APPLICATION ON BERNOULLI EQUATION

VENTURI METER

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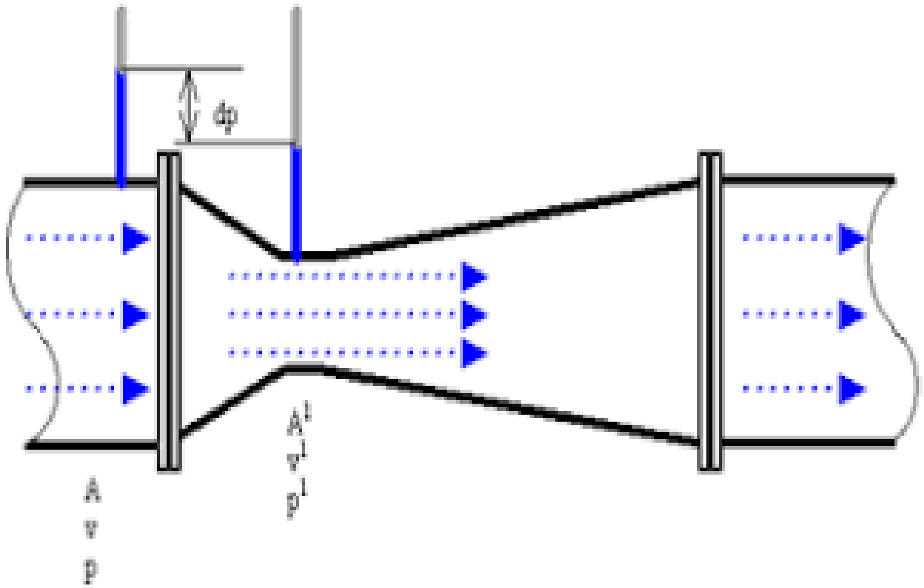
A venture meter is a device used to measure the fluid flow through pipes. This flow measurement device is based on the principle of Bernoulli's equation. Inside the pipe, pressure difference is created by reducing the cross-sectional area of the flow passage. This difference in pressure (heads) is measured with the help of manometer and helps in determining rate of fluid flow or other discharge from the pipe line. As the main inlet area is more as compared to throat, velocity of fluid at throat increases therefore pressure decreases. By this, a pressure difference is created between the inlet and the throat of the venture meter. Hence, by reducing the cross-sectional area of the flow passage, a pressure difference is created and we measure that difference in pressure by using Bernoulli equation and discharge formula (Continuity equation).

