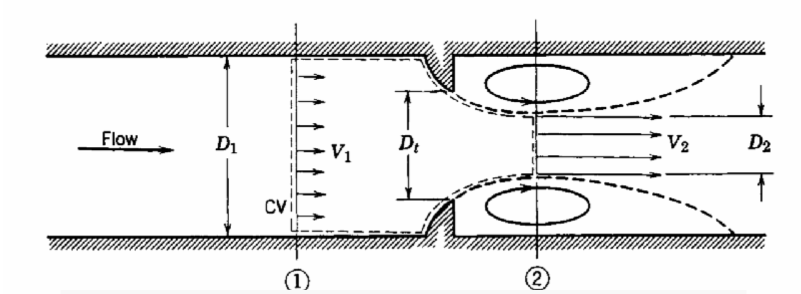
Obstruction Flow-meters



From Energy (Bernouli + Loss) Eq. :

$$Q = V_2 \cdot A_2 = \frac{A_2}{\sqrt{1-\left(A_2 / A_1\right)^2}} \cdot \sqrt{\frac{2(p_1 - p_2)}{r} + 2gh_{loss,1-2}}$$

NOTE :

$U \equiv V,\ d \equiv D,\ d_0 \equiv D_t$ *etc.* in different references

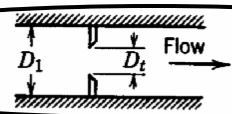
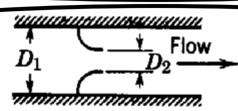
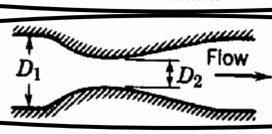
Volume and Mass Flow-rates

$$Q = CEAY\sqrt{\frac{2\Delta p}{r}};\quad \dot{m} = rQ = K_0 AY\sqrt{2r\Delta p}$$

- $C = C_f C_c =$ discharge coefficient [$fn($ Re or $Q, b)$]
  - $C_f \propto h_{loss}$ friction coefficient
  - $C_c = A_2 / A_0$ contruction coefficient
- $E = 1 / \sqrt{1-\left(A_0 / A_1\right)^2} = 1 / \sqrt{1-b^4}$ velocity of aproach factor
- Also, $K_0 = K = C \cdot E$ flow coefficient
- $A = A_0 = A_t$ *area*; $b = d_0 / D_1$ diameter ratio
- $Y = Y(\Delta p / p_1)$ expansion (compressibility) factor

Orifice, Nozzle, & Venturi ...

TABLE Characteristics of Orifice, Flow Nozzle, and Venturi Flow Meters

Flow Meter Type	Diagram	Head Loss	Cost
Orifice		High	Low
Flow nozzle		Intermediate	Intermediate
Venturi		Low	High

Orifice Flow-meter

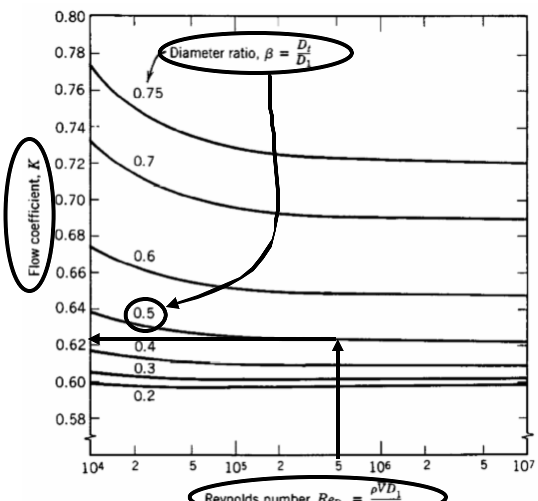


FIGURE Flow coefficients for concentric orifices with corner taps.

