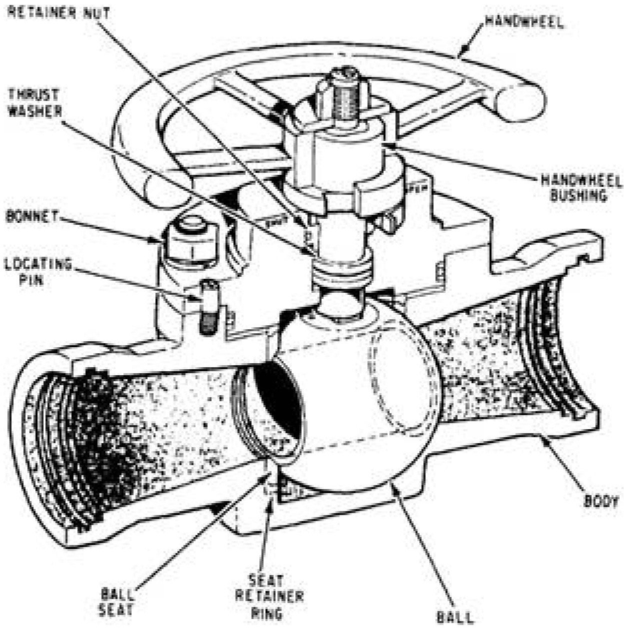
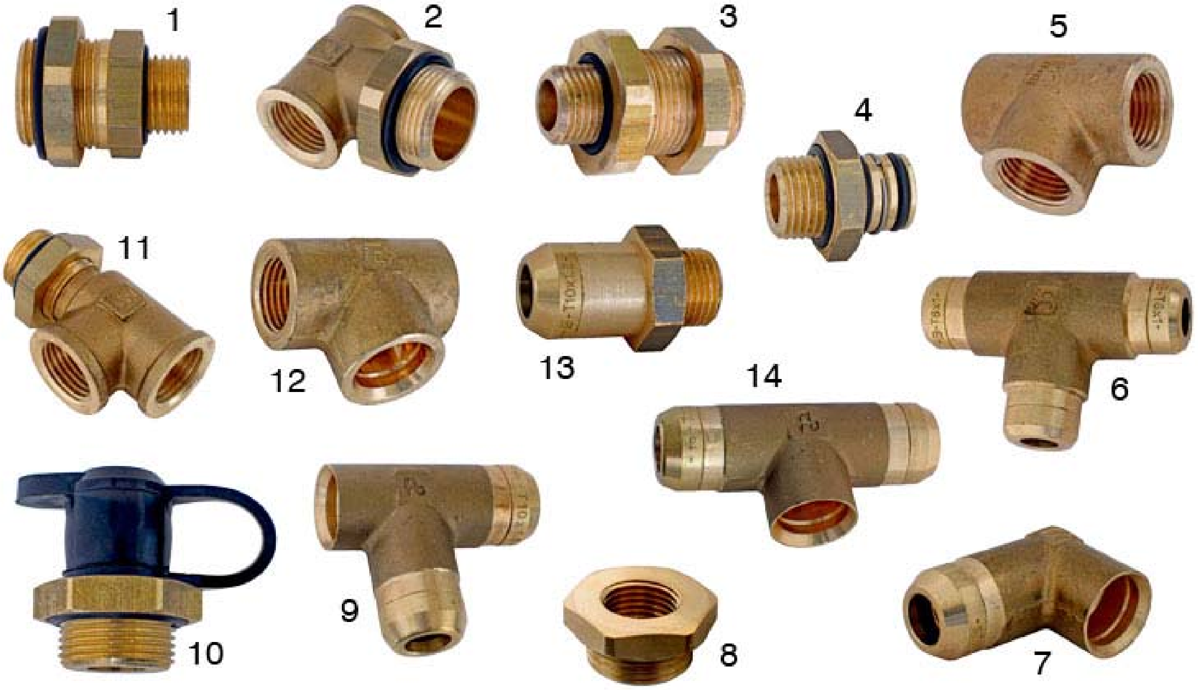
MINOR LOSSES IN PIPES

- Losses caused by **fittings, bends, valves**, etc.





- Minor in comparison to friction losses which are considered major.

- Losses are **proportional to** – **velocity of flow, geometry of device**.

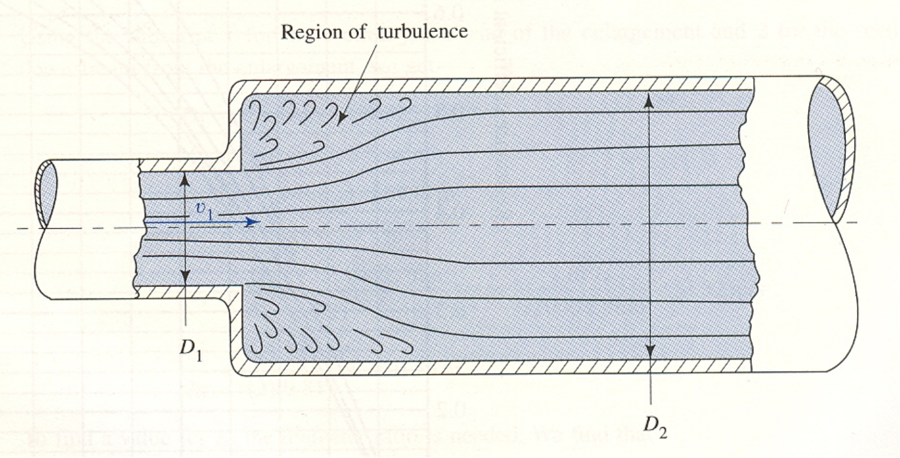
$$h_L = K(v^2/2g)$$

- The value of **K is typically provided for various devices**.

- Energy lost – units – **N.m/N or lb-ft/lb**

- K - loss factor - has no units (dimensionless)

