PÉRDIDAS SINGULARES EN TUBERÍAS

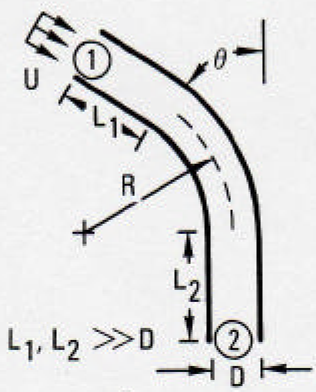
REFERENCIA:

Blevin R.D., (1984) "Applied Fluid Dynamics Handbook", van Nostrand Reinhold Co. Inc.

CURVAS

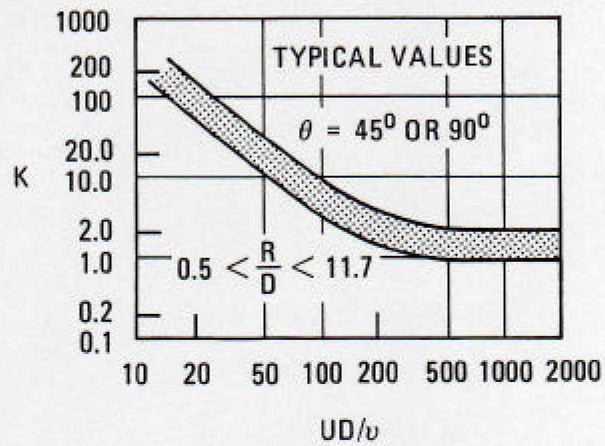
Description and Δp	Loss Coefficient, K

1. Smooth Bend in Circular Pipe



$$\frac{\Delta p}{\frac{1}{2}\rho U^2} = K + \frac{f(L_1 + L_2)}{D}$$

Laminar Flow, $UD/\nu < 2000$



Refs. 6-47, 6-48. Ref. 6-48 suggests that for θ = 180°, values of K are about twice the above values.

Turbulent Flow, $UD/\nu > 4000$

A. Moderate bends, $R/D \geq 1.8$

$\frac{UD}{\nu}\left(\frac{D}{R}\right)^2$	K
0-360	$0.0175\, \alpha f_c \theta\, R/D$
> 360	$0.00431\, \alpha\, \theta \left(\frac{UD}{\nu}\right)^{-0.17} \left(\frac{R}{D}\right)^{0.84}$

Description and Δp	Loss Coefficient, K
1. Smooth Bend in Circular Pipe (Continued) (Values of K are given in Fig. 6-8)	θ in degrees. f_c from frame 2 for same R, D, UD/ν. α is given as follows:

θ (deg)	α
45	$1.0 + 5.13\,(D/R)^{1.47}$
90	$\begin{cases} 0.95 + 4.42\,(D/R)^{1.96} & \text{for } R/D < 9.85 \\ 1.0 & \text{for } R/D > 9.85 \end{cases}$
180	$1.0 + 5.06\,(D/R)^{4.52}$

Ref. 6-49. Interpolate for other θ.
$\alpha = 1$ for $R > 50D$ regardless of θ.

B. Sharp Bends, $R/D \leq 2$ for $UD/\nu \geq 5 \times 10^5$.

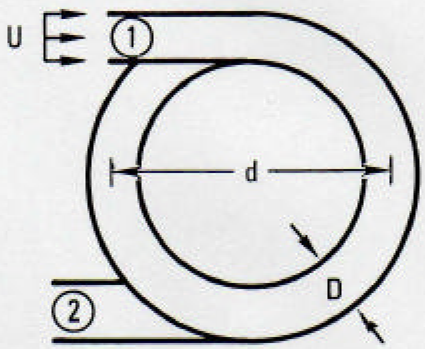
	K					
	θ (degrees)					
R/D	20	30	45	75	90	180
0.5	0.053	0.12	0.27	0.80	1.1	--
0.75	0.038	0.070	0.14	0.31	0.40	0.70
1.0	0.035	0.058	0.10	0.20	0.25	0.28
1.5	0.040	0.060	0.090	0.15	0.18	0.21
2.0	0.045	0.065	0.089	0.14	0.16	0.19

Ref. 6-49, pp. 15, 156
For $UD/\nu < 5 \times 10^5$,

$$K\big|_{Re} = \left(K\big|_{Re \geq 5\times10^5}\right)\left(\frac{5 \times 10^5}{Re}\right)^{0.17}$$

Description and Δp	Loss Coefficient, f_c

2. Coil of Circular Pipe



$$\frac{\Delta p}{\frac{1}{2}\rho U^2} = \frac{f_c L}{D}$$

(L = length of pipe in coil, i.e., πd × number of turns.)

Laminar Flow $\frac{UD}{\nu} < 2100\left[1 + 12\left(\frac{D}{d}\right)^{1/2}\right]$,

$N = \frac{UD}{\nu}\left(\frac{D}{d}\right)^{1/2}$	$\frac{f_c}{f}$ (a)
0-11.6	1.0
11.6-2000	$\dfrac{11}{1 - \left[1 - \left(\frac{11.6}{N}\right)^{0.45}\right]^{2.2}}$
>2000	$0.11\ N^{1/2}$ (b)

$0.01 < d/D < 0.15$, Ref. 6-50.

(a) f = friction factor for laminar flow in straight pipe, Table 6-2.

(b) For square cross section, this becomes $0.13\ N^{1/2}$, where D is the length of one side (Ref. 6-51).