Nozzle Flow-meter

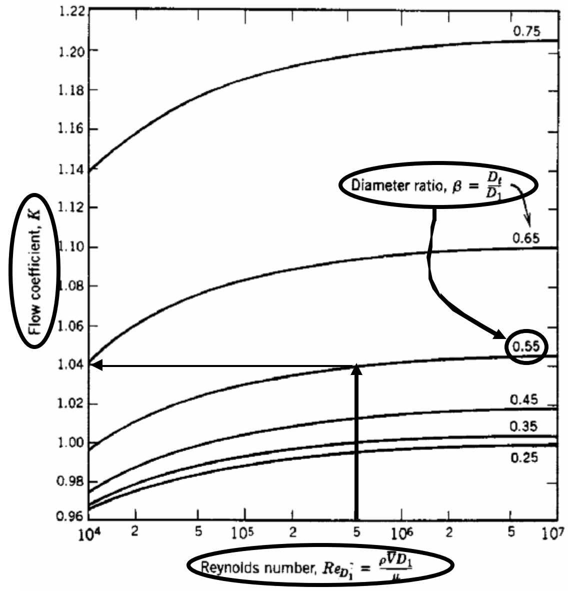


FIGURE Flow coefficients for ASME long-radius flow nozzles.

Flow-meter Permanent Δp_{Loss}

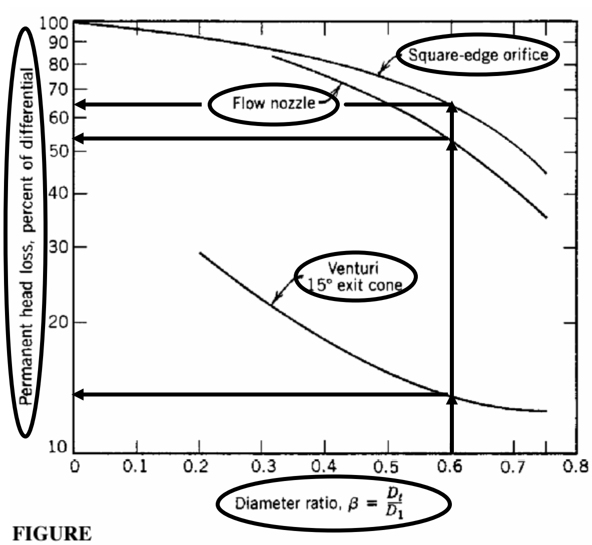
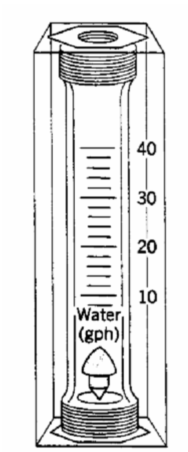
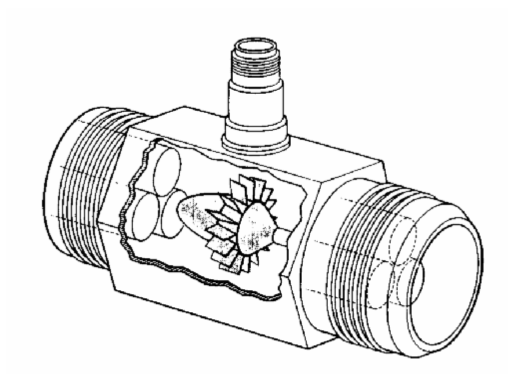


FIGURE
Permanent head loss produced by various flow metering elements.

Many Other Flow-meter Types...





Turbine Flow Meter
….etc.

Float-type Rotameter

PROBLEM 10.7

KNOWN: Flow of water through orifice meter at 20°C
d_1 = 10 cm
β = 0.4

FIND: Q at which $C = f(\beta, Re_{d1})$ becomes $C = f(\beta)$ only, not Re_{d1}

ASSUMPTIONS: Flange pressure taps are used so that Figure 10.6 is applicable.