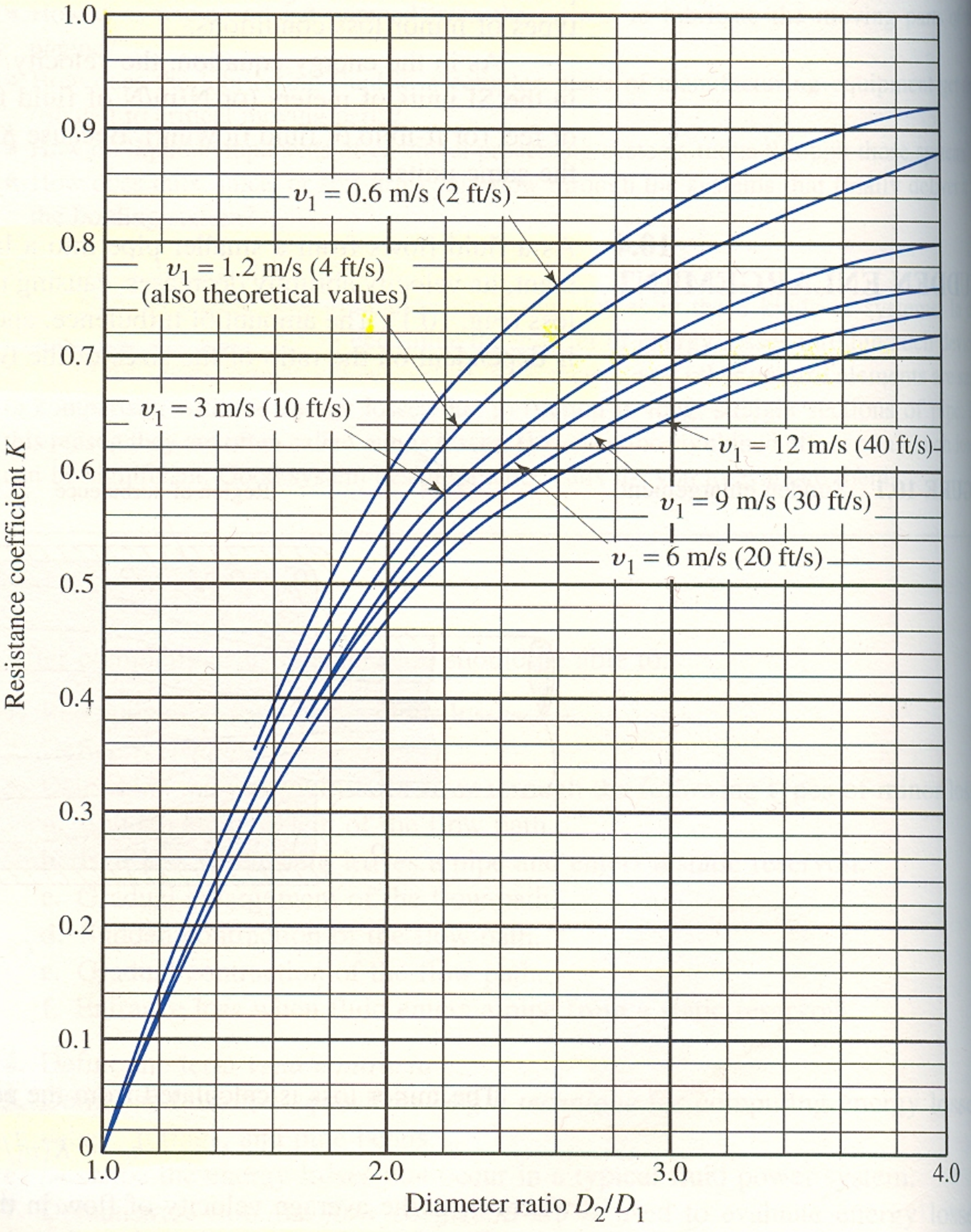
Sudden enlargement



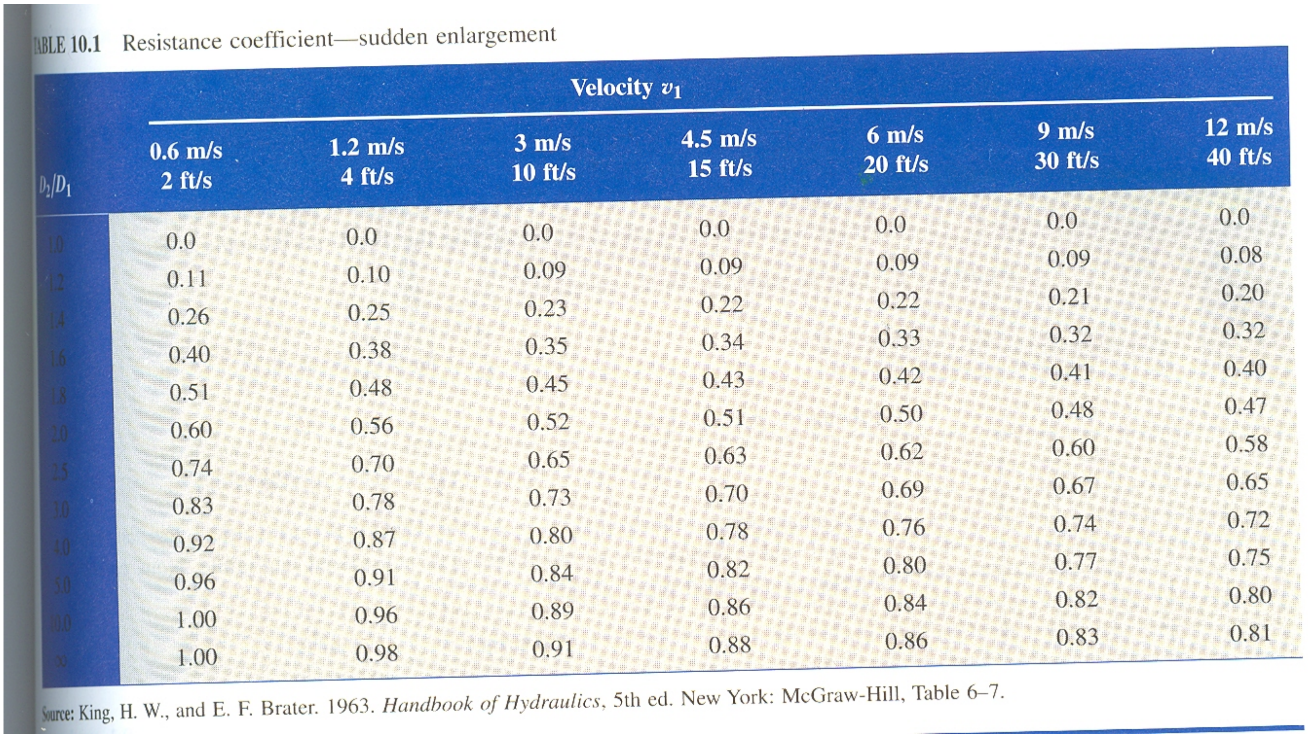
Energy lost is because of turbulence. Amount of turbulence depends on the differences in pipe diameters

$$h_L = K(v_1^2 / 2g)$$

The values of K have been experimentally determined and provided in Figure 10.2 and Table 10.1.



1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Resistance coefficient K
$v_1 = 0.6$ m/s (2 ft/s)
$v_1 = 1.2$ m/s (4 ft/s) (also theoretical values)
$v_1 = 3$ m/s (10 ft/s)
$v_1 = 12$ m/s (40 ft/s)
$v_1 = 9$ m/s (30 ft/s)
$v_1 = 6$ m/s (20 ft/s)
1.0
2.0
3.0
4.0
Diameter ratio D_2/D_1



ABLE 10.1 Resistance coefficient—sudden enlargement

	Velocity v_1						
D_2/D_1	0.6 m/s 2 ft/s	1.2 m/s 4 ft/s	3 m/s 10 ft/s	4.5 m/s 15 ft/s	6 m/s 20 ft/s	9 m/s 30 ft/s	12 m/s 40 ft/s
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.2	0.11	0.10	0.09	0.09	0.09	0.09	0.08
1.4	0.26	0.25	0.23	0.22	0.22	0.21	0.20
1.6	0.40	0.38	0.35	0.34	0.33	0.32	0.32
1.8	0.51	0.48	0.45	0.43	0.42	0.41	0.40
2.0	0.60	0.56	0.52	0.51	0.50	0.48	0.47
2.5	0.74	0.70	0.65	0.63	0.62	0.60	0.58
3.0	0.83	0.78	0.73	0.70	0.69	0.67	0.65
4.0	0.92	0.87	0.80	0.78	0.76	0.74	0.72
5.0	0.96	0.91	0.84	0.82	0.80	0.77	0.75
10.0	1.00	0.96	0.89	0.86	0.84	0.82	0.80
∞	1.00	0.98	0.91	0.88	0.86	0.83	0.81

Source: King, H. W., and E. F. Brater. 1963. *Handbook of Hydraulics*, 5th ed. New York: McGraw-Hill, Table 6–7.

D2/D1 = 1.0 -> 10.0 -> to infinity

<u>Analytical expression of K</u> -

If the **velocity v_1 < 1.2 m/s or 4 ft/s,** the K values can be given as

$$K = \left[1-(A_1/A_2)\right]^2 = [1-(D_1/D_2)^2]^2$$

Example 10.1

Determine **energy loss** when 100 L/min of water moved from **1”** copper tube to **3”** copper tube

Procedure - Find velocity of flow and then find K.

