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Venturix

Version 2.0

VENTURIMETER THEORY
for
INCOMPRESSIBLE & COMPRESSIBLE FLOW

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A) FLOW RATE for INCOMPRESSIBLE FLOW

For incompressible flow from Bernoulli Equation;

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

$$Z_1=Z_2$$

$$Q=A_1.V_1=A_2.V_2 \quad \Rightarrow \quad V_1=\frac{Q}{A_1} \quad ; \quad V_2=\frac{Q}{A_2}$$

$$\frac{Q^2}{2g.A_1^2}-\frac{Q^2}{2g.A_2^2}=\frac{P_2}{\gamma}-\frac{P_1}{\gamma}$$

$$\frac{Q^2}{2g.A_1^2}-\frac{Q^2}{2g.A_2^2}=\frac{P_2}{\gamma}-\frac{P_1}{\gamma} \qquad h_1=\frac{P_1}{\gamma} \quad ; \quad h_2=\frac{P_2}{\gamma}$$

$$\frac{Q^2}{2g}\left(\frac{1}{A_1^2}-\frac{1}{A_2^2}\right)=h_2-h_1$$

$$Q^2=\frac{2g\left(h_2-h_1\right)}{\left(\frac{1}{A_1^2}-\frac{1}{A_2^2}\right)}$$

$$\boxed{Q=A_2\sqrt{\frac{2g\left(h_2-h_1\right)}{\left(1-\left(\frac{d_1}{d_2}\right)^4\right)}}}$$

Flow Rate For Incompressible Flow (m^3/sec)

$$\boxed{Q^*=C_d.A_2\sqrt{\frac{2g\left(h_2-h_1\right)}{\left(1-\left(\frac{d_1}{d_2}\right)^4\right)}}}$$

Real Flow Rate For Incompressible Flow (m^3/sec)

$$\beta=\frac{D_2}{D_1}$$

Long Radius Nozzle

$$\boxed{C=C_d \approx 0.9965-0.00653\left(\beta\right)^{1/2}\left(\frac{10^6}{\mathrm{Re}_{D_1}}\right)^{1/2}}$$

Short Radius ISA 1932 Flow Nozzle

$$\boxed{C=C_d=0.9900-2262\beta^{4.1}+(0.000215-0.001125\beta+0.00249\beta^{4.7})\left(\frac{10^6}{\mathrm{Re}_D}\right)^{1.15}}$$

Venturimeter

$$\boxed{C=C_d \approx 0.9858-0.196\beta^{4.5}}$$

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B) FLOW RATE for COMPRESSIBLE FLOW

Energy Equation for Two Point;

$$\frac{U_2^2 - U_1^2}{2} = h_1 - h_2$$

$$U_2^2 - U_1^2 = 2\left(h_1 - h_2\right)$$

$$U_2^2 - U_1^2 = 2c_p T_1\left(1 - \frac{T_2}{T_1}\right)$$

$$\boxed{\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}}$$

$$\boxed{\frac{\rho_2}{\rho_1} = \left(\frac{P_2}{P_1}\right)^{\frac{1}{k}}}$$

$$U_2^2\left(1 - \left(\frac{U_1}{U_2}\right)^2\right) = 2c_p T_1\left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}\right)$$

$$\rho_1 U_1 A_1 = \rho_2 U_2 A_2$$

$$\boxed{\frac{U_1}{U_2} = \frac{\rho_2 A_2}{\rho_1 A_1} = \left(\frac{P_2}{P_1}\right)^{\frac{1}{k}}\left(\frac{A_2}{A_1}\right)}$$

$$U_2^2 = \frac{2c_p T_1\left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}\right)}{1 - \left(\frac{A_2}{A_1}\right)^2\left(\frac{P_2}{P_1}\right)^{\frac{2}{k}}}$$

$$\boxed{U_2 = \sqrt{\frac{\frac{2kRT_1}{k-1}\left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}\right)}{1 - \left(\frac{A_2}{A_1}\right)^2\left(\frac{P_2}{P_1}\right)^{2/k}}}}$$

Velocity at Throad (m/sec)

$$\boxed{Q = C.A_2.U_2}$$

$$\boxed{Q = C.A_2\sqrt{\frac{\frac{2kRT_1}{k-1}\left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}\right)}{1 - \left(\frac{A_2}{A_1}\right)^2\left(\frac{P_2}{P_1}\right)^{2/k}}}}$$

Real Flow Rate For Compressible Flow (m^3/sec);

Resources:
Theory and Problems of Fluid Mechanics and Hydraulics, Ranald V. GILES
Mechanics of Fluids, Merle C. POTTER, David C. WIGGERT, Midhat HONDZO
Fluid Mechanics, Frank M. WHITE,
Hidrolik Makinalar Laboratuar Deneyleri, Yasar PANCAR