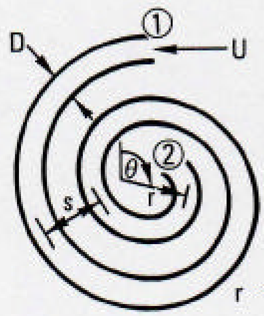
Turbulent Flow, $\frac{UD}{\nu} > 2100\left[1 + 12\left(\frac{D}{d}\right)^{1/2}\right]$,

$$f_c = \frac{0.336}{\left[\frac{UD}{\nu}\left(\frac{D}{d}\right)^{1/2}\right]^{0.2}}$$

$0.01 < \frac{d}{D} < 0.15$, Ref. 6-52.

Description and Δp	Loss Coefficient, K

3. Spiral of Circular Pipe



$$r = \frac{s\theta}{2\pi}$$

$$\frac{\Delta p}{\frac{1}{2}\rho U^2} = \frac{fL}{D}$$

(L = length of pipe in spiral.)

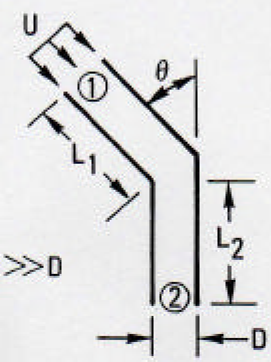
Loss Coefficient, K:

$$f = \frac{\alpha (n_1^{\beta} - n_2^{\beta})^{\gamma}}{\left[\frac{UD}{\nu}\left(\frac{2s}{D}\right)^{1/2}\right]^{\delta}} \quad , \quad 7.3 < \frac{2s}{D} < 15.5$$

$\frac{UD}{\nu}\left(\frac{2s}{D}\right)^{1/2}$	α	β	γ	δ
500–2000 (laminar)	2.5	0.7	2.0	0.6
2×10^3 – 4×10^3 (transitional)	2.1	0.75	1.0	0.5
4×10^3 – 150×10^3 (turbulent)	0.030	0.9	1.5	0.2

n_1, n_2 = number of turns in spiral from origin (θ = 0) to points ① and ②, respectively. Ref. 6-52.

4. Miter Bend in Circular Pipe



$L_1, L_2 \gg D$

$$\frac{\Delta p}{\frac{1}{2}\rho U^2} = K + \frac{f(L_1 + L_2)}{D}$$

Loss Coefficient, K:

Turbulent Flow, $\frac{UD}{\nu} > 4 \times 10^3$

θ (deg)	$K^{(a)}$
10	0.025
20	0.055
30	0.10
40	0.20
50	0.35

θ (deg)	$K^{(a)}$
60	0.50
70	0.70
80	0.90
90	1.1
120	1.5

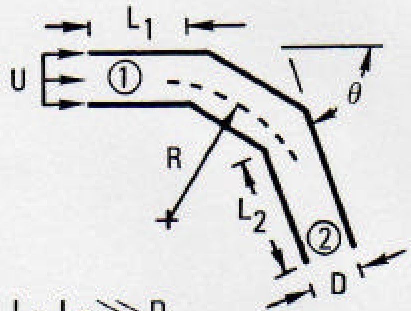
Refs. 6-39, p. 216; 6-4, p. 19; 6-53.

(a) For Re = $UD/\nu \geq 2 \times 10^5$.
For Re $< 2 \times 10^5$,

$$K|_{Re} = \left(K|_{Re=2\times10^5}\right)\left(\frac{2\times10^5}{Re}\right)^{0.2}$$

Description and Δp	Loss Coefficient, K

5. Compound Miter Bend in Circular Pipe



$L_1, L_2 \gg D$

All bend angles are equal.
n = 2 bends shown.

$$\frac{\Delta p}{\frac{1}{2}\rho U^2} = K + \frac{f(L_1 + L_2)}{D}$$

Turbulent Flow, $UD/\nu > 4000$

θ (deg)	R/D	K[a] n=2[b]	n=3	n=4
45	2.95	0.11	--	--
60	2.95	0.15	--	--
90	0.5	0.70	0.75	0.75
	1.0	0.45	0.40	0.40
	1.5	0.35	0.35	0.30
	2.0	0.30	0.30	0.25
	3.0	0.35	0.20	0.20
	4.0	0.40	0.25	0.20
	5.0	0.45	0.25	0.20
180	0.5	4.0	--	--

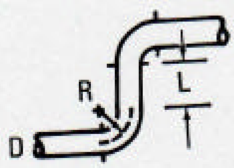
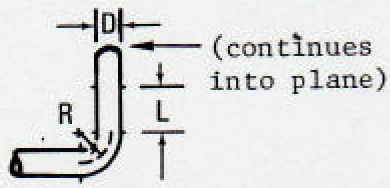
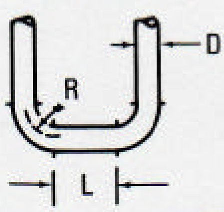
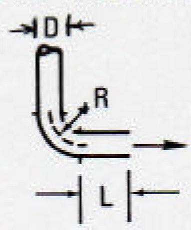
Refs. 6-4, p. 19; 6-39, pp. 223-226.