$D_1 = 25.3$ mm
$A_1 = 0.0005017$ m^2

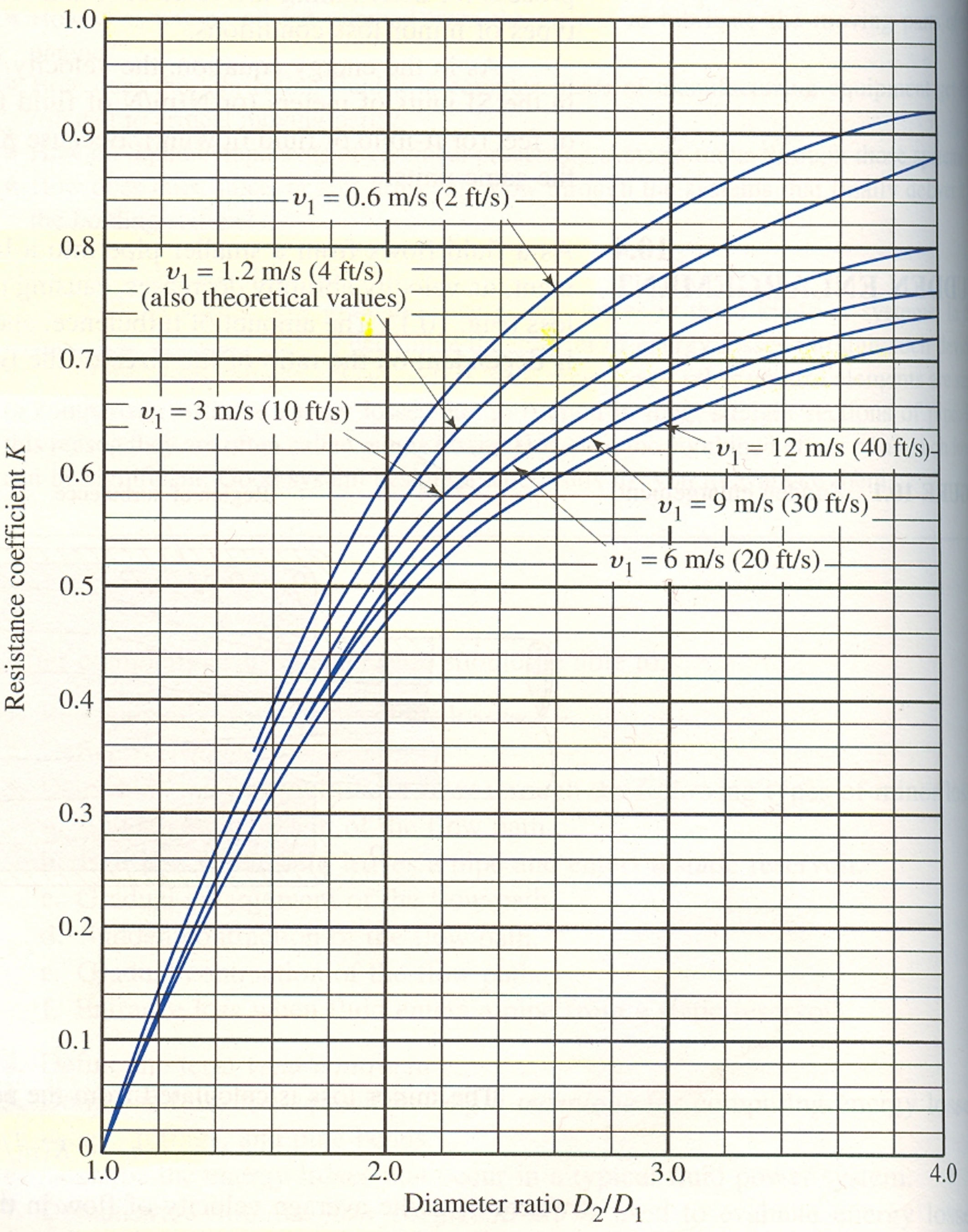
$D_2 = 73.8$ mm
$A_2 = 0.004282$ m^2

$V_1 = Q_1/A_1 = [(100 \text{ L/min})/(60{,}000)] / 0.0005017 = \mathbf{3.32}$ m/s

(convert L/min to m^3/s)

$D_2/D_1 = 2.92$

Use graph – Figure 10.2



K = 0.72

Therefore, $\mathbf{h_L = 0.72 * (3.32)^2 /2*9.81 = 0.40\ m}$

Example problem 10.2

Determine the pressure difference between the two pipes of the previous problem

Apply general energy equation –

$$p_1/\gamma + z_1 + v_1^2/2g - h_L = p_2/\gamma + z_2 + v_2^2/2g$$

rearrange –

$$p_1 - p_2 = \gamma[(z_2 - z_1) + (v_2^2 - v_1^2)/2g + h_L)]$$

$v_2 = Q/A_2 =$ **0.39 m/s**

put the values in the equation and solve for p_1-p_2

$$p_1 - p_2 = \gamma[(z_2 - z_1) + (v_2^2 - v_1^2)/2g + h_L)]$$

$p1-p2 = 9.81\ [\ 0 + ((0.39)^2 - (3.32)^2)/(2*9.81) + 0.40]$

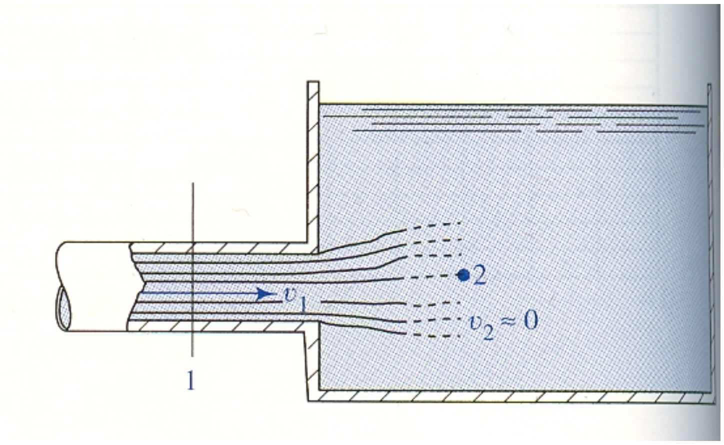
only minor loss is considered because of short pipe length.

$$p_1 - p_2 = - 1.51\ \mathrm{kPa}$$

$p_2 > p_1$.

Exit Loss

- Case of where pipe enters a tank – a very large enlargement.
- The tank water is assumed to be stationery, that is, the velocity is zero.
- Therefore **all kinetic energy in pipe is dissipated**, therefore K =1.0

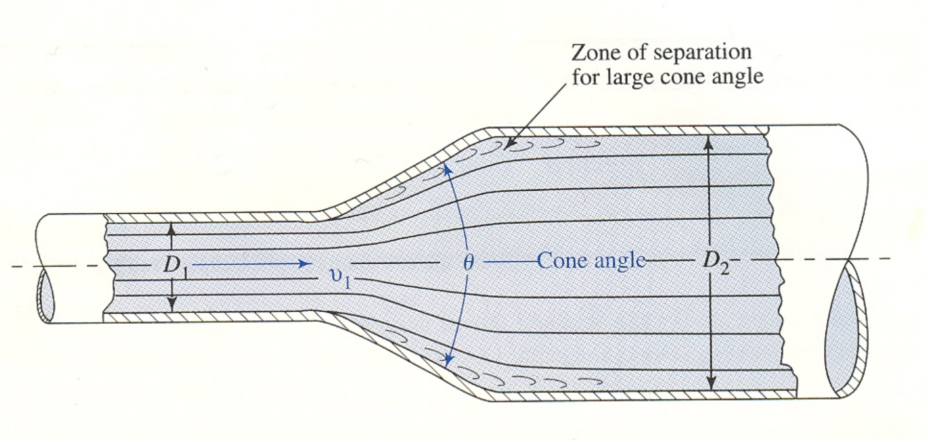


$$h_L = 1.0 * (v_1^2 / 2g)$$

Gradual Enlargement

If the enlargement is gradual (as opposed to our previous case) – the energy losses are less.

