} - (2 K_T) \frac{8 Q_1^2}{g \pi^2 D_1^4}}{\left(K_{R_3} + 2 K_{ELB} + f_3 \cdot \frac{L_3}{D_3} + K_{EXP_3}\right) \frac{8}{g \pi^2 D_3^4}}}$$

Set denominators equal to find K of the valve

$$\left(\frac{8}{g \pi^2 D_2^4}\right)\left(K_{R_2} + 2 K_{ELB} + f_2 \cdot \frac{L_2}{D_2} + K_{GV} + K_{EXP_2}\right) = \left(K_{R_3} + 2 K_{ELB} + f_3 \cdot \frac{L_3}{D_3} + K_{EXP_3}\right) \frac{8}{g \pi^2 D_3^4}$$

Q_1 & 4	1000	L/min	0.01667	m^3/s			
Q_2 & 3	500	L/min	0.00833	m^3/s			
g	9.81	m/s^2					
T	10	°C					
y	9.81	kN/m^3					
v	1.30E-06	m^2/s					
L	30	m					
D_1	0.149	m					
D_2	0.093	m					
D_3	0.047	m					
e	1.50E-06		Iteration	K_Valve	HL_2	HL_3	% Diff
D_1/e	99333.333		1	1500	1757302.624	1699425.02	3.41%
D_2/e	62000		2	1400	1646540.298	1699425.02	-3.11%
D_3/e	31333.333		3	1450	1701768.314	1699425.02	0.14%
f_1	0.017592		4	1448	1699559.194	1699425.02	0.01%
f_2	0.0184517						
f_3	0.016235						
Re #_1	1.10E+05						
Re #_2	8.78E+04						
Re #_3	1.74E+05						
K_T	60	fT					
K_R_2	20	fT					
K_ELB	30	fT					
K_EXP_2	5	fT					
K_T	60	fT					
K_R_3	25	fT					
K_EXP_3	5	fT					

$K_{valve} \approx 1448$