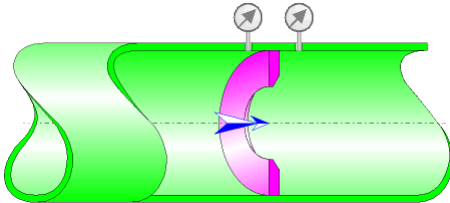




Square-Edge Orifice Flowmeter Flange pressure tapplings (ISO 5167-2:2003)



Model description:

This model of component determines the fluid flow through a square-edge orifice flowmeter with flange pressure tapplings, according to the international standard "ISO-5167-2:2003".

Model formulation:

Diameter ratio:

$$\beta = \frac{d}{D}$$

Orifice cross-sectional area (m²):

$$s = \pi \cdot \frac{d^2}{4}$$

Pipe cross-sectional area (m²):

$$S = \pi \cdot \frac{D^2}{4}$$

Mean velocity in orifice (m/s):

$$v = \frac{q_v}{s}$$

Mean velocity in pipe (m/s):

$$V = \frac{q_v}{S}$$

Reynolds number referred to orifice diameter:

$$Re_d = \frac{v \cdot d}{\nu}$$

Reynolds number referred to internal pipe diameter:

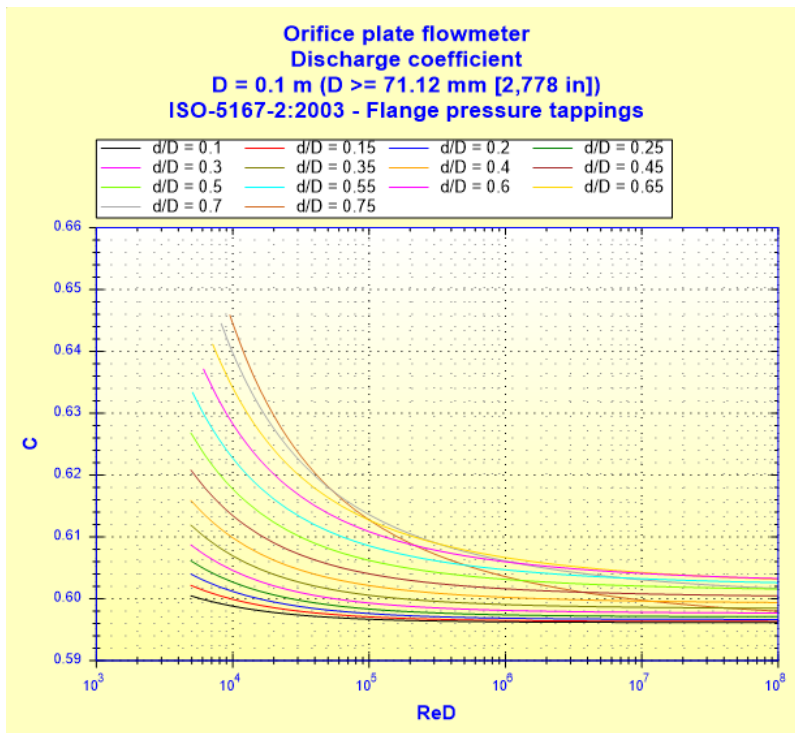
$$\text{Re}_D = \frac{V \cdot D}{\nu}$$

Discharge coefficient (Reader-Harris/Gallagher (1998) equation):

■ $D \geq 71.12 \text{ mm (2.8 in)}$

$$C = 0.5961 + 0.0261 \cdot \beta^2 - 0.216 \cdot \beta^8 + 0.000521 \cdot \left(\frac{10^6 \cdot \beta}{\text{Re}_D} \right)^{0.7} \\ + (0.0188 + 0.0063 \cdot A) \cdot \beta^{3.5} \cdot \left(\frac{10^6}{\text{Re}_D} \right)^{0.3} \\ + (0.043 + 0.08 \cdot e^{-10 \cdot L1} - 0.123 \cdot e^{-7 \cdot L1}) \cdot (1 - 0.11 \cdot A) \cdot \frac{\beta^4}{1 - \beta^4} \\ - 0.031 \cdot (M'_2 - 0.8 \cdot M'_2{}^{1.1}) \cdot \beta^{1.3}$$