The **loss again depends on the ratio of the pipe diameters and the angle of enlargement**.



$$h_L = K(v_1^2/2g)$$

K can be determined from Fig 10.5 and table 10.2 -

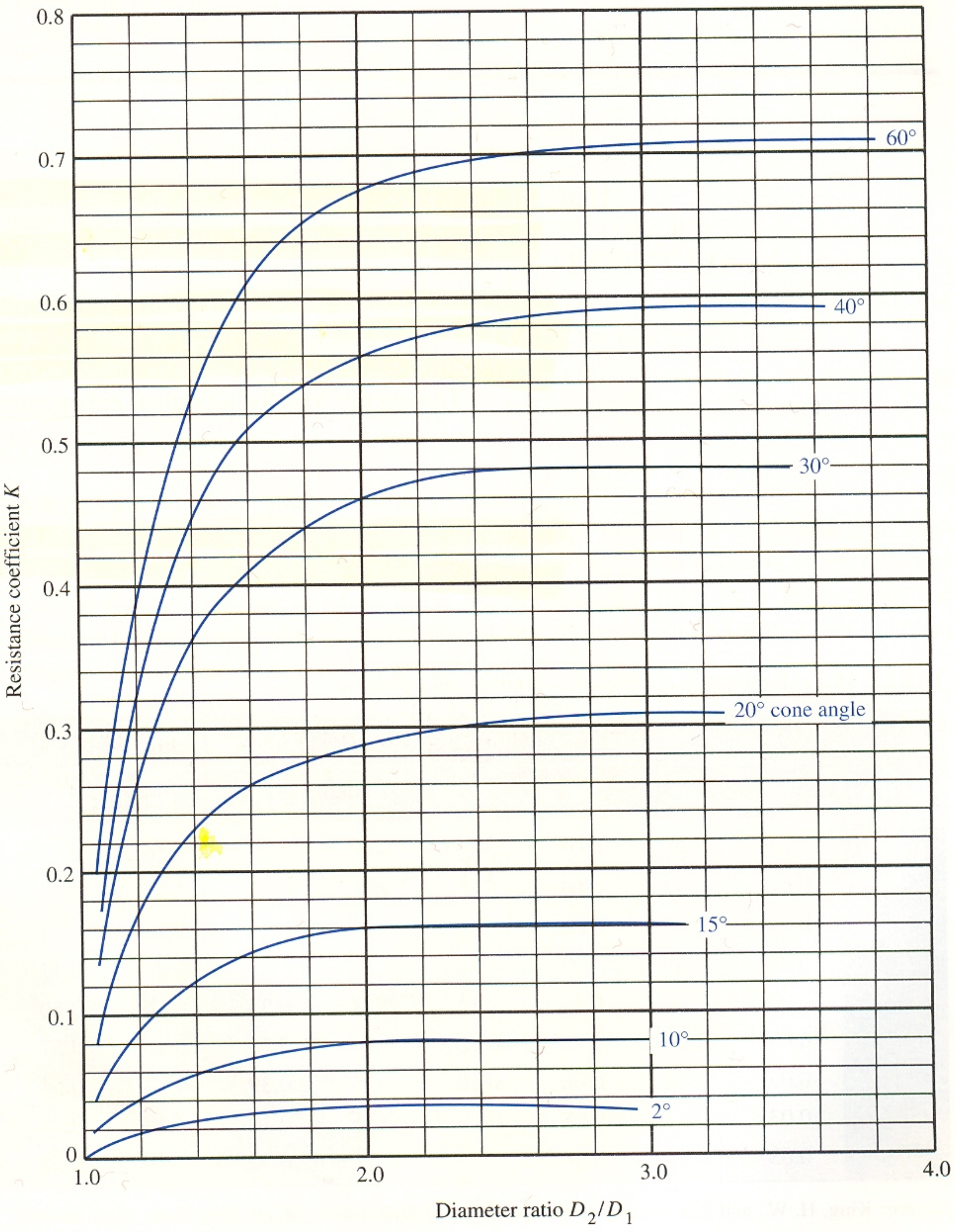

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Resistance coefficient K
1.0
2.0
3.0
4.0
Diameter ratio D2/D1
60°
40°
30°
20° cone angle
15°
10°
2°

Figure 10.5 -

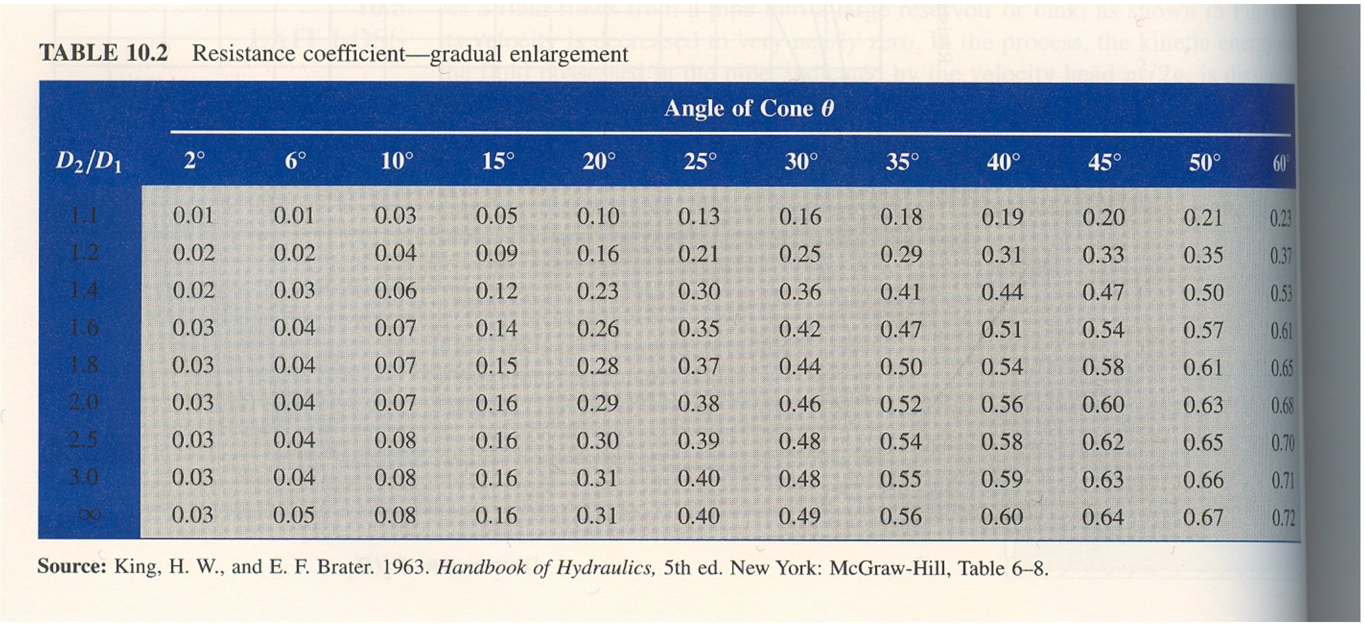


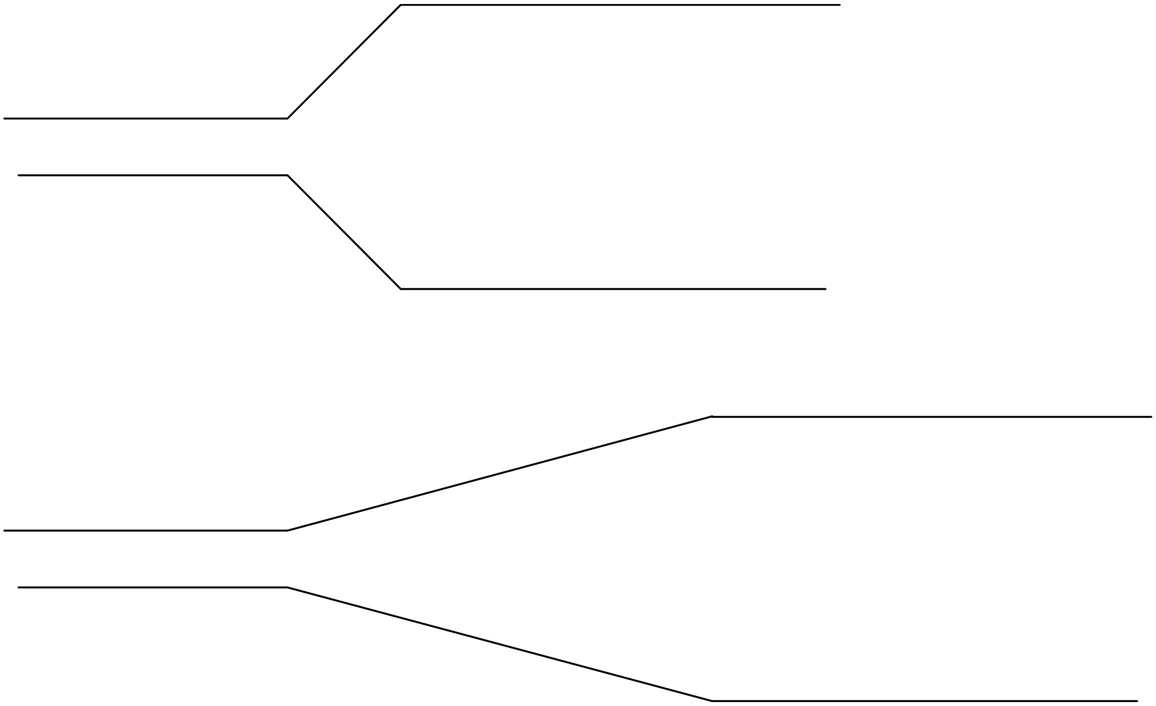
TABLE 10.2 Resistance coefficient—gradual enlargement