[a] For $UD/\nu = Re \geq 2 \times 10^5$.
For $Re < 2 \times 10^5$,

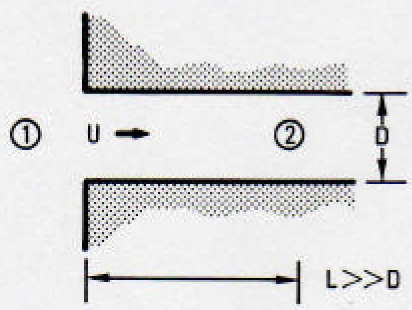
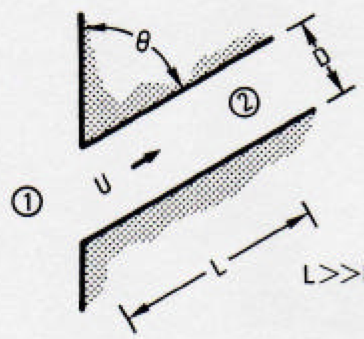
$$K\Big|_{Re} = \left(K\Big|_{Re=2\times10^5}\right)\left(\frac{2\times10^5}{Re}\right)^{0.2}$$

[b] n = number of individual bends.

INTERACCIÓN EN CAMBIOS DE DIRECCIÓN (CODOS)

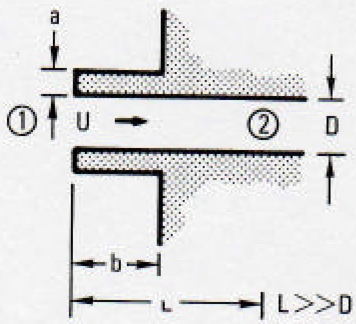
Description of Bends	R/D	$K_{combination}/\Sigma K_{components}$ — Spacing Between Components, L/D: 0	4	10	20	30
1. S of Two 90° Bends	1.85	0.86	0.72	0.82	0.95	0.96
	3.3	0.84	0.82	0.86	0.96	1.0
	7.5	0.93	0.96	0.97	1.0	1.0
2. Twisted S of Two 90° Bends	1.85	0.88	0.73	0.86	0.96	0.97
	3.3	0.86	0.81	0.88	0.97	1.0
3. U of Two 90° Bends	1.85	0.58	0.72	0.83	0.92	0.98
	3.3	0.73	0.80	0.88	0.97	0.98
	7.5	0.97	0.97	0.98	1.00	1.00
4. 90° Bend and Exit into Plenum.	1.15	1.91	0.64	0.82	0.93	0.99
 (K_{exit} includes loss plus expansion)	3.45	0.56	0.62	0.87	0.96	1.0

CONTRACCIONES Y EXPANSIONES

Description and Static Pressure Change	Non-Recoverable Loss Coefficient, K
1. Entrance Flush with Wall At Right Angle  $\frac{p_1 - p_2}{\frac{1}{2}\rho U^2} = 1 + K + \frac{fL}{D}$	$K = 0.5$
2. Entrance Flush with Wall at Arbitrary Angle  $\frac{p_1 - p_2}{\frac{1}{2}\rho U^2} = 1 + K + \frac{fL}{D}$	$K = 0.5 + 0.3 \cos\theta + 0.2 \cos^2\theta$ Ref. 6-73

Description and Static Pressure Change	Non-Recoverable Loss Coefficient, K

3. Protruding Entrance

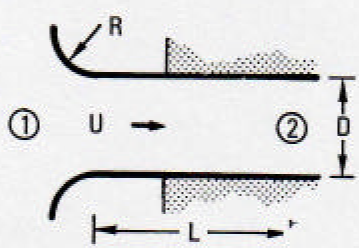


$$\frac{p_1 - p_2}{\frac{1}{2}\rho U^2} = 1 + K + \frac{fL}{D}$$

	K					
	b/D					
a/D	0.005	0.01	0.10	0.50	>0.5	>0.5 (Ref. 6-74)
0	0.63	0.68	0.86	1.0	1.0	1.0
0.005	0.57	0.62	0.79	0.93	0.93	0.90
0.01	0.54	0.57	0.71	0.86	0.86	0.82
0.02	0.51	0.52	0.60	0.72	0.72	0.66
0.03	0.50	0.51	0.54	0.61	0.61	0.50
0.05	0.50	0.50	0.50	0.50	0.50	0.43
>0.05	0.50	0.50	0.50	0.50	0.50	0.44

Ref. 6-39, p. 92, except as noted.

4. Rounded Entrance



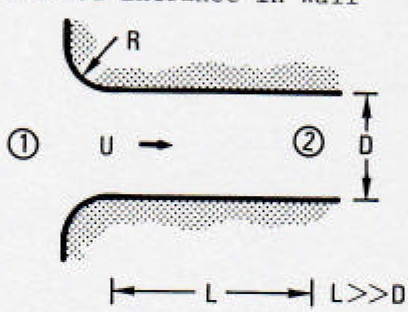
$$\frac{p_1 - p_2}{\frac{1}{2}\rho U^2} = 1 + K + \frac{fL}{D}$$

R/D	K
0	1.0
0.01	0.87
0.02	0.74
0.03	0.61
0.04	0.51
0.05	0.40

R/D	K
0.06	0.32
0.08	0.20
0.12	0.10
0.16	0.06
0.20	0.03
0.60	0.01

Ref. 6-39, p. 93.