…see next slide

SOLUTION

For $\beta = 0.4$, Figure 10.6 indicates a Reynolds number independence in flow coefficient for $Re_{d1} > 20{,}000$. Because $K_o = CE$ and E depends only on β, we conclude that $C = f(\beta)$ for all $Re_{d1} > 20{,}000$.

$$Re_{d1} = 4Q/\pi d_1 \nu > 20{,}000$$

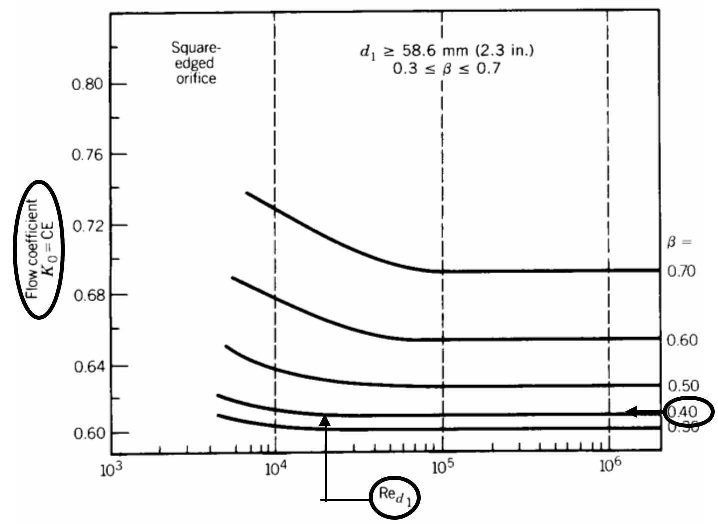
$$Q > \pi \nu d_1 Re_{d1}/4 = \pi(1 \times 10^{-6}\ m^2/s)(0.1m)(20000)/4 = 1.6 \times 10^{-4}\ m^3/s$$

with ν from Appendix C.

COMMENT

Aside from the usual sources of error in an measurement, data reduction errors enter into the obstruction meter relations from the assumed values of the various coefficients and from the ability to read these values from the tables and charts.

FIGURE 10.6 Flow coefficients for a square-edged orifice meter having flange pressure taps. (Compiled from data in [2]).



$$K_0 = \frac{1}{(1-\beta^4)^{1/2}}(0.5959 + 0.0312\beta^{2.1} - 0.184\beta^8 + B_1 d_1^{-1}\beta^4(1-\beta^4)^{-1} - B_2 d_1^{-1}\beta^3 + 91.71\beta^{2.5} Re_{d_1}^{-0.75})$$

where $B_1 = 0.09$ (US) $= 2.286$ (SI) $B_2 = 0.0337$ (US) $= 0.8560$ (SI)

PROBLEM 10.14

KNOWN: Water flow at 80°F through an ASME long radius nozzle.

$\beta = 0.6$

H = 10 in Hg

$d_1 = 6$ in.

FIND: Q

ASSUMPTIONS: Steady, incompressible (Y = 1) flow.

PROPERTIES: Water: $\rho = 62.2\ lb_m/ft^3$ $\nu = 1 \times 10^{-5}\ ft^2/s$

SOLUTION

Incompressible

From (10.14) with A and β based on throat diameter d_o,

$Q = CEAY(2\Delta p/\rho_1)^{.5}$ → $CE = K_0$; $Y = 1$, incompr. fluid

With $\beta = d_o/d_1 = 0.6$, $d_o = (0.6)(6)$ in. = 3.6 in. And $\Delta p = \rho g H/g_c = 703$ psf. The value for $K_o = f(\beta, Re_{d1})$. From Figure 10.11, guess $K_o = 1.03$. Then, with $A = \pi(3.6/12)^2/4 = 0.071\ ft^2$:

$Q = (1.03)(0.071\ ft^2)[2(703\ psf)(32.2\ lb_m\text{-}ft/lb\text{-}s^2)/62.2\ lb_m/ft^3)]^{0.5}$
$= 1.96$ cfs

Then, $Re_{d1} = 4(1.96\ cfs)/\pi(.5\ ft)(1 \times 10^{-5}\ ft^2/s) = 5 \times 10^{-5}$

From Figure 10.11, $K_o = (0.6, 5 \times 10^{-5}) = 1.03$. **So $Q = 1.96\ ft^3/s$.**