	Angle of Cone θ											
D_2/D_1	2°	6°	10°	15°	20°	25°	30°	35°	40°	45°	50°	60°
1.1	0.01	0.01	0.03	0.05	0.10	0.13	0.16	0.18	0.19	0.20	0.21	0.23
1.2	0.02	0.02	0.04	0.09	0.16	0.21	0.25	0.29	0.31	0.33	0.35	0.37
1.4	0.02	0.03	0.06	0.12	0.23	0.30	0.36	0.41	0.44	0.47	0.50	0.53
1.6	0.03	0.04	0.07	0.14	0.26	0.35	0.42	0.47	0.51	0.54	0.57	0.61
1.8	0.03	0.04	0.07	0.15	0.28	0.37	0.44	0.50	0.54	0.58	0.61	0.65
2.0	0.03	0.04	0.07	0.16	0.29	0.38	0.46	0.52	0.56	0.60	0.63	0.68
2.5	0.03	0.04	0.08	0.16	0.30	0.39	0.48	0.54	0.58	0.62	0.65	0.70
3.0	0.03	0.04	0.08	0.16	0.31	0.40	0.48	0.55	0.59	0.63	0.66	0.71
∞	0.03	0.05	0.08	0.16	0.31	0.40	0.49	0.56	0.60	0.64	0.67	0.72

Source: King, H. W., and E. F. Brater. 1963. *Handbook of Hydraulics,* 5th ed. New York: McGraw-Hill, Table 6–8.

Note –

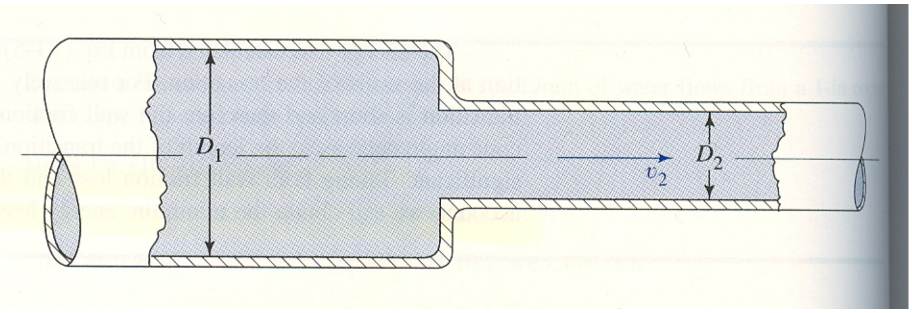
- If angle increases (in pipe enlargement) – minor losses increase
- **If angle decreases – minor losses decrease, but you also need a longer pipe to make the transition – that means more FRICTION losses - therefore there is a tradeoff**!



- **Minimum loss including minor and friction losses occur for <u>angle of 7 degrees – OPTIMUM angle</u>!**

Sudden Contraction

Decrease in pipe diameter –



Loss is given by –

$$h_L = K(v_2^2 / 2g)$$

Note that the **loss is related to the velocity in the second (smaller) pipe!**

The **loss is associated with the contraction of flow and turbulence** –

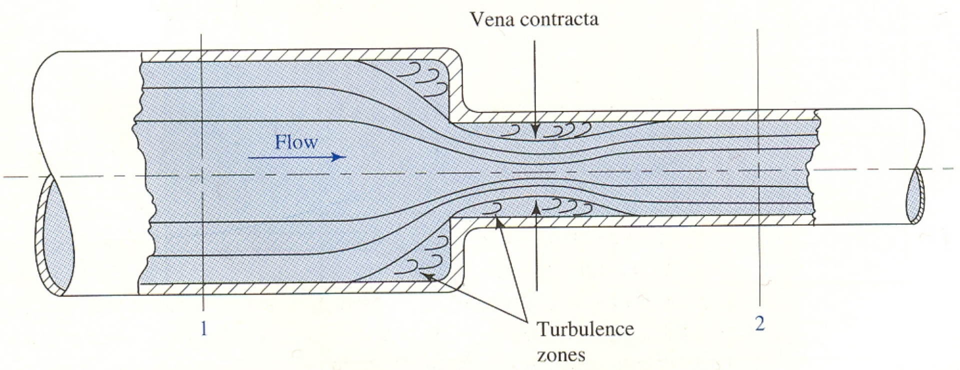
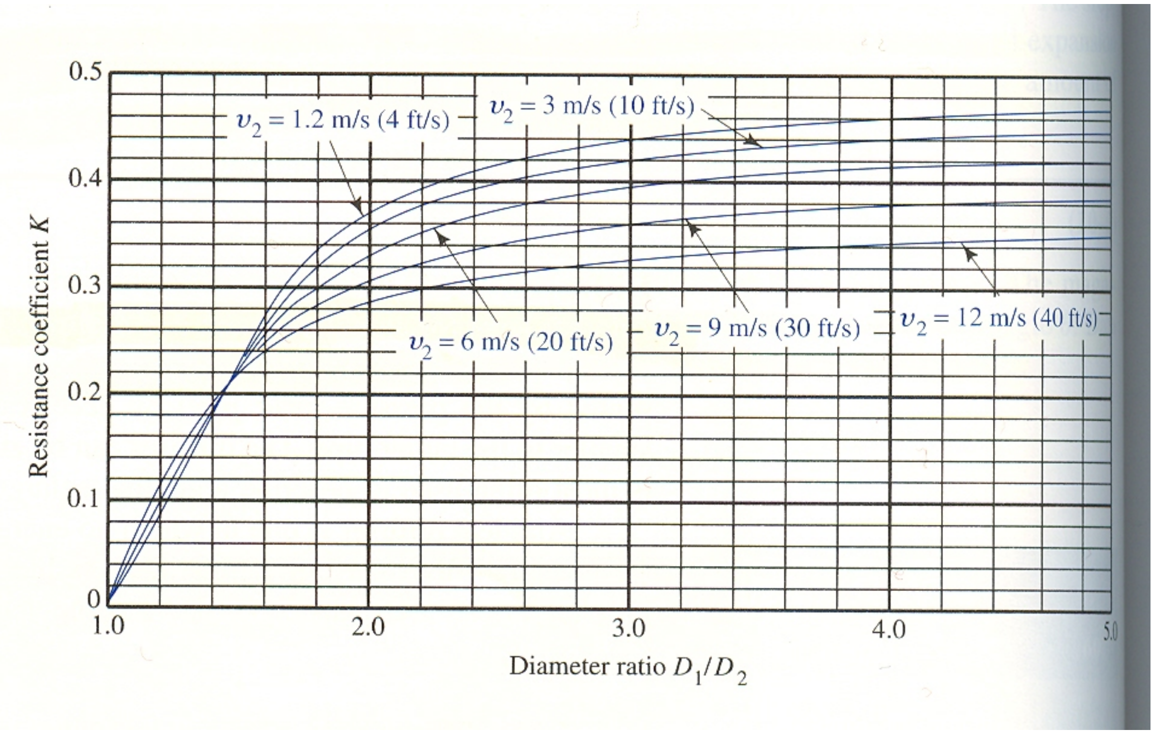


FIGURE 10.8 Vena contracta formed in a sudden contraction.

- The section at which the flow is the narrowest – **Vena Contracta**

- At vena contracta, the velocity is maximum.