5. Rounded Entrance in Wall

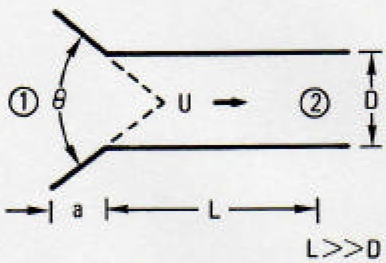


$$\frac{p_1 - p_2}{\frac{1}{2}\rho U^2} = 1 + K + \frac{fL}{D}$$

	K	
R/D	Ref. 6-39	Ref. 6-75
0	0.50	0.44
0.01	0.43	0.35
0.02	0.36	0.28
0.03	0.31	0.22
0.04	0.26	0.17
0.05	0.22	0.13
0.06	0.20	0.10
0.08	0.15	0.07
0.12	0.09	0.03
0.16	0.06	0.0
>0.16	0.03	0.0

Description and Static Pressure Change	Non-Recoverable Loss Coefficient, K

6. Conical Entrance

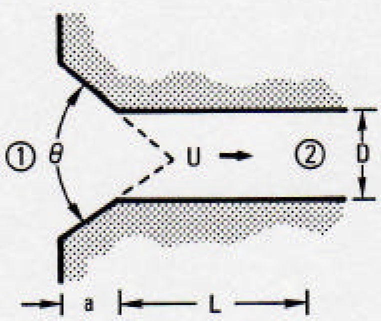


$$\frac{p_1 - p_2}{\frac{1}{2}\rho U^2} = 1 + K + \frac{fL}{D}$$

a/D	K, θ(deg): 0	10	20	40	60	100	140
0.025	1.0	0.96	0.93	0.86	0.80	0.69	0.59
0.050	1.0	0.93	0.86	0.75	0.67	0.58	0.53
0.10	1.0	0.80	0.67	0.48	0.41	0.41	0.44
0.25	1.0	0.68	0.45	0.22	0.17	0.22	0.34
0.60	1.0	0.46	0.27	0.14	0.13	0.21	0.33
1.00	1.0	0.32	0.20	0.11	0.10	0.18	0.30

Ref. 6-39, p. 95.

7. Conical Entrance in Wall

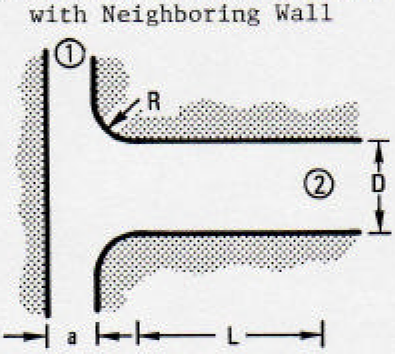


$$\frac{p_1 - p_2}{\frac{1}{2}\rho U^2} = 1 + K + \frac{fL}{D}$$

a/D	K, θ(deg): 0	10	20	40	60	100	140	180
0.025	0.5	0.47	0.45	0.41	0.40	0.42	0.45	0.5
0.050	0.5	0.45	0.41	0.33	0.30	0.35	0.42	0.5
0.075	0.5	0.42	0.35	0.26	0.23	0.30	0.40	0.5
0.10	0.5	0.39	0.32	0.22	0.18	0.27	0.38	0.5
0.15	0.5	0.37	0.27	0.16	0.15	0.25	0.37	0.5
0.60	0.5	0.27	0.18	0.11	0.12	0.23	0.36	0.5

Ref. 6-39, p. 96.

8. Rounded Entrance in Wall with Neighboring Wall



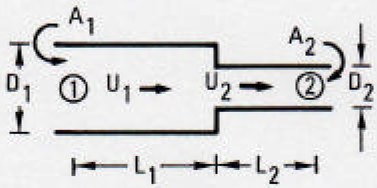
$$\frac{p_1 - p_2}{\frac{1}{2}\rho U^2} = 1 + K + \frac{fL}{D}$$

a/D	K, R/D: 0.1	0.125	0.15	0.20	0.30	0.50	0.80
0.2	--	0.80	0.45	0.19	0.09	0.05	0.05
0.3	--	0.50	0.32	0.17	0.07	0.04	0.04
0.5	0.65	0.36	0.25	0.10	0.05	0.03	0.03

Ref. 6-39, p. 94.

Description and Static Pressure Change	Non-Recoverable Loss Coefficient, K

11. Abrupt Contraction



$L_1 >> D_1,\ L_2 >> D_2$

$$\frac{p_1 - p_2}{\frac{1}{2}\rho U_2^2} = 1 - \left(\frac{A_2}{A_1}\right)^2 + K + \frac{f_1 L_1}{D_1} + \frac{f_2 L_2}{D_2}$$

$$K = \frac{1}{2}\left(1 - \frac{A_2}{A_1}\right)$$ Refs. 6-39, p. 98, 6-76.

An alternative expression, based on experimental data, is (Ref. 6-77):

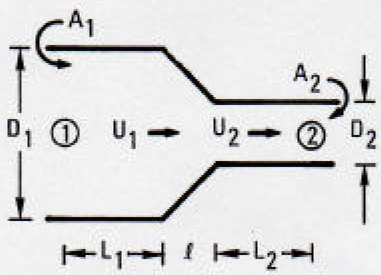
$$K = 0.5781 + 0.3954\ \beta^{1/2} - 4.5385\ \beta + 14.24\ \beta^{3/2} - 19.22\ \beta^2 + 8.540\ \beta^{5/2},$$

where $\beta = A_2/A_1$. A_1 and A_2 are flow areas.

