AULA Nº3

A. Luis Mariani

PERDA de CARGA SINGULAR (OU LOCALIZADA)

EXP.: "PERDA de CARGA DISTRIBUÍDA NO ESCOAMENTO LAMINAR"

PLANO de AULA:

I - PERDA de CARGA SINGULAR
  1. Definição
  2. Forma Adimensional
  3. Conceito de Comprimento Equivalente
  4. Tipos Particulares

II - LABORATÓRIO
  1. O Relatório
  2. Seminário e Discussão
  3. Experiência: Movimento Laminar e perda de carga

I - PERDA DE CARGA SINGULAR

Motivação Inicial: FILME "LOOP" Nº12

"FLOW SEPARATION AND VORTEX SHEDDING"

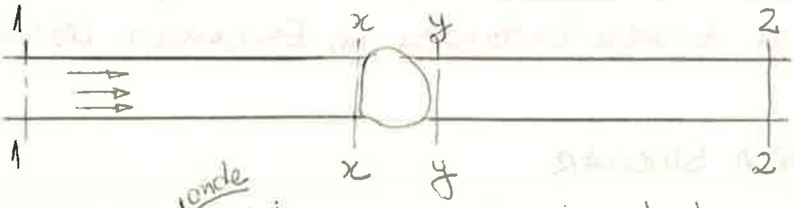
"O que ocorre quando temos um corpo, objeto, inserido no meio de um escoamento? E quando um contorno obriga a mudança de trajetória das partículas, o que ocorre nas proximidades do contorno sólido?"

1. Definição

Perda de Carga Singular, ou localizada ou secundária ocorre em uma instalação onde existe qualquer uma das ocorrências:

- Mudança de seção
- " de direção
- Acessórios diversos
- Instrumentação.

Suponhamos uma singularidade qualquer, vejamos como determinaremos o valor da perda de carga nesta:



ENTRE x e y, onde existe uma singularidade, é muito difícil determinar qual o valor $\Delta H_{xy} = H_x - H_y = h_s$ então o que se faz é tomar a diferença dos valores das cargas entre duas seções anterior e posterior à singularidade, onde o escoamento encontra-se dinâmicamente estabelecido, e verificar qual a perda de carga total entre 1-1 e 2-2:

$$\Delta H_{1;2} = H_1 - H_2 = \underset{\text{distribuída}}{h_f} + \underset{\text{singular}}{h_s}$$

$$\boxed{h_s = \Delta H_{12} - h_{f_{12}}}$$

∴ podemos calcular a perda de carga singular subtraindo da Variação total da carga entre 1 e 2 a perda de carga distribuída.

2. FORMA ADIMENSIONAL

Da experiência podemos relacionar a perda de carga singular com as grandezas: ρ, V, D, μ e com a geometria da singularidade

$$\underbrace{\gamma h_s}_{\text{perda sing. em unidades de pressão}} = \Phi(\rho, V, D, \mu, \text{coeficiente de Forma})$$

que pode ser arranjada na seguinte relação:

$$\frac{\gamma h_p}{\frac{1}{2}\rho V^2} = K_S \quad \text{onde} \quad K_S = K_S\left(\frac{\rho V D}{\mu}, \text{ coef. forma}\right)$$

$$\boxed{h_p = K_S \frac{V^2}{2g}}$$

Onde:

$K_S \Rightarrow$ coeficiente de perda de carga singular.

3. CONCEITO de COMPRIMENTO EQUIVALENTE

Fazendo uma analogia entre perda de carga singular e perda de carga distribuída, podemos chegar a um conceito artificial: Comprimento Equivalente.

Substituindo o valor [illegible] de K_S por um comprimento de tubulação que proporcionará uma perda de carga distribuída equivalente àquela perda de carga singular.

$$K_S \frac{V^2}{2g} = f \frac{L_{eq}}{D_H} \frac{V^2}{2g}$$

Obs:
Velocidade média nas duas eq. devem ser =s

chegamos a:

$$\boxed{K_S = f \frac{L_{eq}}{D_H}} \overset{\text{ou}}{\Longrightarrow} \boxed{L_{eq} = \frac{K_S D_H}{f}}$$

Este conceito ajuda-nos a relacionar em uma mesma equação todos os tipos de perda de carga (de maneira prática):