K can be computed using **Figure 10.7 and table 10.3** – Again based on diameter ratio and velocity of flow



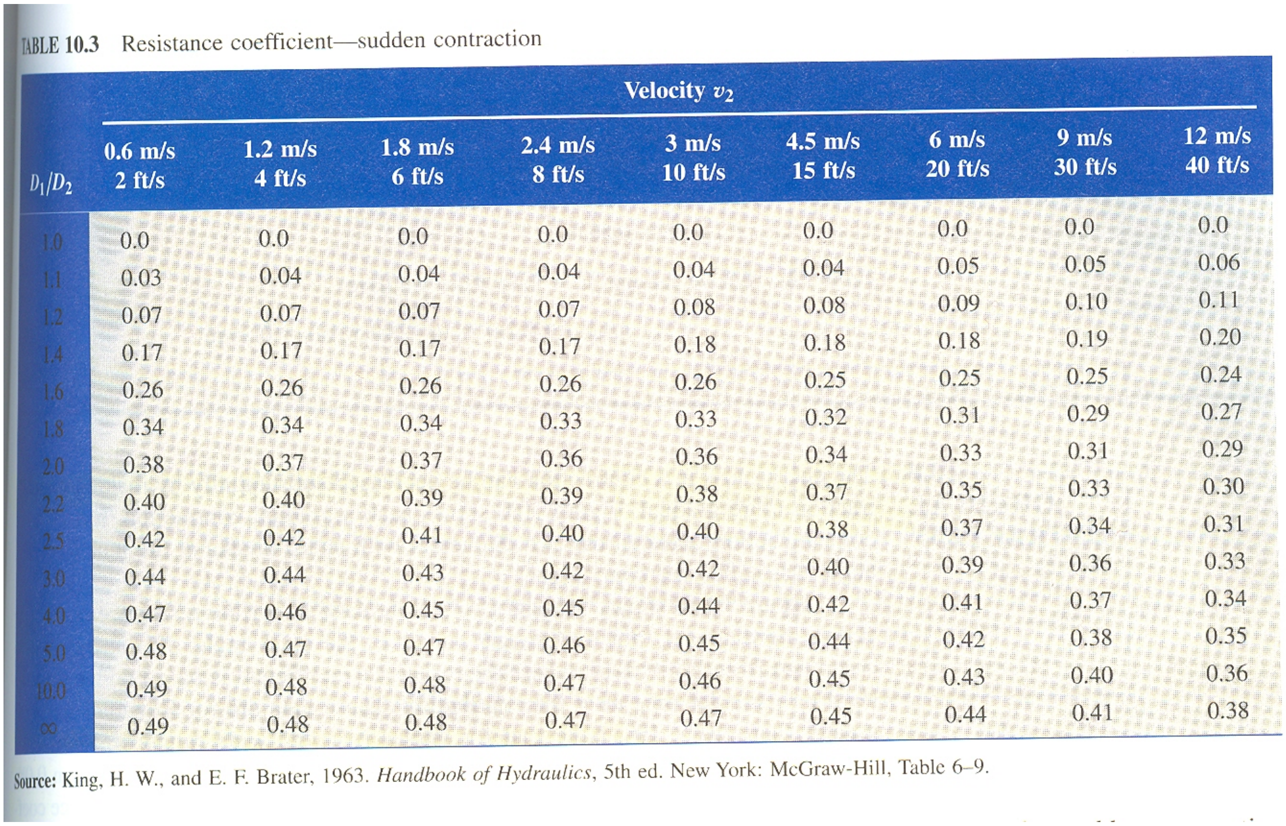
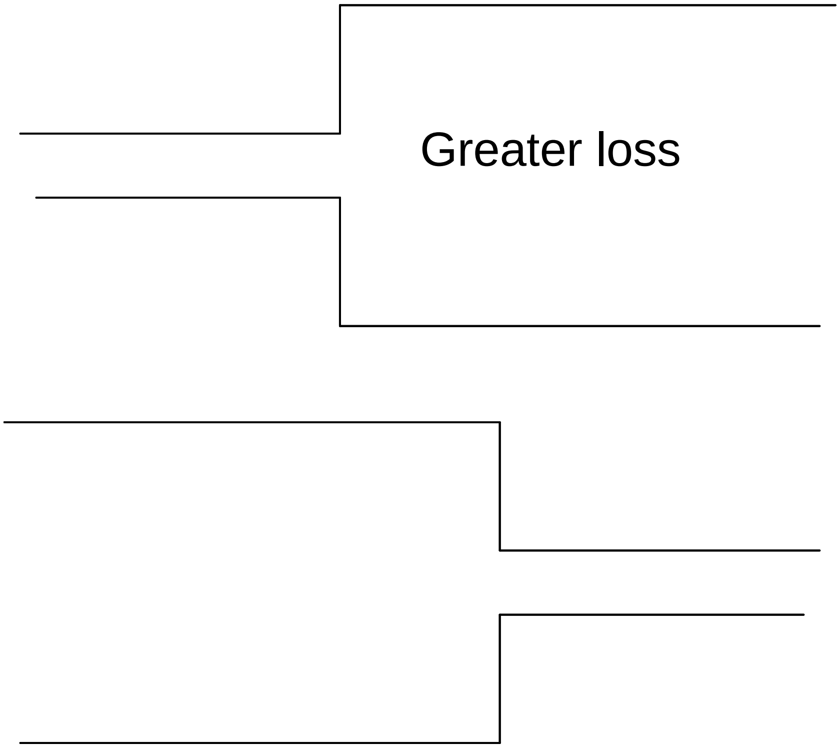


TABLE 10.3 Resistance coefficient—sudden contraction

	Velocity v_2								
D_1/D_2	**0.6 m/s 2 ft/s**	**1.2 m/s 4 ft/s**	**1.8 m/s 6 ft/s**	**2.4 m/s 8 ft/s**	**3 m/s 10 ft/s**	**4.5 m/s 15 ft/s**	**6 m/s 20 ft/s**	**9 m/s 30 ft/s**	**12 m/s 40 ft/s**
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.1	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.06
1.2	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.10	0.11
1.4	0.17	0.17	0.17	0.17	0.18	0.18	0.18	0.19	0.20
1.6	0.26	0.26	0.26	0.26	0.26	0.25	0.25	0.25	0.24
1.8	0.34	0.34	0.34	0.33	0.33	0.32	0.31	0.29	0.27
2.0	0.38	0.37	0.37	0.36	0.36	0.34	0.33	0.31	0.29
2.2	0.40	0.40	0.39	0.39	0.38	0.37	0.35	0.33	0.30
2.5	0.42	0.42	0.41	0.40	0.40	0.38	0.37	0.34	0.31
3.0	0.44	0.44	0.43	0.42	0.42	0.40	0.39	0.36	0.33
4.0	0.47	0.46	0.45	0.45	0.44	0.42	0.41	0.37	0.34
5.0	0.48	0.47	0.47	0.46	0.45	0.44	0.42	0.38	0.35
10.0	0.49	0.48	0.48	0.47	0.46	0.45	0.43	0.40	0.36
∞	0.49	0.48	0.48	0.47	0.47	0.45	0.44	0.41	0.38

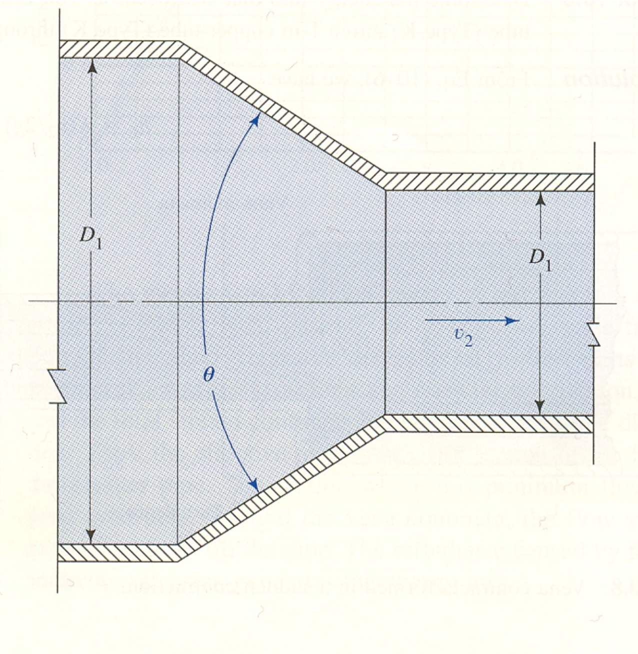
Source: King, H. W., and E. F. Brater, 1963. *Handbook of Hydraulics*, 5th ed. New York: McGraw-Hill, Table 6–9.