([2] § 5.3.2.1 eq. 4)



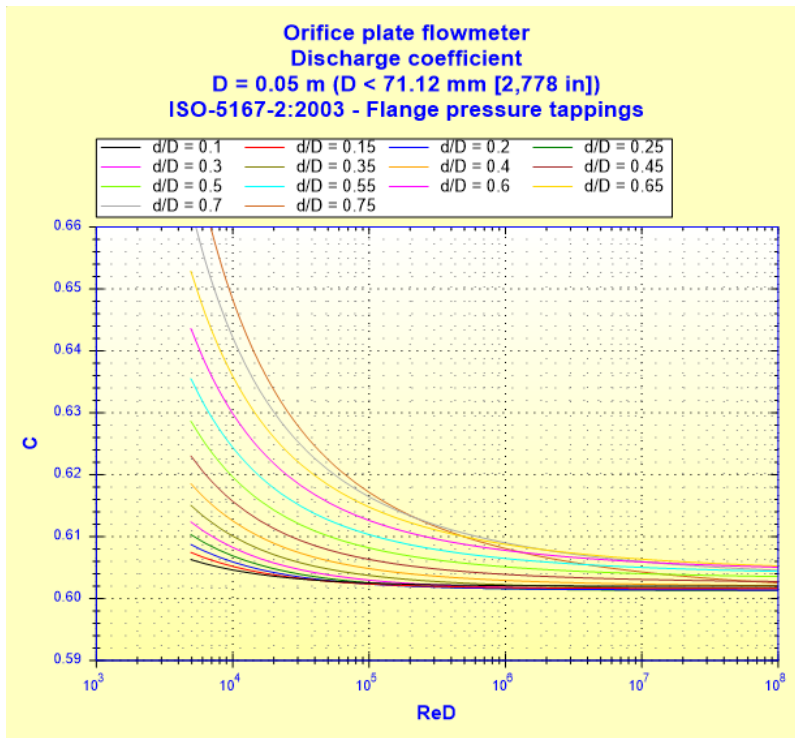
with $D = 100 \text{ mm}$

■ $D < 71.12 \text{ mm (2.8 in)}$

$$C = 0.5961 + 0.0261 \cdot \beta^2 - 0.216 \cdot \beta^8 + 0.000521 \cdot \left(\frac{10^6 \cdot \beta}{\text{Re}_D} \right)^{0.7} \\ + (0.0188 + 0.0063 \cdot A) \cdot \beta^{3.5} \cdot \left(\frac{10^6}{\text{Re}_D} \right)^{0.3} \\ + (0.043 + 0.08 \cdot e^{-10 \cdot L1} - 0.123 \cdot e^{-7 \cdot L1}) \cdot (1 - 0.11 \cdot A) \cdot \frac{\beta^4}{1 - \beta^4} \\ - 0.031 \cdot (M'_2 - 0.8 \cdot M'_2{}^{1.1}) \cdot \beta^{1.3} \\ + 0.011 \cdot (0.75 - \beta) \cdot \left(2.8 - \frac{D}{25.4} \right)$$

([2] § 5.3.2.1 eq. 4)

