Module 6: Minor Losses (CIVL 318)

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\epsilon)} + \frac{5.74}{N_R^{0.9}}\right)\right]^2}$$

$$h_L = K \cdot \frac{v^2}{2g}$$

Flow through valves:

$$h_L = f_T \cdot \frac{L_e}{D} \cdot \frac{v^2}{2g}$$

K-values for Sudden Contraction

	Velocity, v								
D_1/D_2	0.6 m/s	1.2 m/s	1.8 m/s	2.4 m/s	3 m/s	4.5 m/s	6 m/s	9 m/s	12 m/s
1	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	0.38	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

K-values for Gradual Contraction

$$K = \begin{cases} 0.5\sqrt{\sin\frac{\theta}{2}}\left(1 - \left(\frac{D_2}{D_1}\right)^2\right), & 45^\circ < \theta \leq 180^\circ \\ 0.8\sin\frac{\theta}{2}\left(1 - \left(\frac{D_2}{D_1}\right)^2\right), & 15^\circ < \theta \leq 45^\circ \end{cases}$$

where D_2 is the smaller (downstream) diameter of the pipe after the contraction and D_1 is the diameter of the larger (upstream) pipe and the head loss is based on the velocity of the smaller pipe.

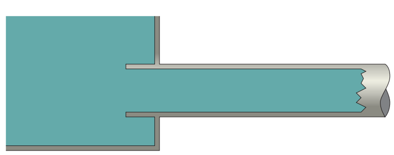
K-values for Sudden Enlargement:

	Velocity, v						
D_2/D_1	0.6 m/s	1.2 m/s	3 m/s	4.5 m/s	6 m/s	9 m/s	12 m/s
1	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

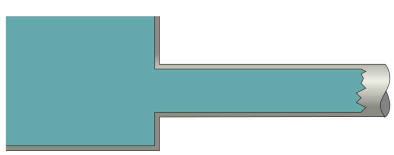
K-values for Gradual Enlargement

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	0.81	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	0.03	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