- **Energy losses for sudden contraction are less than those for sudden enlargement**


Greater loss

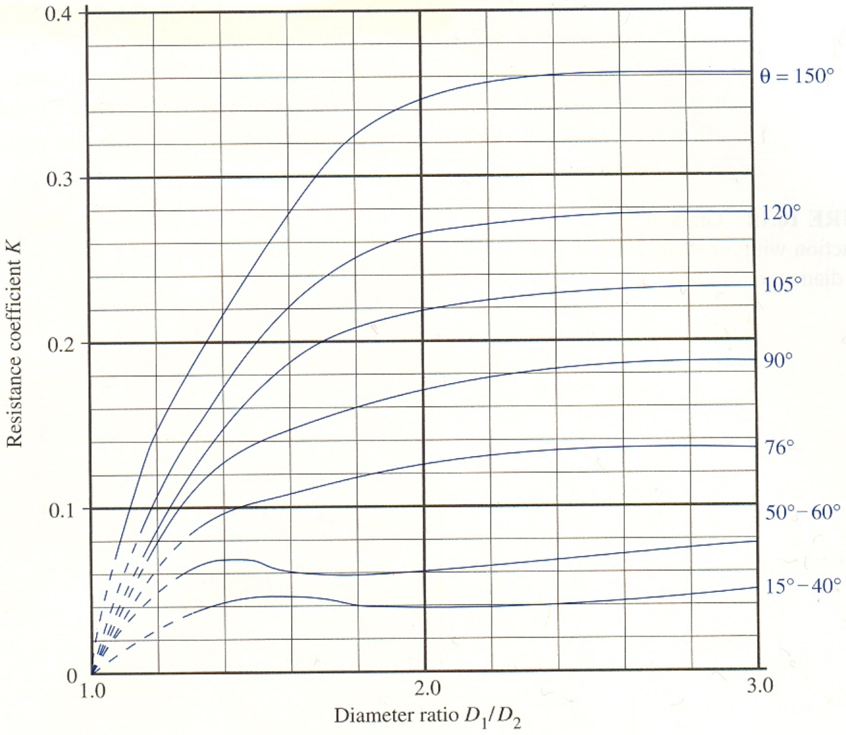
Gradual Contraction

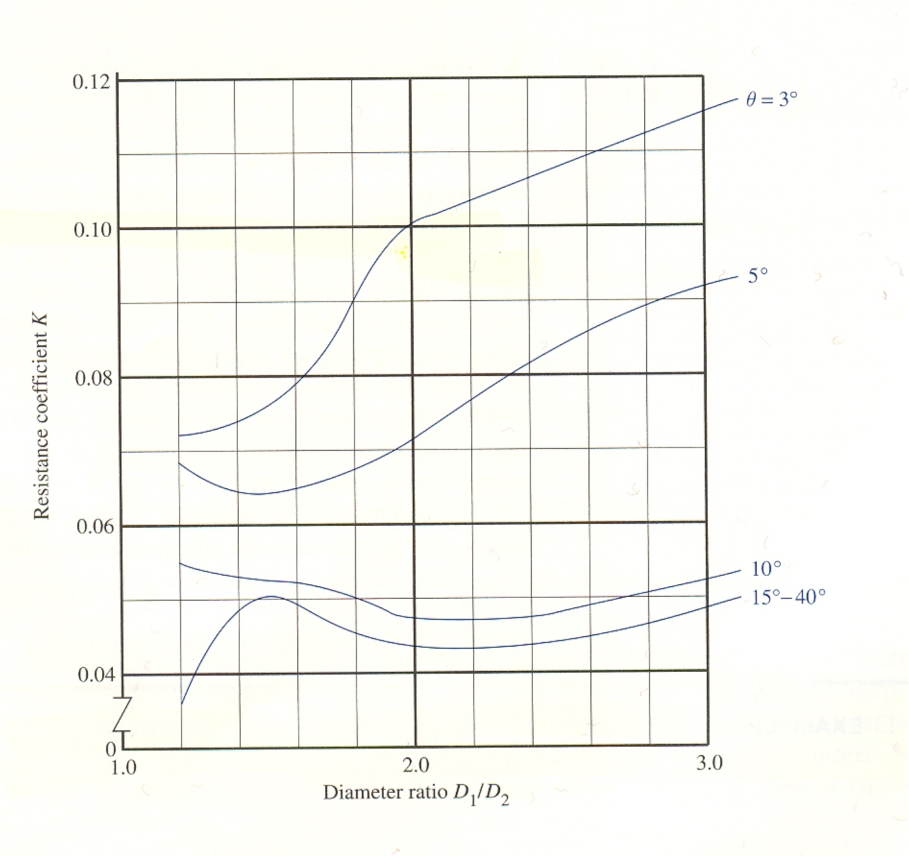
Again a **gradual contraction will lower the energy loss** (as opposed to sudden contraction). θ is called the cone angle.



$$h_L = K(v_2^{\ 2}/2g)$$

K is given by **Figs 10.10 and 10.11**


0.4
0.3
0.2
0.1
0
Resistance coefficient K
θ = 150°
120°
105°
90°
76°
50°−60°
15°−40°
1.0
2.0
3.0
Diameter ratio D_1/D_2

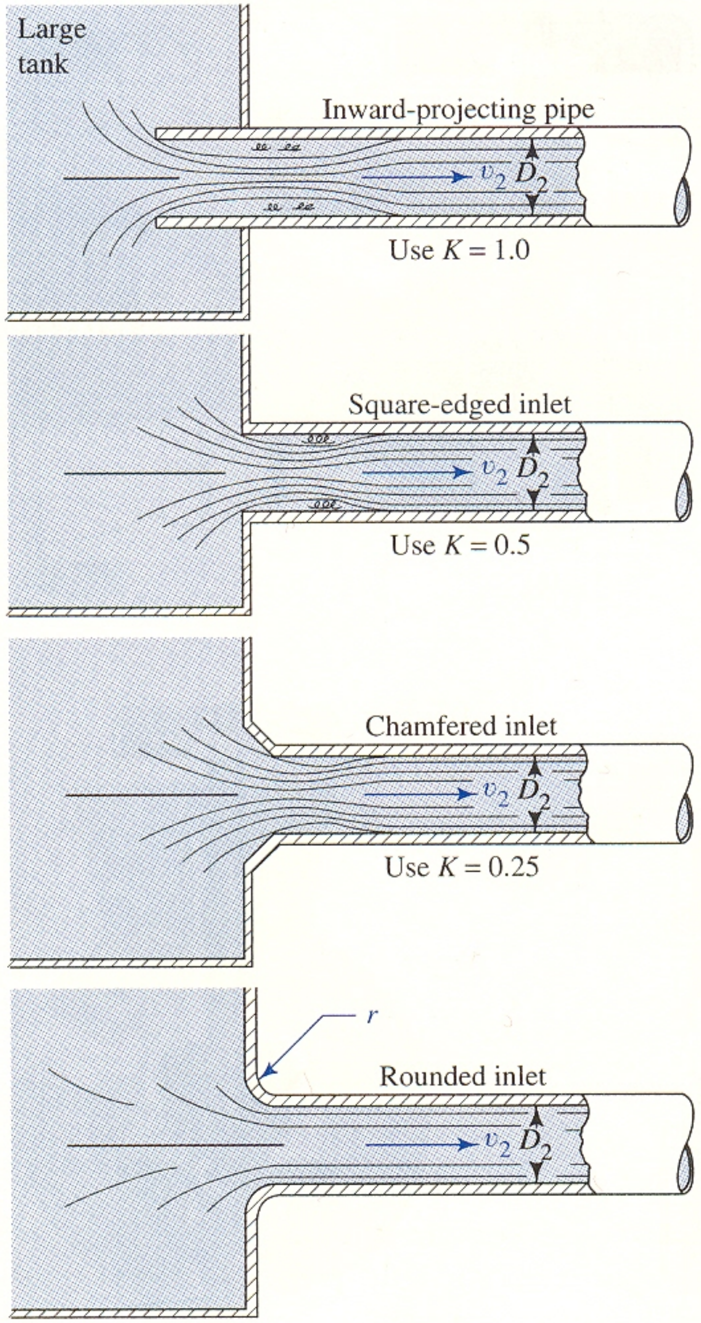


Note that K values increase for very small angles (less than 15 degrees)

Why – the plot values includes both the effect flow separation and friction!