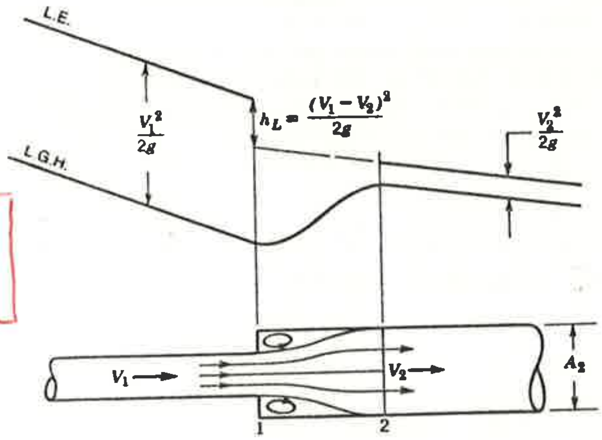
$$\Delta h_{Total} = h_f + \Sigma h_p = \left(f \frac{L}{D} + \Sigma K_s \right) \frac{V^2}{2g}$$

$$\boxed{\Delta h_{total} = \frac{f}{D} \, \Sigma \left(L + L_{eq} \right) \frac{V^2}{2g}}$$

4. TIPOS PARTICULARES DE PERDA DE CARGA SINGULAR

4.1. MUDANÇA DE SEÇÃO.

4.1.1. ALARGAMENTO BRUSCO



$$\boxed{K_s = \left(1 - \frac{S_1}{S_2}\right)^2}$$

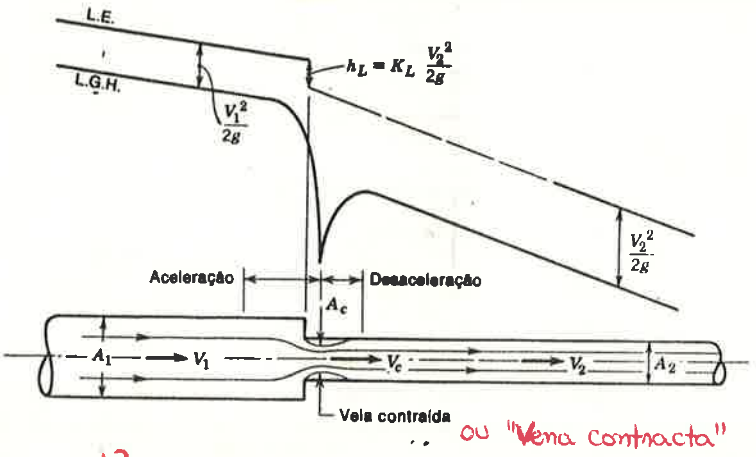
$$h_s = K_s \frac{V_1^2}{2g}$$

* CASO PARTICULAR : $S_2 \rightarrow \infty$ (ENTRADA de RESERVATÓRIO)

TEÓRICAMENTE : $K_{s_{TEÓRICO}} = 1$

NA PRÁTICA : $K_s = \{1{,}06 \text{ a } 1{,}10\}$

4.1.2. REDUÇÃO BRUSCA



ou "Vena contracta"

$K_s = \left(\frac{1}{C_c} - 1\right)^2$ onde $C_c = \frac{S_c}{S_2}$ (Coeficiente de Contração)

Dados experimentais nos oferecem dados para K_s como

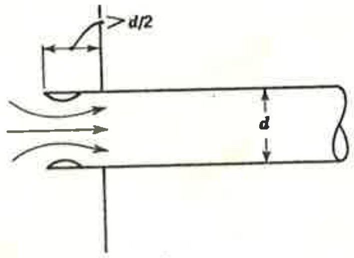
$$K_s \cong 0{,}42 \left[1 - \left(\frac{d}{D} \right)^2 \right]$$

$$h_p = K_s \cdot \frac{V_2^2}{2g}$$

* CASOS PARTICULARES:

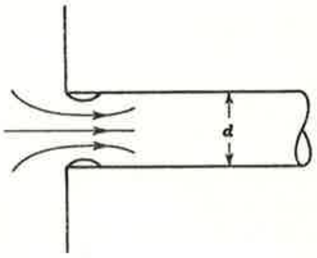
(SAÍDA de RESERVATÓRIOS PARA TUBULAÇÃO)

CONDUTO REENTRANTE
(NO RESERVATÓRIO)



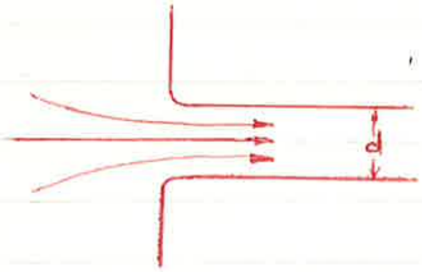
$K_s \cong 0{,}8$

QUINA QUADRADA
(BORDOS VIVOS)



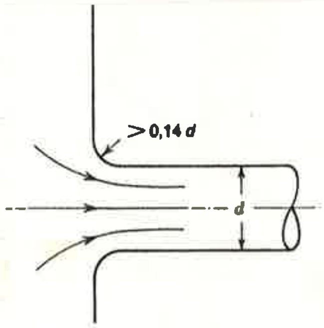
$K_s \cong \{0{,}4 \text{ a } 0{,}5\}$

BORDOS LIGEIRAMENTE ARREDONDADOS



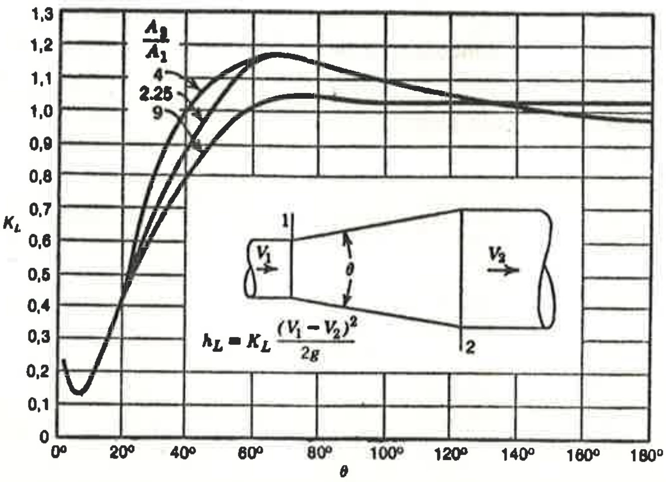
$K_s \cong \{0{,}2 \text{ a } 0{,}25\}$

BORDOS BEM ARREDONDADOS
("BOCA de SINO)



$K_s \cong \{0{,}05 \text{ a } 0{,}10\}$

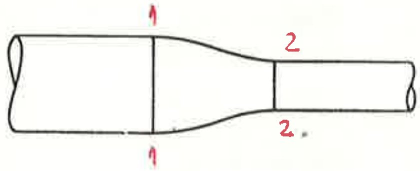
4.1.3. ALARGAMENTO GRADUAL



$\Delta H_{1,2} = K_T \dfrac{V_1^2}{2g}$ onde K_T ⇒ Coeficiente de perda de carga total (sing.+ distrib.)

e onde K_T = função(θ ; Re ; S_1/S_2 ; ε ; outros)

4.1.4. CONTRAÇÃO (REDUÇÃO GRADUAL)

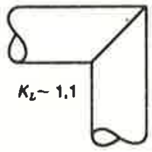


$\Delta H_{1,2} = K_T \dfrac{V_2^2}{2g}$ onde K_T ⇒ Coef. de perda de carga total

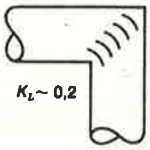
4.2. MUDANÇA de DIREÇÃO

4.2.1. JOELHOS (OU COTOVELOS)

(Mudança de direção brusca)



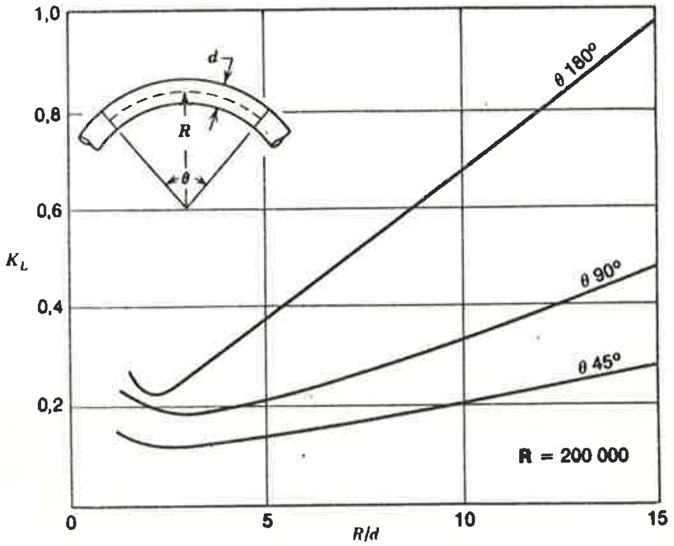
ALTERNATIVA:



USAR ALETAS DIRETRIZES.
(Pás)

4.2.2. CURVAS (Raio de curvatura definido)

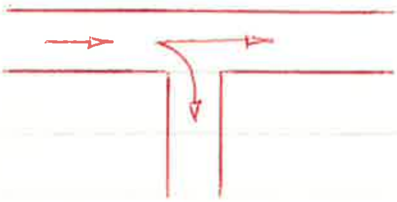
(Mudança de direção gradual)

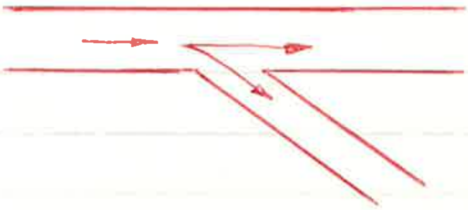


$$K_S = K_S\,(Re\,;\,\theta\,;\,R/d$$

$$h_p = K_S \cdot \frac{V^2}{2g}$$

4.2.3. TÊS





4.3. APARELHOS DIVERSOS

4.3.1. VÁLVULAS

- Esfera
- Bomboleta
- Gaveta
- Retenção
- Globo
- Agulha

Nota: Variação: Flangeada ou Rosqueada.

4.3.2. MEDIDORES EM GERAL

- Vazão
- Temperatura
- Velocidade

etc. ...

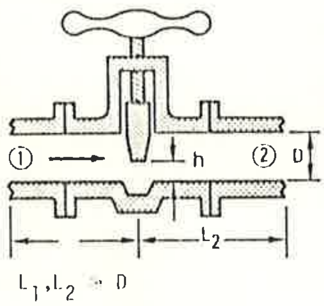
Table 6-10. Pressure Loss In Valves.

Notation: D = internal diameter of pipe; f = friction factor for fully developed pipe flow (Section 6.3); h = opening of valve element; K = nonrecoverable pressure loss coefficient; L = length of attached piping; Δp = difference in static and total pressure between points 1 and 2; U = flow velocity averaged over pipe cross section; ρ = fluid density; θ = angle; ν = kinematic viscosity. See Table 3-1 for consistent sets of units. Inlet piping and outlet piping are assumed to have equal diameter; see Sections 6.5.1 and 6.5.2 for correction for other cases. Results are for turbulent flow, $UD/\nu > 10^4$. 25.4 mm = 1 inch. Data from more than one reference have been cited for comparison in most frames.

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)

1. Conventional Gate Valve



D (mm)	K		
	Ref. A	Ref. B	Ref. C
12.5	0.50	0.81	0.29
20.0	--	0.28	--
25	0.27	0.23	0.22
50	0.16	0.18	0.15
100	0.10	0.16	0.13
150	0.09	0.15	0.12
200	0.08	0.10	0.11
300	--	0.047	--

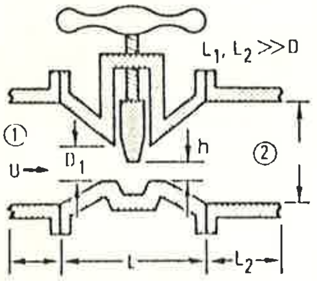
Refs. A: 6-4, p. 52; B: 6-93; C: 6-94, p. 2-9; D: 6-39, p. 360.

h/D	K		
	Ref. A	Ref. B	Ref. D
1.0	(a)	(a)	(a)
0.90	0.2	--	0.3
0.75	0.4	0.75	1.2
0.60	1.2	--	2.8
0.50	2.0	3.2	5.3
0.40	3.5	7.1	12
0.25	9.0	23	30
0.0	∞	∞	∞

(a) See Fully Open Valve.

(50 mm valve for Ref. B, see text for additional values).

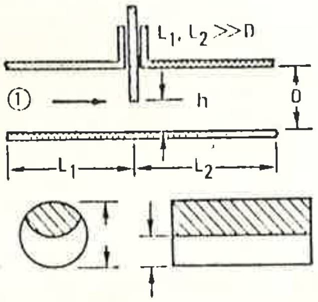
2. Gate Valve with Symmetric Contractions



	D (mm)			
	200	250	300	300
D_1/D	0.75	0.80	0.67	0.67
L/D	1.33	1.5	1.68	2.5
K	0.6	0.39	1.80	1.45

Ref. 6-39, p. 360.

3. Disk-Type Gate Valve



Circular Disk in Circular Pipe

Rectangular Disk in Rectangular Duct

K ≈ 0

Refs. A: 6-39, p. 359;
B: 6-70, p. 24.