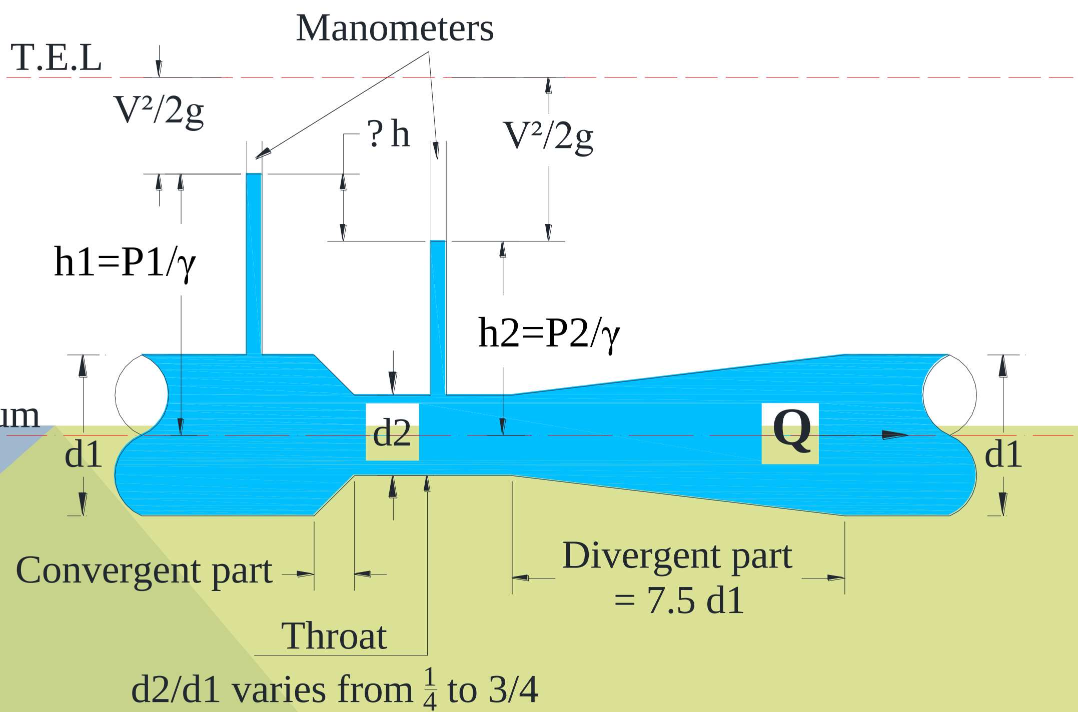


Applying Bernoulli equation, for theoretical condition

$$\frac{P_1}{\gamma_1} + \frac{V_{1theo}^2}{2g} + Z_1 = \frac{P_2}{\gamma_2} + \frac{V_{2theo}^2}{2g} + Z_2$$

For horizontal Venturi meter

$$h_1 + \frac{V_{1theo}^2}{2g} = h_2 + \frac{V_{2theo}^2}{2g} \quad \Rightarrow \quad h_1 - h_2 = \frac{V_{2theo}^2}{2g} - \frac{V_{1theo}^2}{2g} \quad \ldots\ldots\ 1$$



Applying Continuity equation between section 1& 2

$$Q_{theo1} = Q_{theo2}$$

$$Q_{theo} = V_1\, A_1 = V_2\, A_2 \;\Rightarrow\; V_1 = V_2 \frac{A_2}{A_1}$$

Substituting equation 2 in 1

$$h_1 - h_2 = \frac{V_{2theo}^2}{2g} - \frac{(\frac{A_2}{A_1})^2\, V_{2\,theo}^2}{2g}$$

$$h_1 - h_2 = \frac{V_2^2 \;-\; (\frac{A_2}{A_1})^2\, V_2^2}{2g} \qquad \Rightarrow \qquad h_1 - h_2 = \frac{V_2^2\,[1 - \;(\frac{A_2}{A_1})^2]}{2g}$$

$$V_{2theo}^2 = \frac{2g(h_1 - h_2)}{[1 - (\frac{A_2}{A_1})^2]} \qquad \Rightarrow \qquad \boldsymbol{V_{2theo}} = \sqrt{\frac{\boldsymbol{2g(h_1 - h_2)}}{\boldsymbol{[1 - (\frac{A_2}{A_1})^2]}}}$$

$$Q_{theo} = A_2\ V_2\ \ ;\ Q_{act} = C_d\ Q_{theo}\ \ ;\ \ C_d = (0.9 - 0.98);\ \ C_d = C_V\ ;\ \ C_C = 1$$

$$\frac{D_2}{D_1} = \frac{1}{4}\ to\ \frac{3}{4}\ \ ; usually\ \ \frac{D_2}{D_1} = \frac{1}{2}$$

$$C_d = discharge\ cofficient$$
$$C_v = velocity\ cofficient$$
$$C_c = contraction\ cofficient$$

$$A_1 = cross\ section\ area\ of\ the\ pipe$$

$$A_2 = cross\ section\ area\ of\ the\ throut$$

Example : Determine the actual discharge through the Venturi meter if diameter of throat D2= 5 cm, and the pipe diameter D1 = 10 cm, having a different in pressure 50 kpa and C_d= 0.98

Solution:- different in pressure (Δh) = h1 – h2

Δp = 50 Kpa , $\Delta h = \frac{\Delta p}{\gamma} = \frac{50 * 1000}{9806} = 5.0989\ m$

$$A1 = \frac{\pi D_1^2}{4} = \frac{\pi}{4}(0.1)^2 = 0.007854\ m^2 \ ; \ A2 = \frac{\pi D_2^2}{4} = \frac{\pi}{4}(0.05)^2 = 0.001963\ m^2$$

$$Q_{theo} = V_2\, A_2 = A_2 \sqrt{\frac{2g(h_1 - h_2)}{[1 - (\frac{A_2}{A_1})^2]}} = 0.001963 \sqrt{\frac{2g(5.0989)}{[1 - (\frac{0.001963}{0.007854})^2]}}$$

$$= 0.0203\ m^3/sec$$

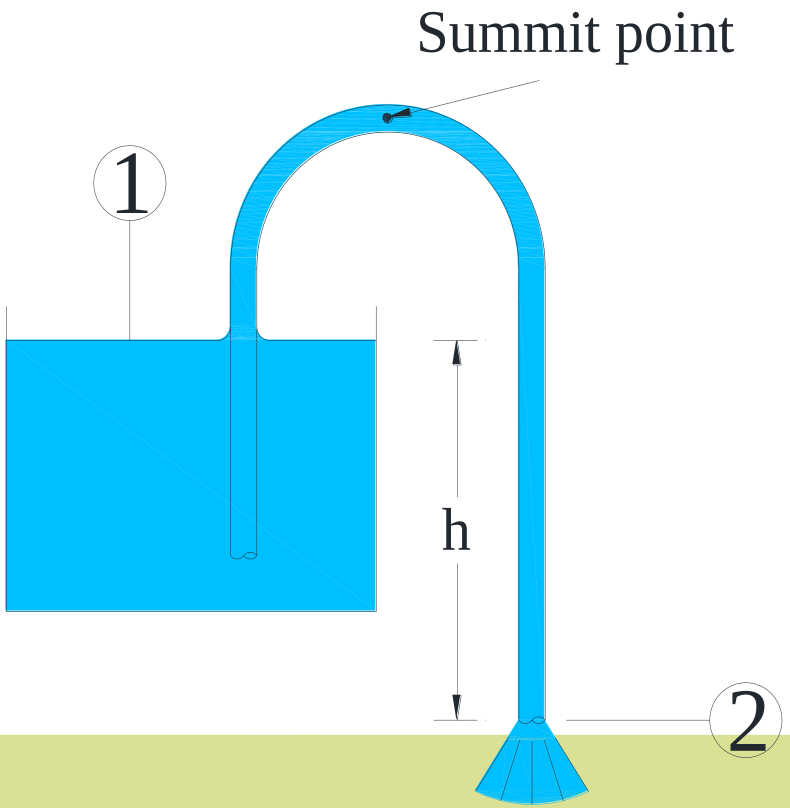
$$Q_{act} = C_d\ Q_{theo} = 0.98 * 0.0203 = \mathbf{0.0199\, m^3/sec}$$

APPLICATION ON BERNOULLI EQUATION

SIPHON

SIPHON

A long bend pipe, used to carry water from a reservoir at a higher level to another reservoir at a lower level when two reservoirs are separated by a hill, is called as siphon. The highest point of siphon is called as summit. The highest point of siphon lies above the free water surface in the reservoir at higher level. Therefore, pressure at this point is below atmospheric. The negative or vacuum pressure is created in the siphon, so that liquid gets pushed into it.
Siphon works on Bernoulli's principle and it is used when the water have to take out from reservoir to another separated by a hill. Siphon is also used to drain out water from a channel without any outlet. The siphon it is used for determine velocity and losses through it.