Entrance Losses

Fluid moves from zero velocity in tank to v_2



r/D_2	K
0	0.50
0.02	0.28
0.04	0.24
0.06	0.15
0.10	0.09
>0.15	0.04 (Well-rounded)

Resistance Coefficients for Valves & Fittings

Loss is given by –

$$h_L = K(v^2/2g)$$

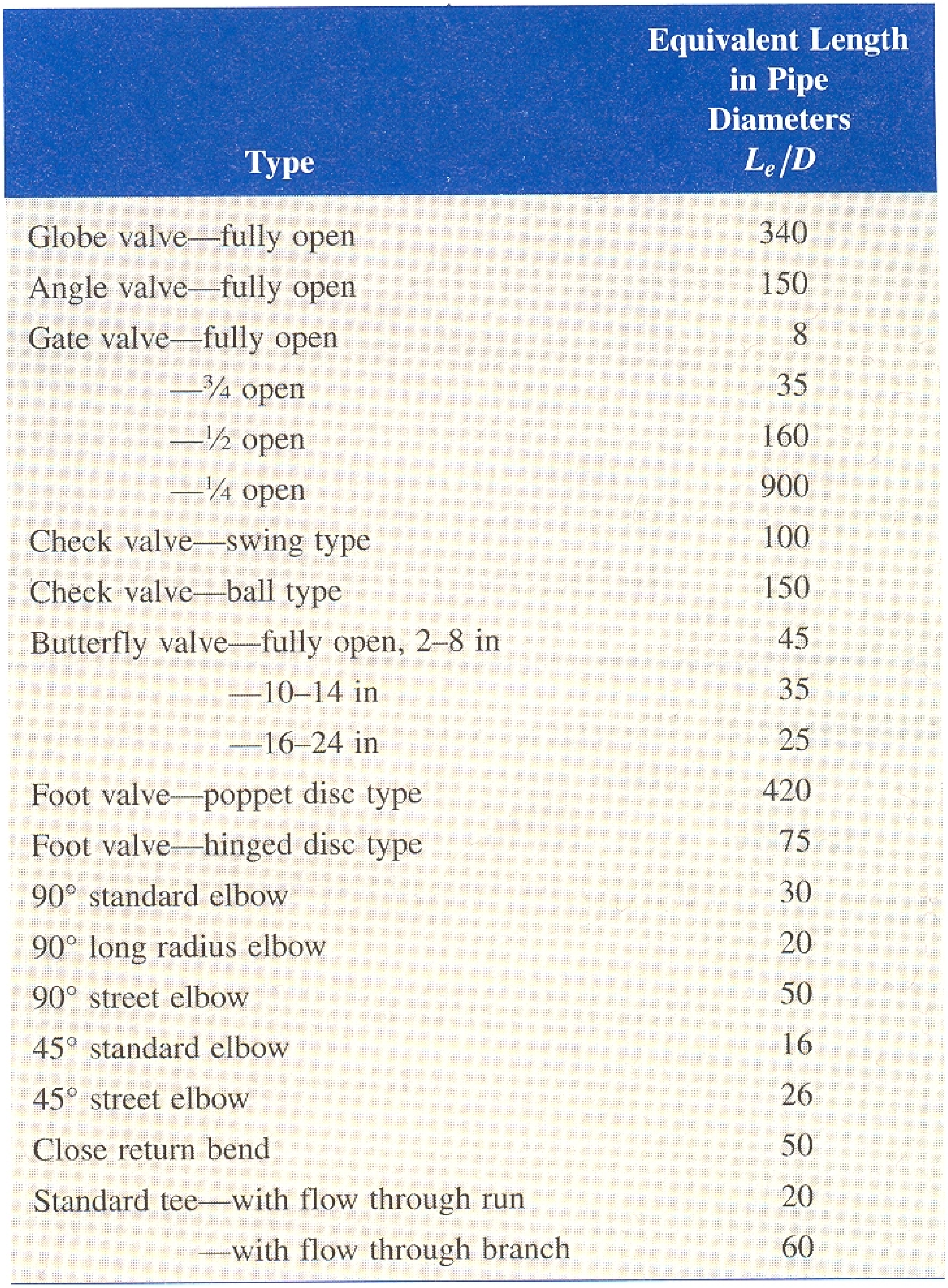
Where K is computed as –

$$K = (L_e/D) * f_t$$

L_e = equivalent length (length of pipe with same resistance as the fitting/valve)

f_T = friction factor

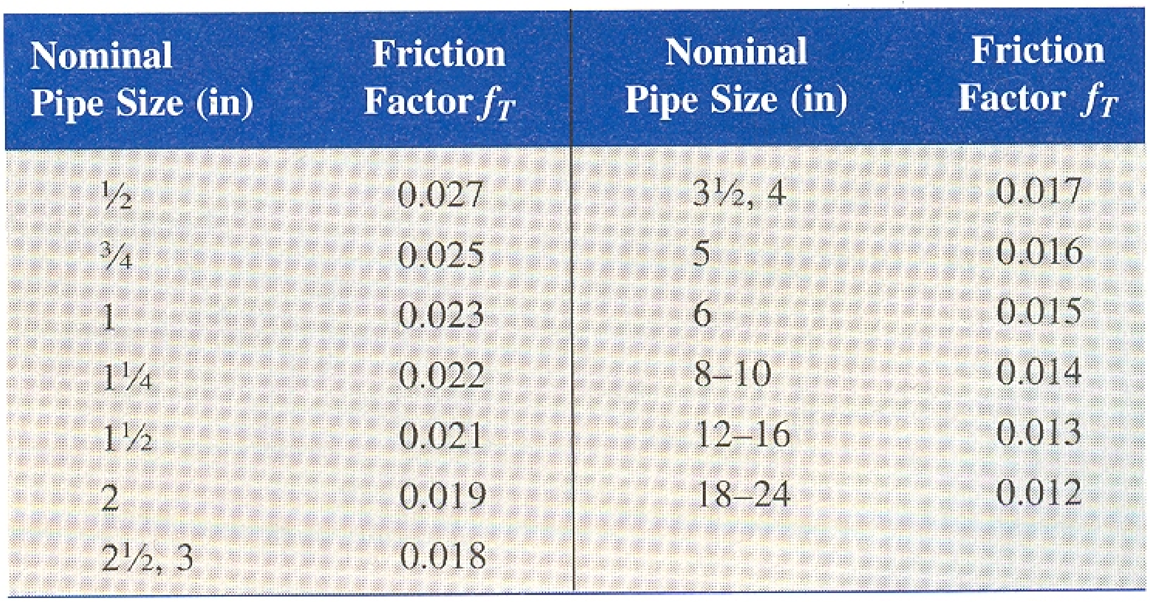
The **equivalent ratio (L_e/D)** can be computed by **Table 10.4** for various valves/fittings



Type	Equivalent Length in Pipe Diameters L_e/D
Globe valve—fully open	340
Angle valve—fully open	150
Gate valve—fully open	8
—¾ open	35
—½ open	160
—¼ open	900
Check valve—swing type	100
Check valve—ball type	150
Butterfly valve—fully open, 2–8 in	45
—10–14 in	35
—16–24 in	25
Foot valve—poppet disc type	420
Foot valve—hinged disc type	75
90° standard elbow	30
90° long radius elbow	20
90° street elbow	50
45° standard elbow	16
45° street elbow	26
Close return bend	50
Standard tee—with flow through run	20
—with flow through branch	60

Source: Crane Valves, Signal Hill, CA.

And
f_T for <u>new steel pipe</u> can be computed using Table 10.5



Nominal Pipe Size (in)	Friction Factor f_T	Nominal Pipe Size (in)	Friction Factor f_T
½	0.027	3½, 4	0.017
¾	0.025	5	0.016
1	0.023	6	0.015
1¼	0.022	8–10	0.014
1½	0.021	12–16	0.013
2	0.019	18–24	0.012
2½, 3	0.018		

For OLD pipes however, f_T cannot be computed by this table.

You have to use the procedure we used for Moody's diagram!

- Get ε for the pipe type from Table 8.2
- Determine D/ε for the pipe
- Then use the Moody diagram to determine the value of f_T for the zone of complete turbulence.

NO ASSIGNMENTS!