PROCEDIMIENTO PARA DIMENSIONAR ELEMENTOS DIFERENCIALES

Ecuación de diseño:

$$S_M = \frac{CY_1\beta^2}{\sqrt{1-\beta^4}} = \frac{4}{\pi\sqrt{2g}} \frac{Q\sqrt{F_p}\sqrt{\rho}}{D^2\sqrt{\Delta p}\sqrt{F_a}} = N\frac{Q\sqrt{F_p}\sqrt{\rho}}{D^2\sqrt{\Delta p}\sqrt{F_a}}$$

PASO 1. Seleccionar las condiciones de flujo máximo y el máximo diferencial de presión. Con las condiciones de proceso y la información de F_a y F_p calcular S_M y el Número de Reynolds (Re).

PASO 2. Calcular el Número de Reynolds para las condiciones operativas (caudal igual a un 80 % del máximo) y verificar si se está dentro de las condiciones operativas (Tablas 1).

PASO 3. Calcular la primera aproximación de β (β_o) con las fórmulas de la Tabla 2)

PASO 4. Usando β y el Re para máximo caudal calcular el coeficiente de descarga C con la fórmula:

$$C = C_\infty + b\,Re^{-n}$$

empleando la información de la Tabla 3. Si no esta considerado el dispositivo en dicha tabla o se está fuera de las condiciones límite, se deberá usar información tabular o gráfica (Handbook de R. Miller).

PASO 5. Para líquidos hacer $Y_1 = 1$. Para vapores y gases calcular Y_1 con el valor de β empleando las fórmulas de la Tabla 4, o de gráficas (Handbook de R. Miller).

PASO 6. Computar el nuevo valor de β con la fórmula:

$$\beta = \left[1 + \left(\frac{CY_1}{S_M}\right)^2\right]^{-0.25}$$

PASO 7. Comparar los valores de β inicial y el obtenido en el paso anterior. Si discrepan en menos de ± 0.0001, continuar con el Paso 8. Si la discrepancia es mayor, con el nuevo valor de β volver al Paso 4.

PASO 8. Calcular el diámetro del dispositivo como: $d = \beta D$

Table 1
Recommended Accuracy and Restrictions

Primary device	Nominal pipe diam., in.	Beta ratio, β	Coefficient accuracy, %
Orifice			
Corner, flange, D and $D/2$	2-36	0.2-0.6	±0.6
		0.6-0.75	$\pm\beta$
2-1/2D and 8D (pipe taps)	2-36	0.2-0.5	±0.8
		0.51-0.7	±1.6
Integral	1/2	0.07-0.7	±3
Eccentric			
Flange and vena contracta	4	0.3-0.75	±2
	6-14	0.3-0.75	±1.5
Segmental			
Flange and vena contracta	4-14	0.35-0.75	±2
Quadrant			
Flange and corner	1-4	0.25-0.6	±2 - ±2.5
Conical			
Corner		0.1-0.3	±-±2.5

Units on β_0 Sizing Method for Approximately 2 Percent Accuracy†

	Liquid	Gas (vapor)
Reynolds number		
Orifice	$R_D \geq 10{,}000$	$R_D \geq 10{,}000$
Venturi nozzle	$R_D \geq 100{,}000$	$R_D \geq 10{,}000$
Lo-Loss	$R_D \geq 100{,}000$	$R_D \geq 10{,}000$
Expansion factor‡	$Y_1 = 1.0$	$\frac{\Delta P_{in.\ WC}}{P_1} \leq 0.5$
	$Y_2 = 1.0$	$\frac{\Delta P_{in.\ WC}}{P_2} \leq 1.0$

† Assumes pipe diameter is measured.

‡ Ratios are based on upper-range differential pressure; operating flow rate is selected as 0.8 of upper-range flow rate, 0.64 of upper-range differential pressure.

(From Miller, *Flow Measurement Engineering Handbook*, ©1982, McGraw-Hill Book Company. Used with permission.)

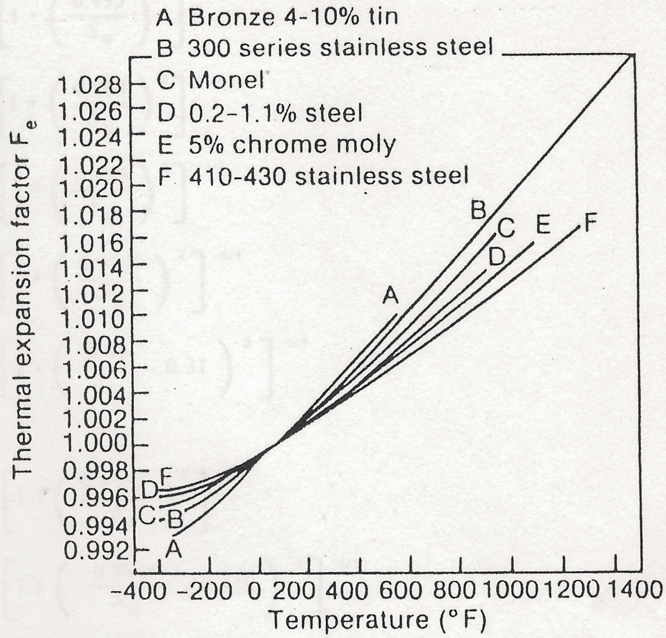

Figure 10-11. Thermal Expansion Factor F_e
(From ASME, *Fluid Meters*, ©1971. Used with permission.)

$F_P = 1.0 + Z_L\,(P/1000)$

$Z_L = 0.269\,T_r - 0.5163\,T_r^2 + 0.3521\,T_r^3 - 0.0461$

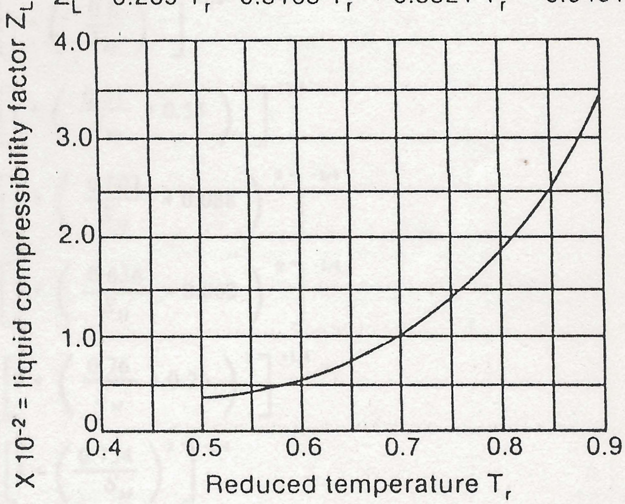

Figure 10-12. Generalized Liquid Compressibility Factor
(From Miller, *Flow Measurement Engineering Handbook*, ©1982, McGraw-Hill Book Company. Used with permission.)

Table 2
β_0 Approximate Sizing Equations

Type	Equation
Venturi	
Machined inlet	$\beta_0 = \left[1 + \left(\frac{0.995}{S_M}\right)^2\right]^{-1/4}$
Rough-cast inlet	$\beta_0 = \left[1 + \left(\frac{0.984}{S_M}\right)^2\right]^{-1/4}$
Rough-welded sheet iron	$\beta_0 = \left[1 + \left(\frac{0.985}{S_M}\right)^2\right]^{-1/4}$
Universal Venturi Tube†	$\beta_0 = \left[1 + \left(\frac{0.9797}{S_M}\right)^2\right]^{1/4}$
Lo-Loss tube‡	$\beta_0 = \left[1 + \left(\frac{0.92}{S_M} - 0.31\right)^2\right]^{-1/4}$
Nozzle	
ASME long radius	$\beta_0 = \left[1 + \left(\frac{0.9975}{S_M}\right)^2\right]^{-1/4}$
ISA	$\beta_0 = \left[1 + \left(\frac{0.9944}{S_M} - 0.118\right)^2\right]^{-1/4}$
Venturi nozzle (ISA inlet)	$\beta_0 = \left[1 + \left(\frac{0.989}{S_M} - 0.09\right)^2\right]^{-1/4}$
Orifice	
Corner, flange, D-and-$D/2$ taps	
$R_D < 200{,}000$	$\beta_0 = \left[1 + \left(\frac{0.6}{S_M} + 0.06\right)^2\right]^{-1/4}$
$R_D > 200{,}000$	$\beta_0 = \left[1 + \left(\frac{0.6}{S_M}\right)^2\right]^{-1/4}$
2-1/2D and 8D taps	$\beta_0 = \left[1 + \left(\frac{0.61}{S_M} + 0.55\right)^2\right]^{-1/4}$
Eccentric, all taps	$\beta_0 = \left[1 + \left(\frac{0.607}{S_M} + 0.088\right)^2\right]^{-1/4}$
Segmental, all taps	$\beta_0 = \left[1 + \left(\frac{0.634}{S_M} - 0.062\right)^2\right]^{-1/4}$
Quadrant ($\beta \leq 0.6$)	$\beta_0 = \left[1 + \left(\frac{0.76}{S_M} + 0.26\right)^2\right]^{-1/4}$
Conic, corner ($\beta \leq 0.3$)	$\beta_0 = \left[1 + \left(\frac{0.734}{S_M}\right)^2\right]^{-1/4}$