Where D is the pipe diameter in mm



with D = 50 mm

where:

$$M'_2 = \frac{2 \cdot L'_2}{1 - \beta}$$

$$A = \left(\frac{19000 \cdot \beta}{Re_D} \right)^{0.8}$$

The values of L_1 and L'_2 to be used in this equations are as follows:

$$L_1 = L'_2 = \frac{25.4}{D}$$

where D is expressed in millimetres

Expansibility factor:

$$\varepsilon = 1 \quad ([1] \text{ §3.3.6) for incompressible fluid (liquid)}$$

Mass flow rate (kg/s):

$$q_m = \frac{C}{\sqrt{1 - \beta^4}} \cdot \varepsilon \cdot \frac{\pi}{4} \cdot d^2 \cdot \sqrt{2 \cdot \Delta p \cdot \rho} \quad ([2] \text{ § 4 eq. 1)}$$

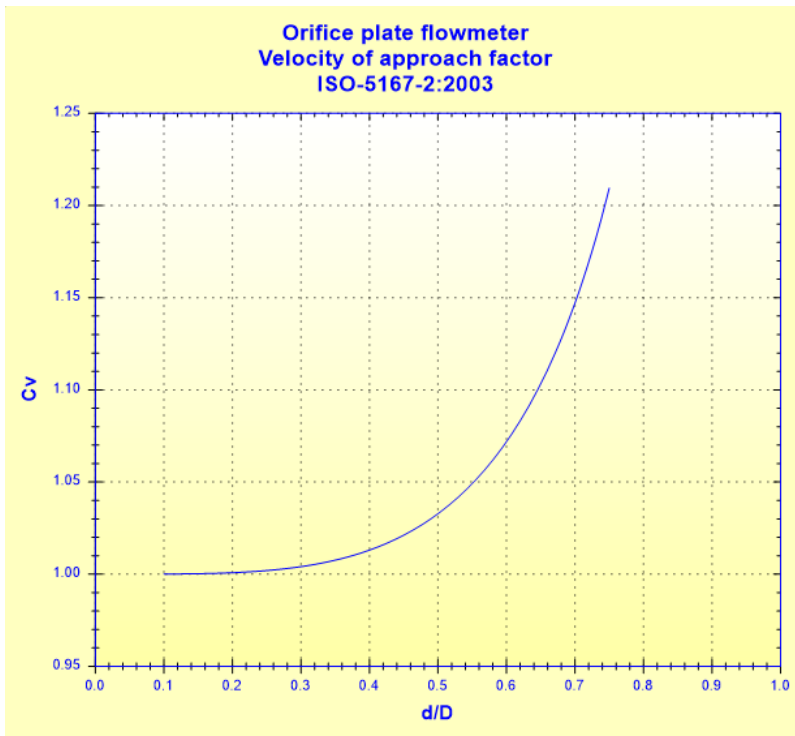
Volume flow rate (m^3/s):

$$q_v = \frac{q_m}{\rho} \quad ([2] \text{ § 4 eq. 2)}$$

Velocity of approach factor:

$$C_v = \frac{1}{\sqrt{1-\beta^4}}$$

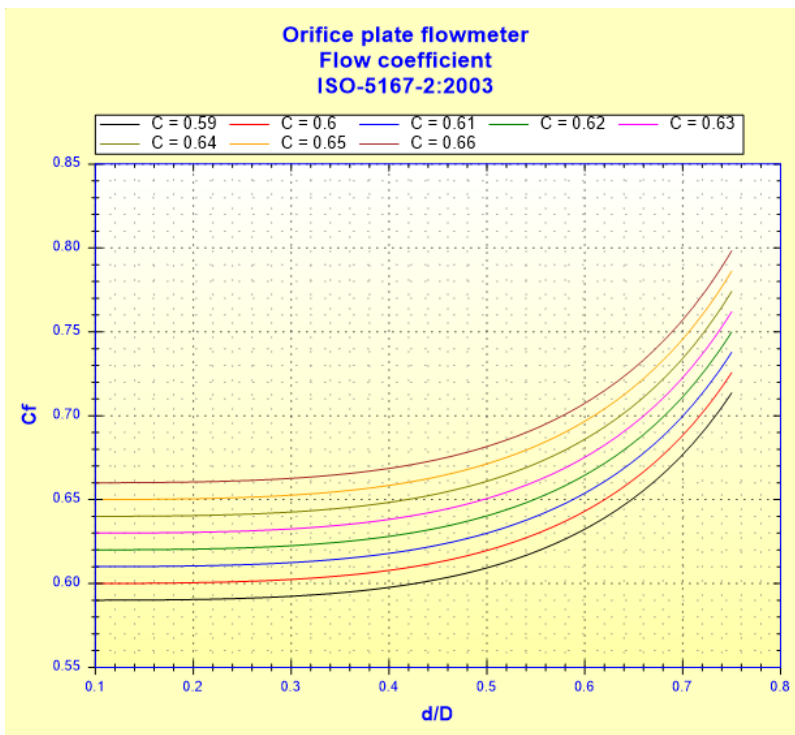
([1] §3.3.5)