$$U_2/U_1 = A_1/A_2$$

For laminar flow use K of Table 6-2

12. Gradual Contraction



$L_1 >> D_1,\ L_2 >> D_2$

CONICAL TRANSITION SHOWN

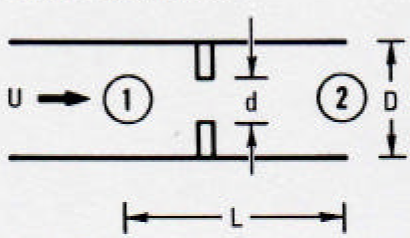
$$\frac{p_1 - p_2}{\frac{1}{2}\rho U_2^2} = 1 - \left(\frac{A_2}{A_1}\right)^2 + K + \frac{f_1 L_1}{D_1} + \frac{f_2 L_2}{D_2}$$

A_1/A_2	K (ℓ/D_2 = 0)	0.05	0.1	0.15	0.6
1.2	0.08	0.06	0.04	0.03	0.03
1.5	0.17	0.12	0.09	0.07	0.06
2.0	0.25	0.23	0.17	0.14	0.06
3.0	0.33	0.31	0.27	0.23	0.08
5.0	0.40	0.38	0.35	0.31	0.18
10.0	0.45	0.45	0.41	0.39	0.27

Ref. 6-39, p. 96. Also see Chapter 7.

$$U_2 = (A_1/A_2)U_1$$

13. Sharp Edged Orifice



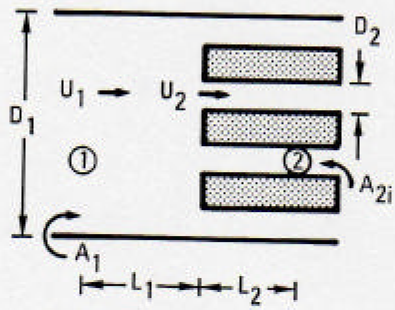
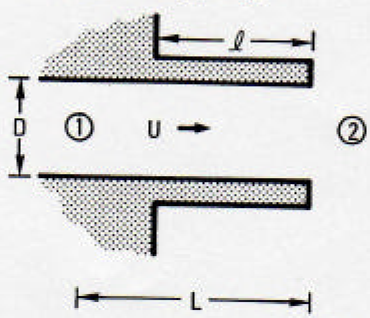
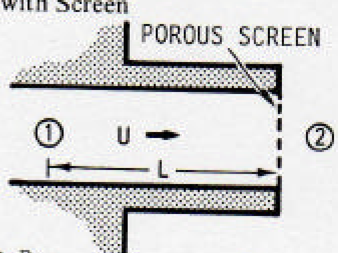
$L >> D$

$$\frac{p_1 - p_2}{\frac{1}{2}\rho U^2} = K + \frac{fL}{D}$$

d/D	0.20	0.25	0.30	0.35	0.40	0.45	0.50
K	65.	39.	27.	19.	14.	10.	7.7

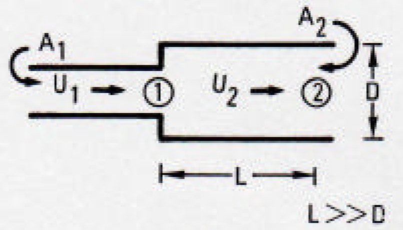
d/D	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
K	5.8	4.2	3.1	2.3	1.5	0.97	0.55	0.26

See Eqs. 6-41, 6-42 and Section 6.5.3.

Description and Static Pressure Change	Non-Recoverable Loss Coefficient, K
14. Flow into Multi-Channel Core  $L_1 >> D_1, L_2 >> D_2$ $\frac{p_1 - p_2}{\frac{1}{2}\rho U_2^2} = 1 - \left(\frac{A_2}{A_1}\right)^2 + K + \frac{f_1 L_1}{D_1} + \frac{f_2 L_2}{D_2}$	$K = \frac{1}{2}\left(1 - \frac{A_2}{A_1}\right)$ $A_2 = \sum_i A_{2i}$ = sum of flow areas. A_1, A_2 are cross-sectional areas. Channels on right are identical. $U_2 = (A_1/A_2)U_1$. Based on Refs. 6-39, p. 98; 6-76. For laminar flow use K of Table 6-2.
15. Exit from Straight Pipe  L>>D $\frac{p_1 - p_2}{\frac{1}{2}\rho U^2} = \frac{fL}{D} - 1 + K$	$K = 1.0$ See text for formulas which take the flow distribution into account. Result is independent of ℓ. The ideal pressure rise is $p_1 - p_2 = -\rho U^2/2$ (Eq. 6-42), but this rise is completely offset by the loss of momentum of the exit stream.
16. Exit from Straight Pipe with Screen  $\frac{p_1 - p_2}{\frac{1}{2}\rho U^2} = K\big\|_{screen} + \frac{fL}{D} - 1 + K$	$K = 1.0$ K_{screen} given in Chapter 10

Description and Static Pressure Change	Non-Recoverable Loss Coefficient, K

17. Abrupt Expansion



$$\frac{p_1 - p_2}{\frac{1}{2}\rho U_1^2} = \left(\frac{A_2}{A_1}\right)^2 - 1 + K + \frac{fL}{D}$$

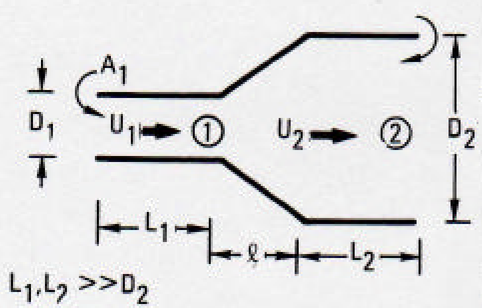
$$K = \left(1 - \frac{A_1}{A_2}\right)^2$$

A_1, A_2 are cross-sectional areas.