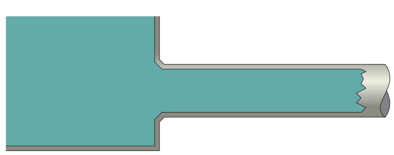
K-values for Entrance Losses



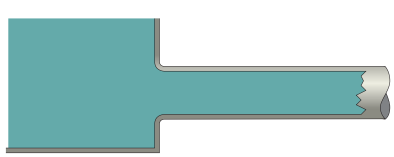
Inward-projecting: $K = 0.78$ — 1.0



Square-edged inlet: $K = 0.5$

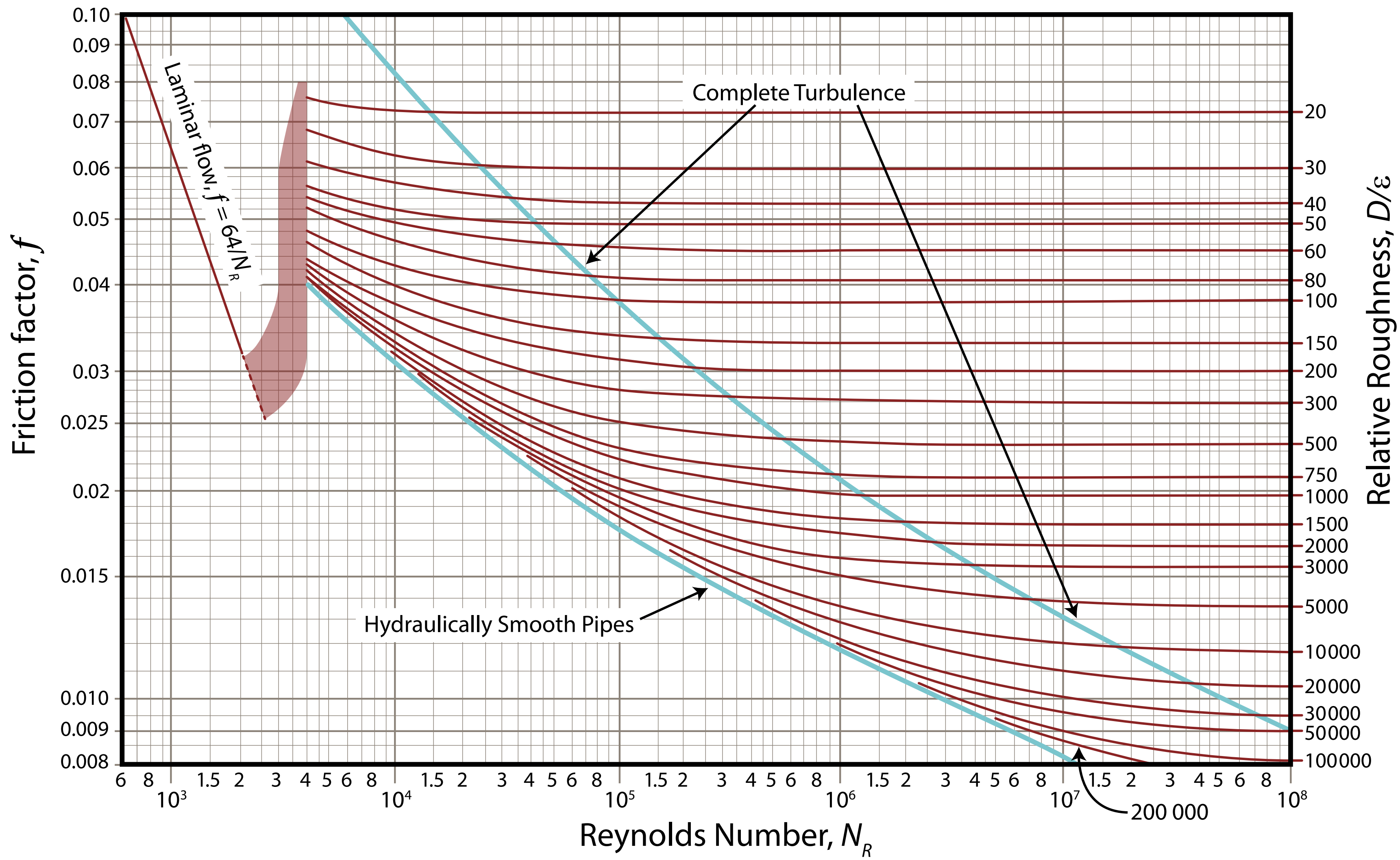


Chamfered Inlet: $K = 0.25$



Rounded inlet:

r/D	K
0	0.5
0.02	0.28
0.04	0.24
0.06	0.15
0.10	0.09
≥ 0.15	0.04



Friction factor, f
Reynolds Number, N_R
Relative Roughness, D/ε
Laminar flow, $f = 64/N_R$
Complete Turbulence
Hydraulically Smooth Pipes
200 000

Exit Loss (i.e. exiting a pipe into a tank where all velocity is lost):

$$K = 1 \Rightarrow h_L = \frac{v^2}{2g}$$

Friction Factor, f_T in the zone of complete turbulence for new clean commercial **steel** pipe:

Nominal Size (in)	f_T	Nominal Size (in)	f_T
$\frac{1}{2}$	0.027	$3\frac{1}{2}, 4$	0.017
$\frac{3}{4}$	0.025	5	0.016
1	0.023	6	0.015
$1\frac{1}{4}$	0.022	$8 - 10$	0.014
$1\frac{1}{2}$	0.021	$12 - 16$	0.013
2	0.019	$18 - 24$	0.012
$2\frac{1}{2}, 3$	0.018		

Equivalent-length ratios for valves:

Type	L_e/D
Globe valve — fully open	340
Angle valve — fully open	150
Gate valve — fully open	8
— 3/4 open	35
— 1/2 open	160
— 1/4 open	900
Check valve — swing type	100
Check valve — ball type	150
Butterfly valve — fully open	45
Foot valve — poppet disc type	420
Foot valve — hinged disc type	75

Table of Equivalent-Length Ratios for Fittings

Type	L_e/D
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 — flow through run	20
Standard tee — flow through branch	60

Example 1:

Determine the head loss that occurs when 100 L/min of fluid flows from 3-in Type K copper tube $(D = 73.84\,\text{mm})$ into 1-in Type K copper tube $(D = 25.27\,\text{mm})$ through a sudden contraction.

Solution:

Example 2:

Determine the head loss for a gradual contraction from 4-in Schedule 80 pipe $(D = 97.2\,\text{mm})$ to a $1\frac{1}{2}$-in Schedule 80 pipe $(D = 38.1\,\text{mm})$ with a cone angle of 76°.
The flow is 450 L/min.

Solution:

Example 3:

Determine the head loss that occurs when 100 L/min flows from 1-in Type K copper tube ($D = 25.27\,\text{mm}$) into 3-in Type K copper tube ($D = 73.48\,\text{mm}$) through a sudden enlargement.

Solution:

Example 4:

Compare the headlosses between an inward-projecting entrance and rounded entrance with a radius of 25 mm for water entering 6-in Schedule 40 steel pipe ($D = 154.1\,\text{mm}$) with a flow of 75L/s. (Use $K = 0.78$.)

Solution:

Example 5:

Find the pressure drop across a fully open globe valve $(L_e/D = 340)$ in 4-in Shedule 40 steel pipe $(D = 102.3\,\mathrm{mm})$ carrying 1600 L/min.

Solution:

Example 6:

Calculate the headloss across a ball-type check valve placed in a $1\frac{1}{4}$-in copper tubing $(D = 31.62\,\text{mm})$ if water is flowing through the tubing with a velocity of 2.35 m/s.

Solution:

Example 7:

Find the pressure drop across a 90° standard elbow in a $2\frac{1}{2}$-in Schedule 40 steel pipe $(D = 62.7\,\text{mm})$ if water is flowing at the rate of 800 L/min.

Solution: