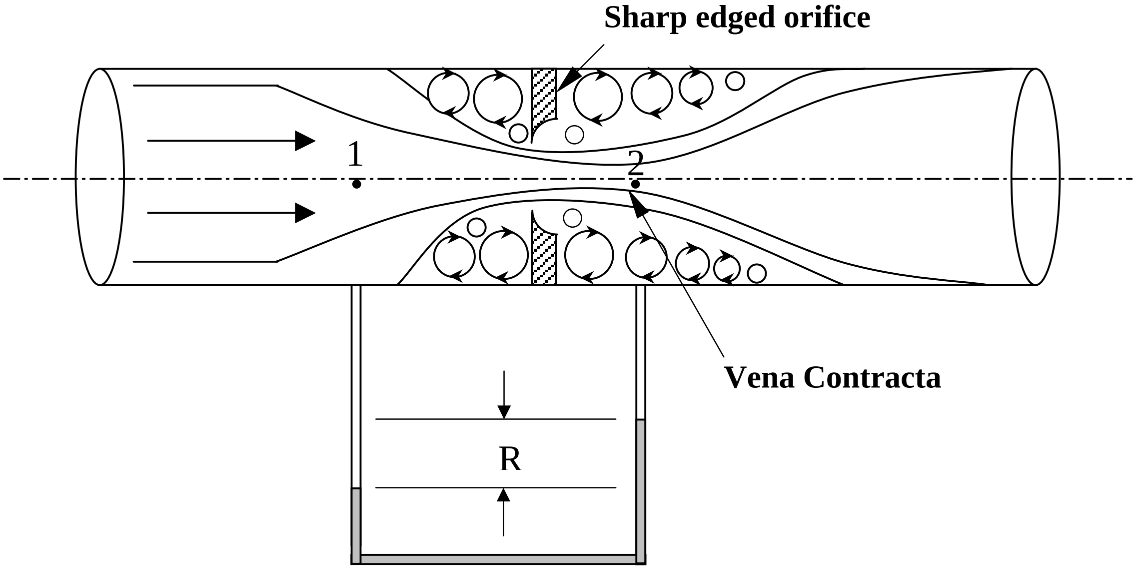
7.2.2.2 <u>Orifice Meter</u>

The primary element of an orifice meter is simply a flat plate containing a drilled located in a pipe perpendicular to the direction of fluid flow as shown in Figure;



At point 2 in the pipe the fluid attains its maximum mean linear velocity u_2 and its smallest cross-sectional flow area A_2. This point is known as "***the vena contracta***". It is occurs at about one-half to two pipe diameters downstream from the orifice plate.

Because of relatively the large friction losses from the eddies generated by the expanding jet below vena contracta, the pressure recovery in orifice meter is poor.

- From continuity equation $A_1u_1 = A_2u_2 \Rightarrow u_1 = (A_2/A_1)\,u_2$
- From Bernoulli's equation between points 1 and 2

$$\frac{P_1}{\rho g}+\frac{u_1^2}{2g}+z_1=\frac{P_2}{\rho g}+\frac{u_2^2}{2g}+z_2$$

$$\Rightarrow \frac{P_1-P_2}{\rho g}=\frac{u_2^2-u_1^2}{2g}=\frac{u_2^2}{2g}\left[1-\left(\frac{A_2}{A_1}\right)^2\right]=\frac{u_2^2}{2g}\left[\frac{A_1^2A_2^2}{A_1^2}\right]$$

But $C_c = A_2/A_o \Rightarrow \quad A_2 = C_cA_o$

C_c: coefficient of contraction [0.6 – 1.0] common value is 0.67

A_2: cross-sectional area at vena contracta

A_o: cross-sectional area of orifice

$$\Rightarrow \quad \frac{P_1-P_2}{\rho}=\frac{u_2^2}{2}\left[1-\left(\frac{C_cA_o}{A_1}\right)^2\right]=\frac{u_2^2}{2}\left[\frac{A_1^2-(C_cA_o)^2}{A_1^2}\right]$$

Using a coefficient of discharge C_d to take into account the frictional losses in the meter and of parameters C_c, α_1, and α_2. Thus the velocity at orifice or the discharge through the meter is;

$$Q=C_d\sqrt{\left(\frac{2(-\Delta P)}{\rho}\right)\left[\frac{A_o^2}{1-(A_o/A_1)^2}\right]}=C_d\sqrt{\frac{2(-\Delta P)}{\rho}}\,\frac{A_1A_o}{\sqrt{A_1^2-A_o^2}}$$

$$\text{or} \qquad Q = C_d \sqrt{(2g\Delta h)\left[\frac{A_o^2}{1-(A_o/A_1)^2}\right]} = C_d\sqrt{2g\Delta h}\,\frac{A_1 A_o}{\sqrt{A_1^2 - A_o^2}}$$