$U_2 = (A_1/A_2)U_1$.

The expansion results in a pressure rise. See text for formulas which take flow distribution into account.

18. Gradual Expansion



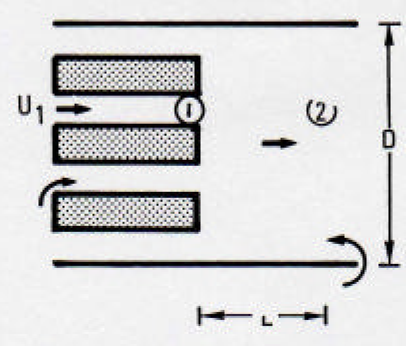
$$\frac{p_1 - p_2}{\frac{1}{2}\rho U_1^2} = \left(\frac{A_2}{A_1}\right)^2 - 1 + K + \frac{fL_2}{D_2}$$

$\frac{A_2}{A_1}$	K, $2\ell/D_1$ = 0.1	0.2	0.3	0.5	1.0	2.0	3.0	5.0
1.2	0.06	–	–	–	–	–	–	–
1.4	0.10	0.09	0.08	0.07	0.06	–	–	–
1.6	0.17	0.13	0.12	0.10	0.08	0.06	–	–
2.0	0.25	0.25	0.23	0.20	0.15	0.08	0.06	–
2.5	0.35	0.35	0.32	0.35	0.25	0.10	0.08	0.06
3.0	0.45	0.45	0.45	0.45	0.37	0.22	0.15	0.10
4.0	0.60	0.60	0.60	0.60	0.55	0.42	0.40	0.30

$U_2 = (A_1/A_2)U_1$. Ref. 6-4. See Chapter 7 for a diffuser with free discharge.

A_1,A_2 are cross-sectional areas.

19. Expansion from Multi-Channel Core



$$\frac{p_1 - p_2}{\frac{1}{2}\rho U_1^2} = \left(\frac{A_2}{A_1}\right)^2 - 1 + K + \frac{fL}{D}$$

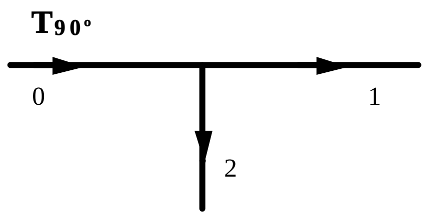
$$K = \left(1 - \frac{A_1}{A_2}\right)^2$$

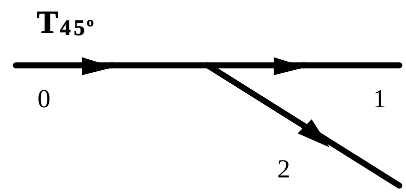
$A_1 = \sum_i A_{1i}$ = sum of flow areas on left-hand side.

A_{1i}, A_2 are cross-sectional areas. All channels on left are identical. $U_2 = (A_1/A_2)U_1$. The expansion results in pressure rise. See text for formulas that take into account flow distribution.

DERIVACIONES

$$\Lambda_{0-1} = k_1 \frac{v_0^2}{2g} \qquad \Lambda_{0-2} = k_2 \frac{v_0^2}{2g}$$



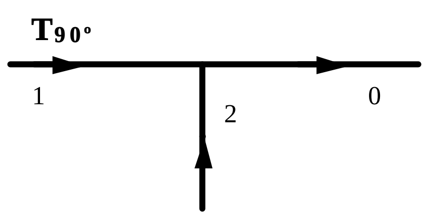


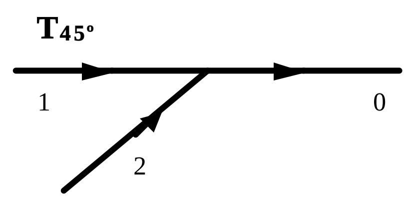
	Q_1/Q_0	0,0	0,2	0,4	0,6	0,8	1,0
	Q_2/Q_0	1,0	0,8	0,6	0,4	0,2	0,0
$T_{90°}$	k_1	0,40	0,35	0,20	0,10	0,05	0,05
	k_2	1,30	1,10	0,96	0,90	0,88	0,96
$T_{45°}$	k_1	0,45	0,40	0,25	0,15	0,10	0,08
	k_2	0,35	0,30	0,33	0,47	0,66	0,90

Todas las tuberías de igual diámetro

CONFLUENCIAS

$$\Lambda_{1-0} = k_1 \frac{v_0^2}{2g} \qquad \Lambda_{2-0} = k_2 \frac{v_0^2}{2g}$$





	Q_1/Q_0	0,0	0,2	0,4	0,6	0,8	1,0
	Q_2/Q_0	1,0	0,8	0,6	0,4	0,2	0,0
$T_{90°}$	k_1	0,60	0,50	0,40	0,30	0,18	0,05
	k_2	0,91	0,72	0,47	0,30	0,10	0,00
$T_{45°}$	k_1	0,60	0,50	0,40	0,30	0,18	0,05
	k_2	0,50	0,40	0,25	0,20	0,10	0,00

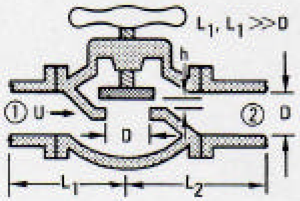
Todas las tuberías de igual diámetro

VÁLVULAS

Pressure Loss Across Valve, $\Delta p / \frac{1}{2} \rho U^2 = K + f(L_1 + L_2)/D$