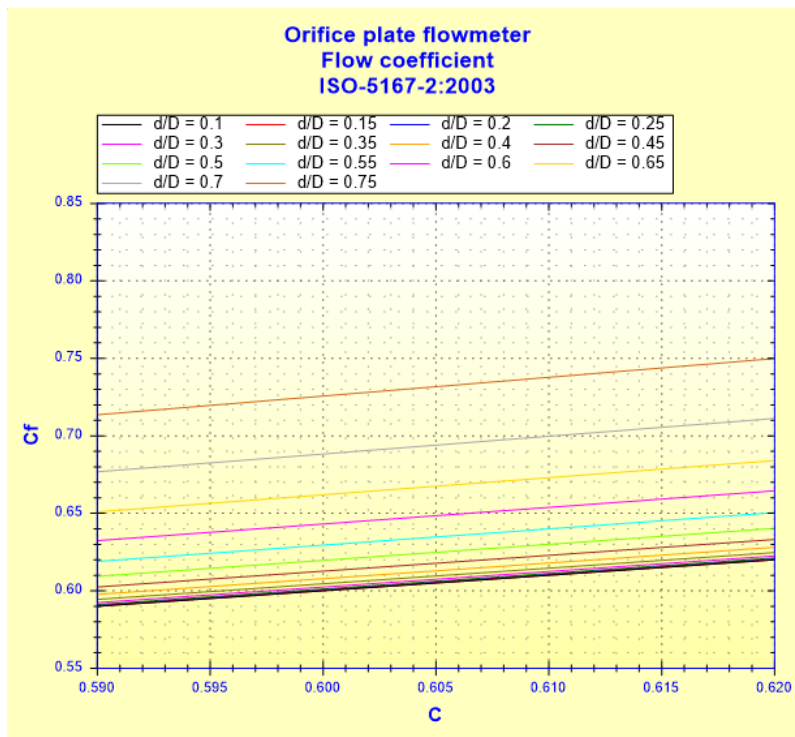


Flow coefficient:

$$C_f = C \cdot \frac{1}{\sqrt{1-\beta^4}}$$

([1] §3.3.5)





Pressure loss coefficient of orifice (based on the mean pipe velocity):

$$K = \left(\frac{\sqrt{1 - \beta^4 \cdot (1 - C^2)}}{C \cdot \beta^2} - 1 \right)^2 \quad ([2] \text{ § 5.4.3})$$

Net pressure loss (Pa):

$$\Delta \varpi = \frac{\sqrt{1 - \beta^4 \cdot (1 - C^2)} - C \cdot \beta^2}{\sqrt{1 - \beta^4 \cdot (1 - C^2)} + C \cdot \beta^2} \cdot \Delta p \quad ([2] \text{ § 5.4.1})$$

Net head loss (m):

$$\Delta h = \frac{\Delta \varpi}{\rho \cdot g}$$

Net hydraulic power loss (W):

$$Wh = \Delta \varpi \cdot q_v$$

Measured head loss (m):

$$\Delta H = \frac{\Delta P}{\rho \cdot g}$$

Symbols, Definitions, SI Units:

- d Orifice diameter (m)
- D Internal pipe diameter (m)
- β Diameter ratio ()
- s Orifice cross-sectional area (m²)

| | |
|-----------------|--|
| S | Pipe cross-sectional area (m ²) |
| q _v | Volume flow rate (m ³ /s) |
| v | Mean velocity in orifice (m/s) |
| V | Mean velocity in pipe (m/s) |
| Re _d | Reynolds number referred to orifice () |
| Re _D | Reynolds number referred to pipe () |
| C | Discharge coefficient () |
| L ₁ | Upstream relative pressure tapping spacing from the upstream face () |
| L' ₂ | Downstream relative pressure tapping spacing from the downstream face () |
| ε | Expansibility factor () |
| q _m | Mass flow rate (kg/s) |
| C _v | Velocity of approach factor () |
| C _f | Flow coefficient () |
| K | Pressure loss coefficient of orifice (based on the mean pipe velocity) () |
| Δω | Net pressure loss (Pa) |
| ΔP | Measured pressure loss (Pa) |
| Δh | Net head loss of fluid (m) |
| Wh | Hydraulic power loss (W) |
| ΔH | Measured head loss of fluid (m) |
| ρ | Fluid density (kg/m ³) |
| ν | Fluid kinematic viscosity (m ² /s) |
| g | Gravitational acceleration (m/s ²) |

Limit of use:

- $d \geq 12.5 \text{ mm}$
- $50 \text{ mm} \leq D \leq 1\,000 \text{ mm}$
- $0.1 \leq \beta \leq 0.75$
- both $Re_D \geq 5\,000$ and $Re_D \geq 170 \beta^2 D$
where D is expressed in millimetres

Example of application:

HydrauCalc 2019a - [Orifice plate flowmeter - ISO 5167-2:2003 - Flange pressure tappings]

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Fluid characteristics

Fluid : Water @ 1 atm [HC]
Ref.: IAPWS IF97

Temperature : T 20 °C
Pressure : P 1.013 bar

Density : ρ 998.2061 kg/m³
Dynamic Viscosity : μ 0.00100159 N.s/m²
Kinematic Viscosity : ν 1.00340E-06 m²/s

Density Dyn. Visc. Kn. Visc.

Geometrical characteristics

Measured differential pressure ΔP 0.5 bar
 ΔH 5.1079 m of fluid

25,4 mm 25,4 mm

q_m 6.0197 kg/s
 q_v 0.006030469 m³/s
 V 1.554 m/s (Turbulent)

6,268 m/s (Turbulent)

0.035 m d 0.0703 m

Net pressure loss Δp_0 0.3670239 bar
 Δh 3.7493 m of fluid

Complementary results

| Designation | Symbol | Value | Unit |
|---|-----------------|--------------|----------------|
| Pipe cross-section area | S | 0.003881508 | m ² |
| Orifice cross-section area | s | 0.0009621127 | m ² |
| Diameters ratio | β | 0.4978663 | |
| Cross-sections area ratio | s/S | 0.2478708 | |
| Pipe Reynolds number | ReD | 108851.2 | |
| Orifice Reynolds number | Re _d | 218635.4 | |
| Discharge coefficient | C | 0.60668 | |
| Expansibility factor | ϵ | 1 | |
| Velocity of approach factor | C _v | 1.032212 | |
| Flow coefficient | C _f | 0.6262225 | |
| Net pressure loss coefficient (based on mean pipe velocity) | K | 30.46512 | |
| Hydraulic power loss | Wh | 221.3326 | W |

References:

- [1] ISO 5167-1:2003 - Measurement of fluid flow by means of pressure differential devices inserted in circular-cross section conduits running full
Part 1: General principles and requirements
- [2] ISO 5167-2:2003 - Measurement of fluid flow by means of pressure differential devices inserted in circular-cross section conduits running full
Part 2: Orifice plates