Applying Bernoulli equation between 1 & 2 without losses

$$\frac{P_1}{\gamma} + \frac{V_{1theo}^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_{2theo}^2}{2g} + Z_2$$

$$0 + 0 + h = 0 + \frac{V_2^2}{2g} + 0$$

$$V_2 = \sqrt{2g\,Z_1} \;\Rightarrow\; \boldsymbol{V_2 = \sqrt{2gh}}$$

If losses exist, the equation will be:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + losses$$

$$0 + 0 + h = 0 + \frac{V_2^2}{2g} + 0 + h_f$$

$$\boldsymbol{Losses = h_f = f\,\frac{L}{D}\,\frac{V_2^2}{2g}}$$

$$h - h_f = \frac{V_2^2}{2g} \;\Rightarrow\; \boldsymbol{V_2 = \sqrt{2g\,(h - h_f)}}$$

Example: the siphon of fig. is filled with water and is discharging at 150 L/sec. Find the losses coefficient (k) from point 1 to point 3 in terms of velocity head $k\frac{V^2}{2g}$. Find the pressure at point 2.

Solution:-

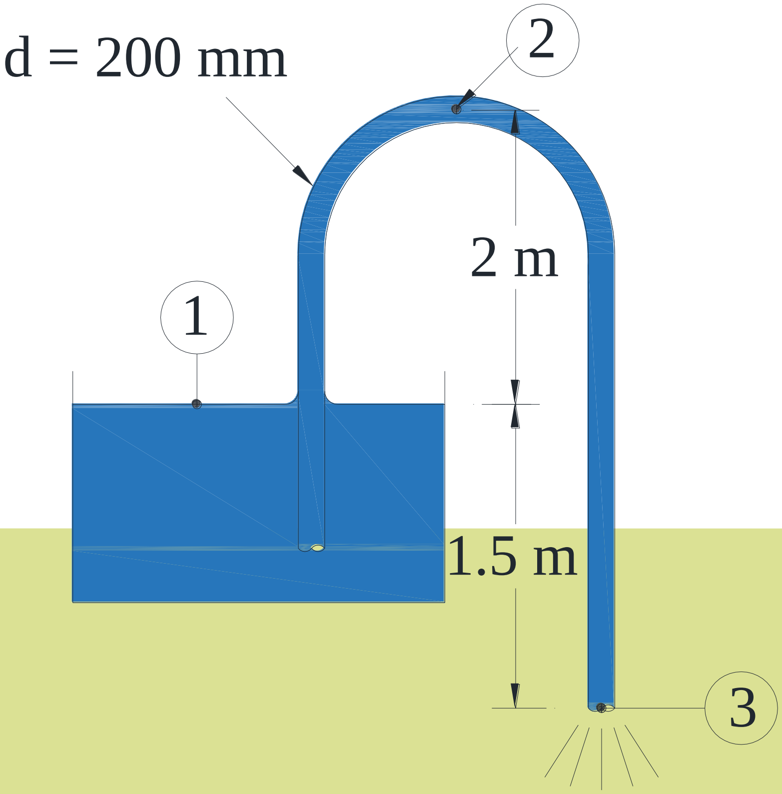
$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + Z_3 + Losses_{1-3}$$

$$0 + 0 + 1.5 = 0 + \frac{V_3^2}{2g} + 0 + k\frac{V_3^2}{2g}$$

$$V_3 = \frac{Q}{A} = \frac{\frac{150}{1000}}{\frac{\pi}{4}(\frac{200}{1000})^2} = 4.77\ m/sec$$

$$1.5 = 1.16 + k\frac{V_3^2}{2g} \qquad \Rightarrow k\frac{V_3^2}{2g} = 0.34\ m$$

$$k = 0.29$$



The pressure head at 2

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + Losses_{1-2}$$

$$0 + 0 + 0 = \frac{P_2}{\gamma} + \frac{(4.77)^2}{2g} + 2 + \left(\frac{2}{(2+2+1.5)}\right) 0.29 \frac{(4.77)^2}{2g}$$

$$\frac{P_2}{\gamma_2} = -3.2825\ m$$

$$P_2 = -32188.14836\ N/m^2$$

* The negative sign mean the pressure is suction for continuity the flow.