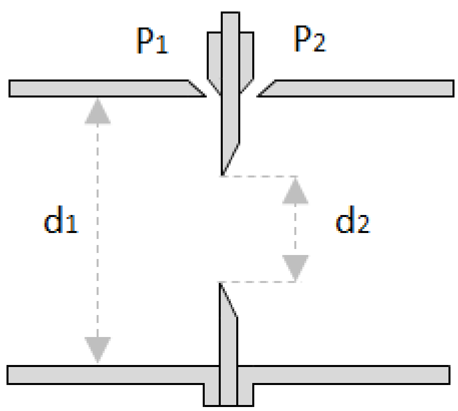
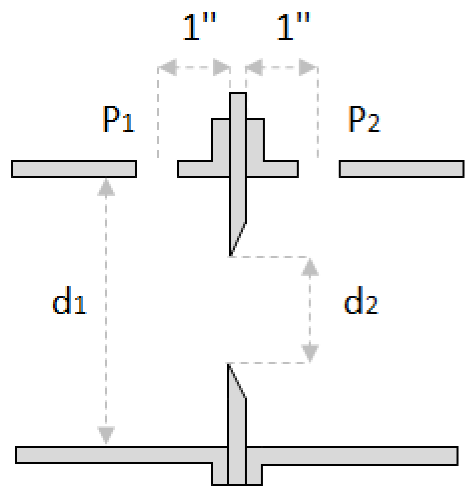
Small Diameter Orifice Flow Meter for Liquids

This application calculates the flowrate through a small diameter orifice flow meter.

Corner taps



Flange taps



Recommended parameters:

$1.2\ \mathrm{cm}\quad d_1 \leq 4\,\mathrm{cm}$ for corner taps

$2.5\quad d_2\quad 4$ cm for flange taps

$0.1\quad d_1/d_2\quad 0.8$ for corner taps

$0.15\quad d_1/d_2 \leq 0.7$ for flange taps

Measurement of Fluid Flow Using Small Bore Precision Orifice Meters,
MFC-14M - 2003(R2018), ASME

Parameters

Extract properties from ThermophysicalData package

Property := ThermophysicalData:-Property

Liquid

liquid := "water"

Density

$\rho :=$ Property(density, liquid, T = 300, P = 101325) = 996.557

Viscosity

$\mu := \text{Property}(\text{viscosity}, \text{liquid}, T = 300, P = 101325)$

$\mu = 8.537 \times 10^{-4}$

Differential pressure

$\Delta P := 2015$

Orifice diameter

$d_2 := 0.027$

Pipe diameter

$d_1 := 0.042$

Tap type ("corner" or "flange")

taptype := "corner"

Equations

Throat area

$$A_{throat} := \frac{\pi \cdot d_2^{\,2}}{4} = 5.726 \times 10^{-4}$$

Pipe area

$$A_{pipe} := \frac{\pi \cdot d_1^{\,2}}{4} = 0.001$$

Diameter ratio

$$\beta := \frac{d_2}{d_1} = 0.643$$

Drag coefficient

$$\text{DragCoeff} := \begin{cases} Cd = Cd_{corner} & \text{taptype} = \text{"corner"} \\ Cd = Cd_{flange} & \text{taptype} = \text{"flange"} \end{cases}$$

Drag coefficient for corner taps

$$Cd_{corner} := \left(0.5991 + \frac{0.0044}{d_1 \cdot 39.3701} + \left(0.3155 + \frac{0.0175}{d_1 \cdot 39.3701}\right) \cdot \left(\left(\frac{d_2}{d_1}\right)^4 + 2 \cdot \left(\frac{d_2}{d_1}\right)^{16}\right)\right) \cdot \sqrt{1 - \left(\frac{d_2}{d_1}\right)^4} + \left(\frac{0.52}{d_1 \cdot 39.3701} - 0.192 + \left(16.48 - \frac{1.16}{d_1 \cdot 39.3701}\right) \cdot \left(\left(\frac{d_2}{d_1}\right)^4 + 4 \cdot \left(\frac{d_2}{d_1}\right)^{16}\right)\right) \cdot \sqrt{1 - \left(\frac{d_2}{d_1}\right)^4 \cdot \frac{1}{Rey}}$$

Drag coefficient for flange taps

$$Cd_{flange} := \left(0.598 + 0.468 \cdot \left(\left(\frac{d_2}{d_1}\right)^4 + 10 \cdot \left(\frac{d_2}{d_1}\right)^{12}\right)\right) \cdot \sqrt{1 - \left(\frac{d_2}{d_1}\right)^4} + \left(0.87 + 8.1 \cdot \left(\frac{d_2}{d_1}\right)^4\right) \cdot \sqrt{\left(1 - \left(\frac{d_2}{d_1}\right)^4\right) \cdot \frac{1}{Rey}}$$

Mass flowrate

$$MassFlowrate := Q_m = \frac{Cd \cdot A_{throat} \cdot \sqrt{2 \cdot \rho \cdot \Delta P}}{\sqrt{1 - \beta^4}} = Q_m = 1.260 \cdot Cd$$

Fluid velocity

$$V_{pipe} := \frac{Q_m}{A_{pipe} \cdot \rho} = 0.724 \cdot Q_m$$

Reynolds number

$$Reynolds := Rey = \frac{V_{pipe} \cdot d_1 \cdot \rho}{\mu} = Rey = 3.551 \times 10^4 \cdot Q_m$$

Results

Equation system

$$eqs := \{DragCoeff, MassFlowrate, Reynolds\}$$

Parameters to solve for

$$vars := indets(eqs, name)$$

$$vars = \{Cd, Q_m, Rey\}$$

Numerical solution

$$res := \mathit{fsolve}(eqs, vars)$$

$$Cd := eval(Cd, res) = 3.470$$

$$Q_m := eval(Cd, res) = 3.470$$

$$Rey := eval(Rey, res) = 1.553 \times 10^5$$

Static pressure loss from a distance d1 upstream and 6 d1 downstream of the orifice

$$w := \frac{\sqrt{1-\beta^4} - Cd \cdot \beta^2}{\sqrt{1-\beta^4} + Cd \cdot \beta^2} \cdot \Delta P = -449.869$$