Description	Fully Open Valve (h = D)	Partially Open Valve (h < D)

4. Conventional Globe Valve with 45° Dividing Walls



Fully Open Valve (h = D)

D (mm)	K Ref. A	K Ref. B	K Ref. C
12.5	10.8	12	11.0
25	7.2	6.4	7.5
50	4.7	4.3	6.6
100	4.1	3.9	--
150	4.4	4.0	--
200	4.7	4.2	--
250	5.1	4.3	--
300	5.4	--	--
350	5.5	--	--

For this valve with 90° dividing walls, Ref. A gives:

D(mm) = 12.5	20	25	30	40	50
K = 16	11	9.3	8.6	7.6	6.9

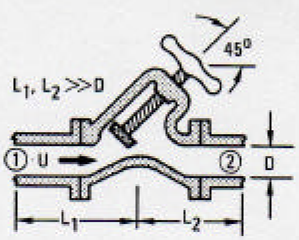
Ref. B suggests values 50% higher are appropriate if seat area is 70% of pipe area.

Partially Open Valve (h < D)

Fraction Fully Open	K Ref. B (D = 100 mm)
1.0	4.1
0.90	4.2
0.75	4.2
0.50	6.0
0.40	7.0
0.25	15.0

Refs. A: 6-39, p. 363; B: 6-49, p. 53; C: 6-94, p. 2-9.

5. Y Pattern Globe Valve



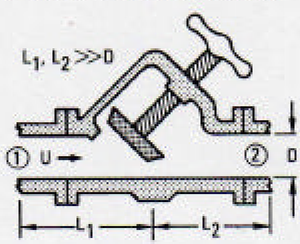
Fully Open Valve (h = D)

D (mm)	K Ref. A	K Ref. B
20	--	4.2
25	--	4.2
50	2.7	3.3
100	2.2	2.7
150	1.9	2.7
200	1.7	--
250	1.5	--
300	1.4	--
350	1.3	--

Partially Open Valve (h < D)

Refs. A: 6-39, p. 363; B: 6-94, p. 2-9. Ref. 6-49, p. 53, suggests that losses are 50% higher if stem angle is 60° instead of 45°.

6. Direct Flow Globe Valve



Fully Open Valve (h = D)

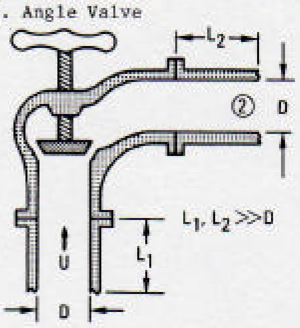
D (mm)	K
25	1.4
50	0.73
100	0.50
150	0.42
200	0.36
250	0.32

$K = 5.2/\sqrt{D}$ (D in mm), $25 < D < 250$

Partially Open Valve (h < D)

Ref. 6-39, p. 364.

7. Angle Valve



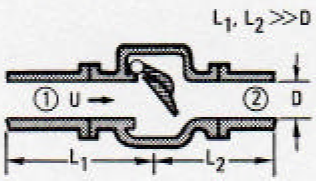
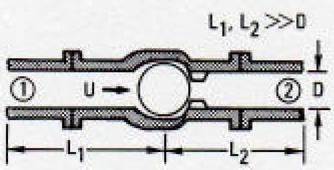
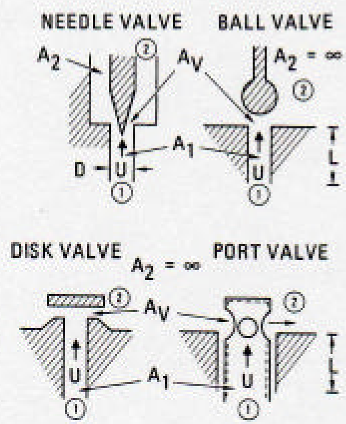
Fully Open Valve (h = D)

D (mm)	K Ref. A[(a)]	K Ref. B
15	4.5	5.5
20	3.8	3.9
25	3.2	3.5
50	2.2	3.7
60	2.1	3.4
100	1.9	--
150	2.0	--
200	2.1	--

(a) Seat area = pipe area. If seat area is 70% of pipe area, multiply values by 2.

Partially Open Valve (h < D)

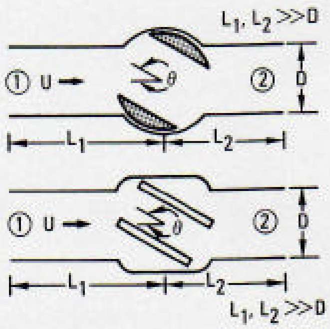
Refs. A: 6-49, p. 54; B: 6-94, p. 2-9.