$$\text{or} \qquad Q = C_d \sqrt{\left(\frac{2R(\rho_m-\rho)g}{\rho}\right)\left[\frac{A_o^2}{1-(A_o/A_1)^2}\right]} = C_d\sqrt{\frac{2R(\rho_m-\rho)g}{\rho}}\,\frac{A_1 A_o}{\sqrt{A_1^2 - A_o^2}}$$

$$\dot{m} = Q\,\rho, \qquad G = \rho\, u = \frac{\dot{m}}{A}$$

$$Re_o = \frac{\rho\, u_o d_d}{\mu}$$

For $Re_o > 10^4$ $C_d = 0.61$

And for $Re_o > 10^4$ C_d From Figure below

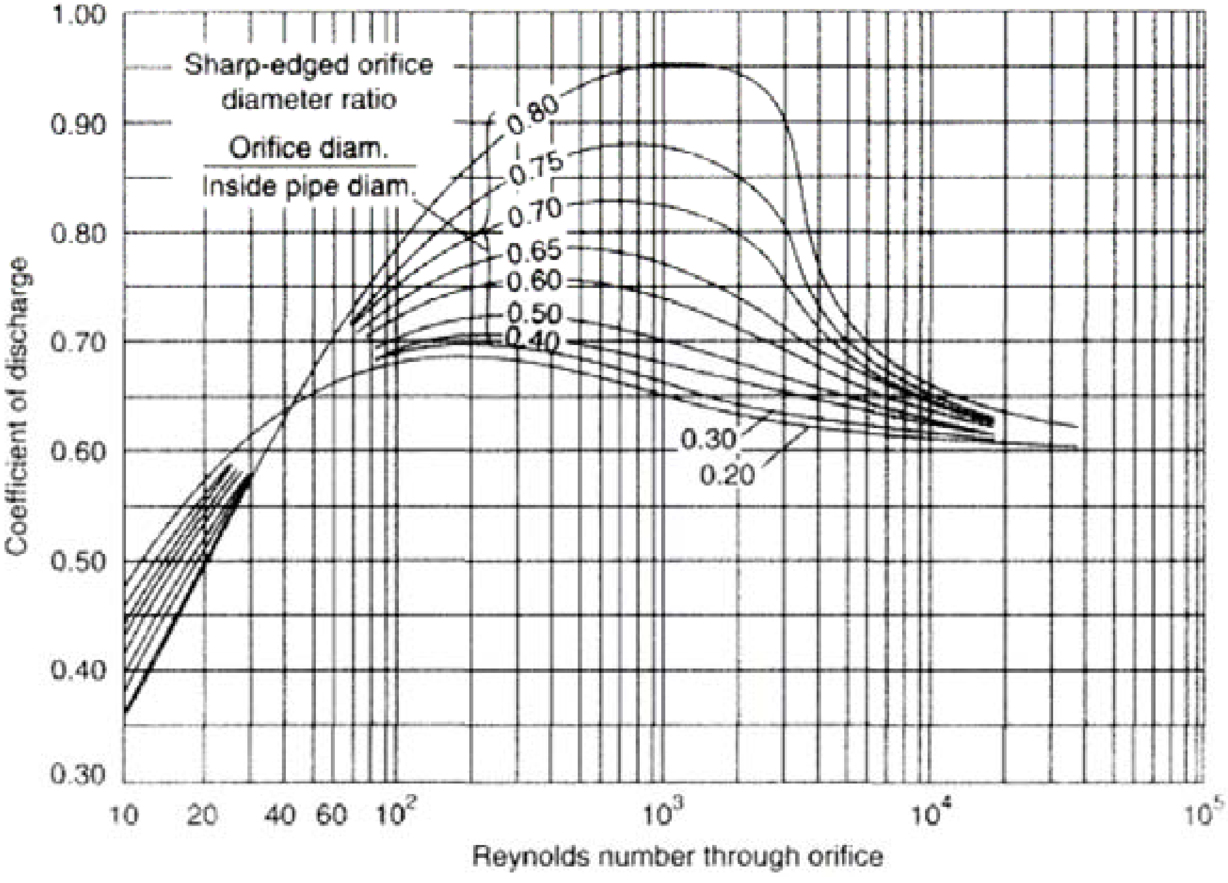


Figure of the discharge coefficient for orifice meter.

The holes in orifice plates may be ***<u>concentric</u>***, ***<u>eccentric</u>*** ***or*** ***<u>segmental</u>*** as shown in Figure. Orifice plates are prone to damage by erosion.

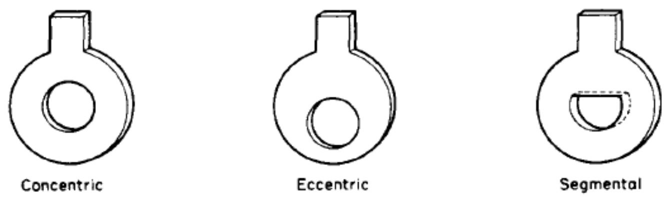


Figure of Concentric. eccentric and segmental orifice plates