† From BIF CALC 440/441; the manufacturer should be consulted for exact coefficient information.
‡ Derived from Badger Meter, Inc. Lo-Loss flow-tube coefficient curve.
(From Miller

Table 3
Equations and Values for C_∞, b, and n

Primary device	Discharge coefficient C_∞ at infinite Reynolds number	Reynolds number term: Coefficient b	Reynolds number term: Exponent n
Venturi			
Machined inlet	0.995	0	0
Rough cast inlet	0.984	0	0
Rough welded sheet-iron inlet	0.985	0	0
Universal Venturi Tube[a]	0.9797	0	0
Lo-Loss tube[b]	$1.005 - 0.471\beta + 0.564\beta^2 - 0.514\beta^3$	0	0
Nozzle:			
ASME long radius	0.9975	$-6.53\beta^{0.5}$	0.5
ISA	$0.9900 - 0.2262\beta^{4.1}$	$1708 - 8936\beta + 19{,}779\beta^{4.7}$	1.15
Venturi nozzle (ISA inlet)	$0.9858 - 0.196\beta^{4.5}$	0	0
Orifice:			
Corner taps	$0.5959 + 0.0312\beta^{2.1} - 0.184\beta^8$	$91.71\beta^{2.5}$	0.75
Flange taps (D in inches)			
$D \geq 2.3$	$0.5959 + 0.0321\beta^{2.1} - 0.184\beta^8 + 0.09\dfrac{\beta^4}{D(1-\beta^4)} - 0.0337\dfrac{\beta^3}{D}$	$91.71\beta^{2.5}$	0.75
$2 \leq D \leq 2.3$	$0.5959 + 0.0312\beta^{2.1} - 0.184\beta^8 + 0.039\dfrac{\beta^4}{1-\beta^4} - 0.0337\dfrac{\beta^3}{D}$	$91.71\beta^{2.5}$	0.75
D and $D/2$ taps	$0.5959 + 0.0312\beta^{2.1} - 0.184\beta^8 + 0.039\dfrac{\beta^4}{1-\beta^4} - 0.0158\beta^3$	$91.71\beta^{2.5}$	0.75
2-1/2D and 8D taps[c]	$0.5959 + 0.461\beta^{2.1} + 0.48\beta^8 + 0.039\dfrac{\beta^4}{1-\beta^4}$	$91.71\beta^{2.5}$	0.75

[a] From BIF CALC-440/441; the manufacturer should be consulted for exact coefficient information.

[b] Derived from the Badger Meter, Inc. Lo-Loss tube coefficient curve; the manufacturer should be consulted for exact coefficient information.

[c] Source: Stolz (1978).

Table 4
Summary of Gas (Vapor) Expansion-Factor Equations

	Equation		Pressure relationships
Contoured primary elements (nozzle, venturi, venturi nozzle, Lo-Loss,† etc.)			
Upstream measurements	$Y_1 = \left\{ \dfrac{(1-\beta^4)\,[k/(k-1)]\,(P_2/P_1)^{2/k}\,[1-(P_2/P_1)^{(k-1)/k}]}{1-\beta^4\,(P_2/P_1)^{2/k}]\,(1-P_2/P_1)} \right\}^{1/2}$	(a)	$\dfrac{P_2}{P_1} = 1 - x_1$
Downstream measurements	$Y_2 = Y_1\sqrt{1+x_2}$	(b)	
Orifice			
Corner, flange, D and $D/2$ taps			
Upstream measurements	$Y_1 = 1 - (0.41 + 0.35\beta^4)\dfrac{x_1}{k}$	(c)	
Downstream measurements	$Y_2 = \sqrt{1+x_2} - (0.41 + 0.35\beta^4)\dfrac{x_2}{k\sqrt{1+x_2}}$	(d)	$x_1 = \dfrac{\Delta P_{in.\,wc}}{27.73\,P_1}$
2-1/2D and 8D			
Upstream measurements	$Y_1 = 1 - [0.333 + 1.145(\beta^2 + 0.7\beta^5 + 12\beta^{13})]\dfrac{x_1}{k}$	(e)	$x_2 = \dfrac{\Delta P_{in.\,wc}}{27.73\,P_2}$
Downstream measurements	$Y_2 = \sqrt{1+x_2} - [0.333 + 1.145(\beta^2 + 0.7\beta^5 + 12\beta^{13})]\dfrac{x_2}{k\sqrt{1+x_2}}$	(f)	

† Registered trademark of Badger Meter, Inc. Manufacturer should be consulted for recommendations.