<table>
<tr><th colspan="3">Pressure Loss Across Valve, $\Delta p/\frac{1}{2}\rho U^2 = K + f(L_1 + L_2)/D$, except frame 10</th></tr>
<tr><th>Description</th><th>Fully Open Valve</th><th>Partially Open Valve</th></tr>
<tr>
<td>8. Conventional Swing Check Valve
</td>
<td><table>
<tr><th>D (mm)</th><th>K (Ref. 6-39, p. 368)</th></tr>
<tr><td>40</td><td>1.3</td></tr>
<tr><td>70</td><td>1.4</td></tr>
<tr><td>100</td><td>1.5</td></tr>
<tr><td>200</td><td>1.9</td></tr>
<tr><td>300</td><td>2.1</td></tr>
<tr><td>500</td><td>2.5</td></tr>
<tr><td>750</td><td>2.9</td></tr>
</table>
Refs. 6-94, p. A-30, and 6-95, p. 5-33 give K = 2.0 for a typical conventional check valve. Refs. 6-94, p. A-30, and 6-96 give K = 0.5 to 0.8 for clearway swing check valve. Ref. 6-160 gives K = 0.6 to 2.3.</td>
<td><table>
<tr><th>Clapper Angle (deg)</th><th>K[a] (D = 200 mm)</th></tr>
<tr><td>0</td><td>∞</td></tr>
<tr><td>10</td><td>16</td></tr>
<tr><td>20</td><td>5.5-10.5</td></tr>
<tr><td>30</td><td>3 -6.5</td></tr>
<tr><td>40</td><td>2 -3.5</td></tr>
<tr><td>50</td><td>1.5-2.</td></tr>
<tr><td>60</td><td>0.9-1</td></tr>
<tr><td>70</td><td>0.5</td></tr>
</table>
[a] Clearway swing valve. Ref. 6-96. Zero angle is fully closed.</td>
</tr>
<tr>
<td>9. Ball Check Valve
</td>
<td>$K = \begin{cases} 2.3 & \text{Ref. 6-94, p. A-30.} \\ 0.5 & \text{Ref. 6-96.} \end{cases}$</td>
<td>The typical minimum pressure drop required to keep a valve open is 10^3 Pa (0.25 lb/in.^{2}) for a horizontally mounted valve and 20×10^3 Pa (2.3 lb/in.^{2}) for a value in a vertically mounted position. Ref. 6-94, p. A-30.</td>
</tr>
<tr>
<td>10. Various Valves in Expansions
</td>
<td>Static pressure change is sum of pressure rise associated with expansion plus valve loss plus entry pipe loss.
$$\frac{p_1 - p_2}{\frac{1}{2}\rho U_1^2} = \left(\frac{A_1}{A_2}\right)^2 - 1 + K + \frac{fL}{D}$$
p_1 = static pressure at 1,
p_2 = static pressure at 2,
A_1 = entry area,
D_1 = entry diameter,
A_v = minimum valve area,
A_2 = exit area.
See discussion of sudden expansions in Section 6.5.2.</td>
<td>Needle Valve:
$K = 0.5 + 0.15\ (A_1/A_v)^2$
Ball Valve:
$K = 0.5 + 0.15\ (A_1/A_v)^2$
Disk Valve:
$K = 1.3 + 0.2\ (A_1/A_v)^2$
Port Valve:
$K = 1.0 + 0.6\ (A_1/A_v)^2$
Ref. 6-160.</td>
</tr>
</table>

Pressure Loss Across Valve, $\Delta p / \frac{1}{2}\rho U^2 = K + f(L_1 + L_2)/D$

Description	Fully Open Valve ($\theta = 0$)	Partially Open Valve
11. Ball Valve and Spherical Valve	$K \simeq 0.$ ($\theta = 0$) Refs. A: 6-39, p. 362; B: 6-95, p. 5-33; C: 6-97 (D = 250 mm).	see table below
12. Butterfly Valve	see table below Refs. 6-99, 6-160	see table below Refs. A: 6-39, p. 361; B: 6-98; C: 6-39, p. 366, D: 6-97. The valve element in B is blunt ended, while that in A and D is thin and streamlined and that in C is a thin flap.

11. Ball Valve and Spherical Valve



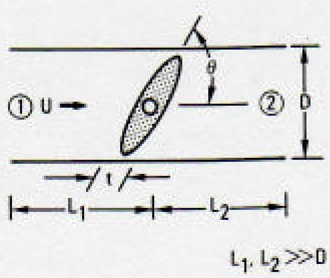
Fully Open Valve ($\theta = 0$): $K \simeq 0.$ ($\theta = 0$)

Refs. A: 6-39, p. 362; B: 6-95, p. 5-33; C: 6-97 (D = 250 mm).

Partially Open Valve:

θ (deg)	K — Ball Valve, Ref. A	K — Ball Valve, Ref. B	K — Spherical Valve, Ref. C
5	0.05	0.05	0.08
10	0.31	0.29	0.32
15	0.88	--	0.56
20	1.8	1.6	1.4
25	3.5	--	2.1
30	6.2	--	3.5
35	11	--	4.8
40	21	17	7.7
45	41	--	12
50	95	--	16
55	275	--	24
60	--	206	36
65	--	--	58
67	∞	--	68
90	∞	∞	∞

12. Butterfly Valve



Fully Open Valve ($\theta = 0$):

t/D	K ($\theta = 0$) — Streamlined Element	K ($\theta = 0$) — Blunt Element
0.1	0.1	0.16
0.15	0.15	0.26
0.20	0.2	0.45
0.25	0.3	0.73
0.30	0.5	1.20
0.35	0.75	1.80

Refs. 6-99, 6-160

Partially Open Valve:

θ (deg)	K — Ref. A	K — Ref. B	K — Ref. C	K — Ref. D
5	0.24	--	--	0.23
10	0.52	2.2	--	0.4
20	1.5	3.7	1.7	1.3
30	3.9	7.1	3.2	3.9
40	11	15	6.6	10
50	33	38	14	30
60	120	130	30	100
70	750	290	62	400
90	∞	∞	∞	∞

Refs. A: 6-39, p. 361; B: 6-98; C: 6-39, p. 366, D: 6-97. The valve element in B is blunt ended, while that in A and D is thin and streamlined and that in C is a thin flap.