	K		
	Circular Pipe		Rect. Duct
h/D	Ref. A	Ref. B	Ref. A
1.0	0	0.	0.
0.9	0.06	0.05	0.09
0.8	0.17	0.16	0.39
0.7	0.44	0.50	0.95
0.6	0.98	0.95	2.1
0.5	2.1	2.0	4.0
0.4	4.6	[illegible]	8.1
0.3	10	10.0	18
0.2	35	27	45
0.125	98	85	--
0.1	--	--	190
0.0	∞	∞	∞

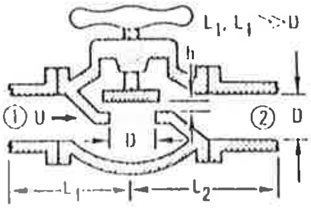
Table 6-10. Pressure Loss in Valves. *(Continued)*

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

GLOBO



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:

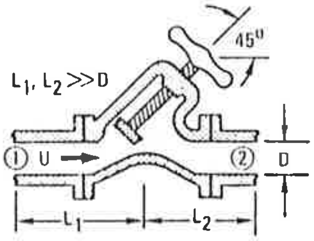
D(mm) =	12.5	20	25	30	40	50
K =	16	11	9.3	8.6	7.6	6.9

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

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.

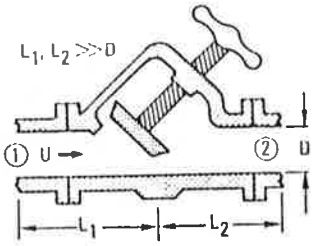
5. Y Pattern Globe Valve



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	--

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

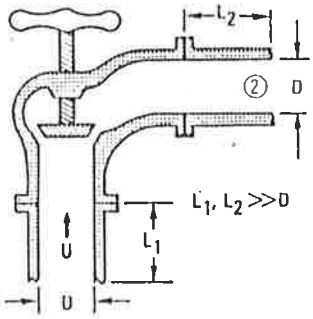


D (mm)	K
25	1.4
50	0.73
100	0.50
150	0.42
200	0.36
250	0.32

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

Ref. 6-39, p. 364.

7. Angle Valve



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.

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

Table 6-10. Pressure Loss In Valves. *(Continued)*

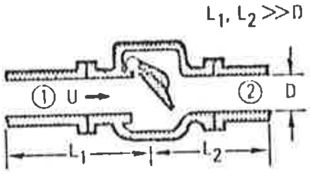
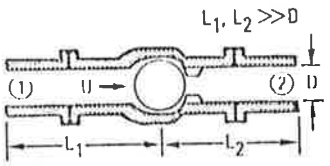
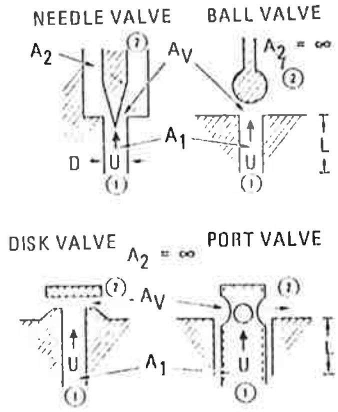
<table>
<tr><th colspan="3">Pressure Loss Across Valve, $\Delta p/\frac{1}{2}\rho U^2 = K + f(L_1 + L_2)/D$, except frame 10</th></tr>
<tr><th>Description</th><th>Fully Open Valve</th><th>Partially Open Valve</th></tr>
<tr>
<td>8. Conventional Swing Check Valve
 </td>
<td><table><tr><th>D (mm)</th><th>K (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 $20 \cdot 10^3$ Pa (2.3 lb/in.^{2}) for a valve 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>

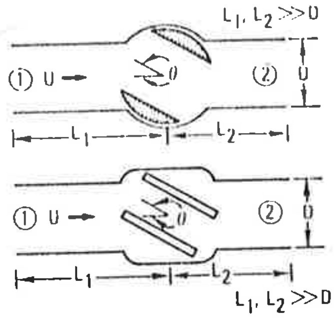
Table 6-10. Pressure Loss in Valves. *(Continued)*

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

Esfera



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

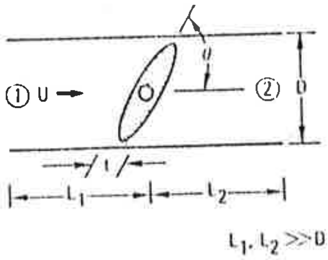
K = 0. (θ = 0)

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	 Ball Valve Ref. B	 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 (θ = 0) Streamlined Element	 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	 Ref. B	 Ref. C	 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.