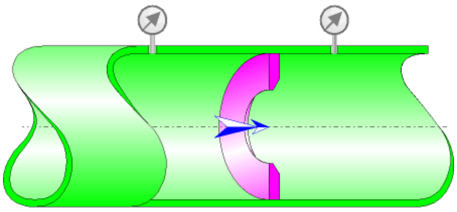
Square-Edge Orifice Flowmeter
D and D/2 pressure tappings
(ISO 5167-2:2003)



Model description:

This model of component determines the fluid flow through a square-edge orifice flowmeter with D & D/2 pressure tappings, 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:

$$\mathrm{Re}_d = \frac{v \cdot d}{\nu}$$

Reynolds number referred to internal pipe diameter:

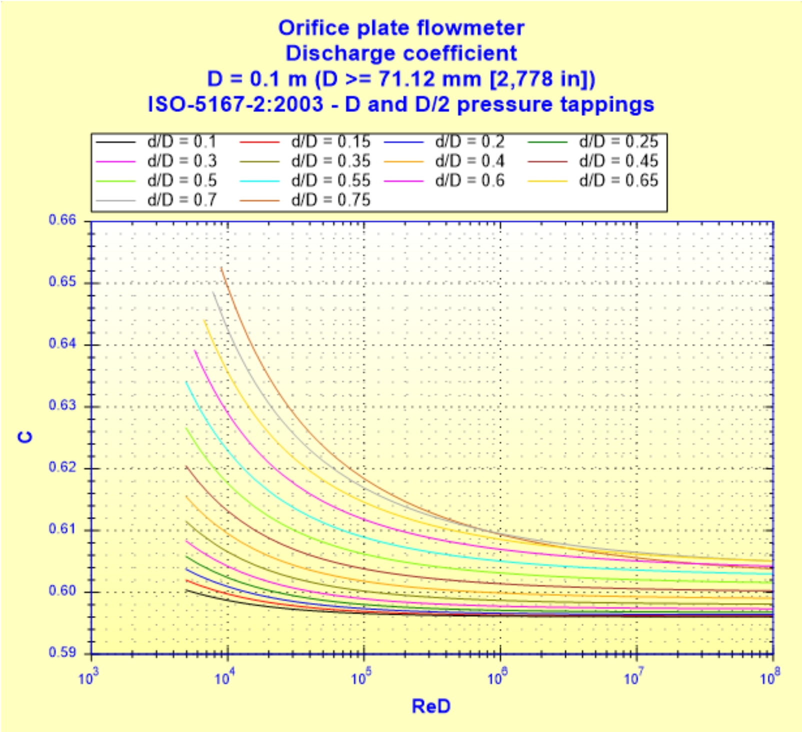
$$\mathrm{Re}_D = \frac{V \cdot D}{\nu}$$

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

- D ≥ 71.12 mm (2.8 in)

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

([2] § 5.3.2.1 eq. 4)



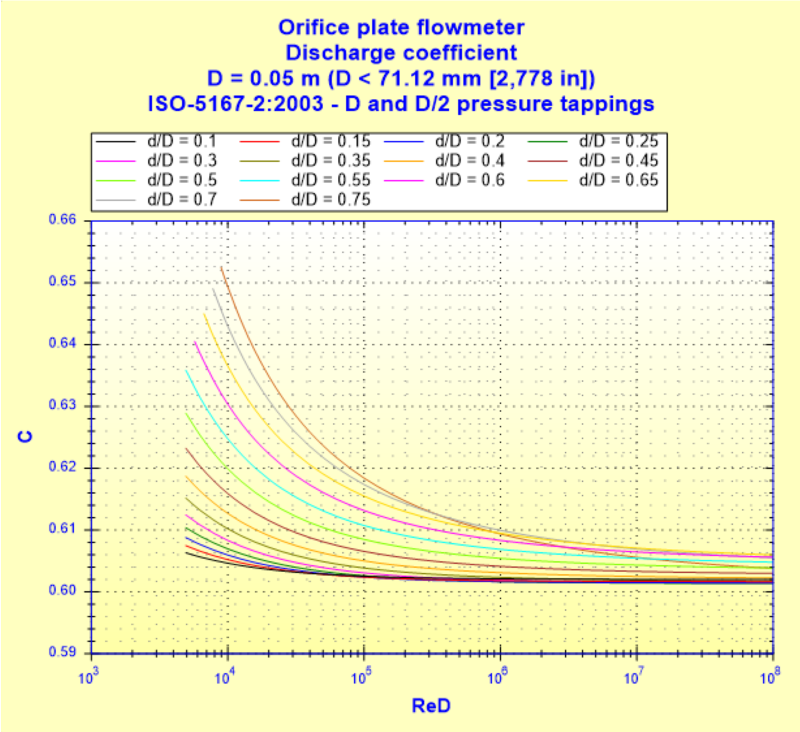
with D = 100 mm

- D < 71.12 mm (2.8 in)

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

([2] § 5.3.2.1 eq. 4)

Where D is the pipe diameter in mm



with D = 50 mm

where:

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

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

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

$$L_1 = 1$$

$$L'_2 = 0.47$$

Expansibility factor:

$$\varepsilon = 1$$

([1] §3.3.6) for incompressible fluid (liquid)

Mass flow rate (kg/s):

$$q_m = \frac{C}{\sqrt{1-\beta^4}} \cdot \varepsilon \cdot \frac{\pi}{4} \cdot d^2 \cdot \sqrt{2 \cdot \Delta p \cdot \rho}$$

([2] § 4 eq. 1)

Volume flow rate (m^3/s):

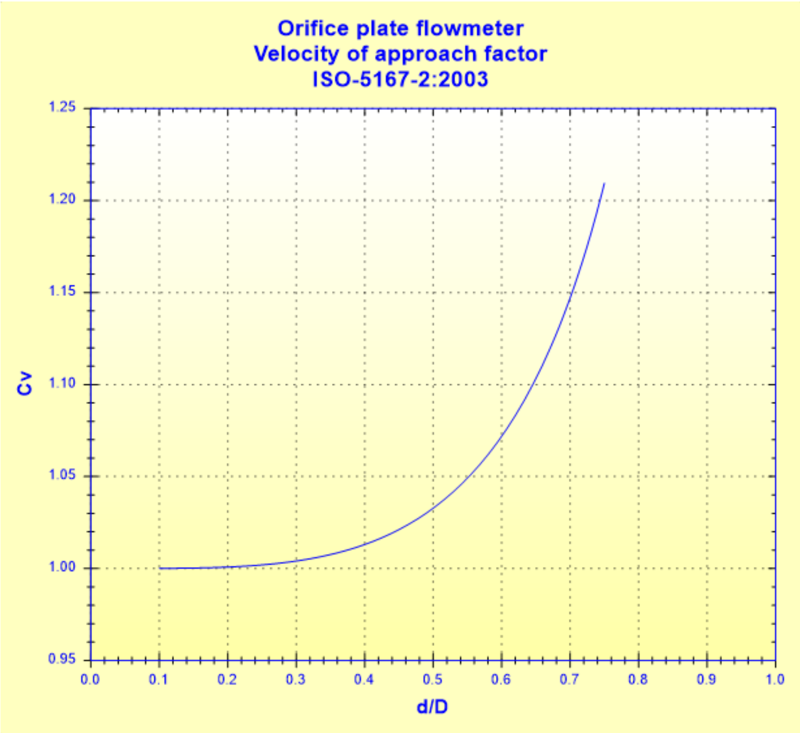
$$q_v = \frac{q_m}{\rho}$$

([2] § 4 eq. 2)

Velocity of approach factor:

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

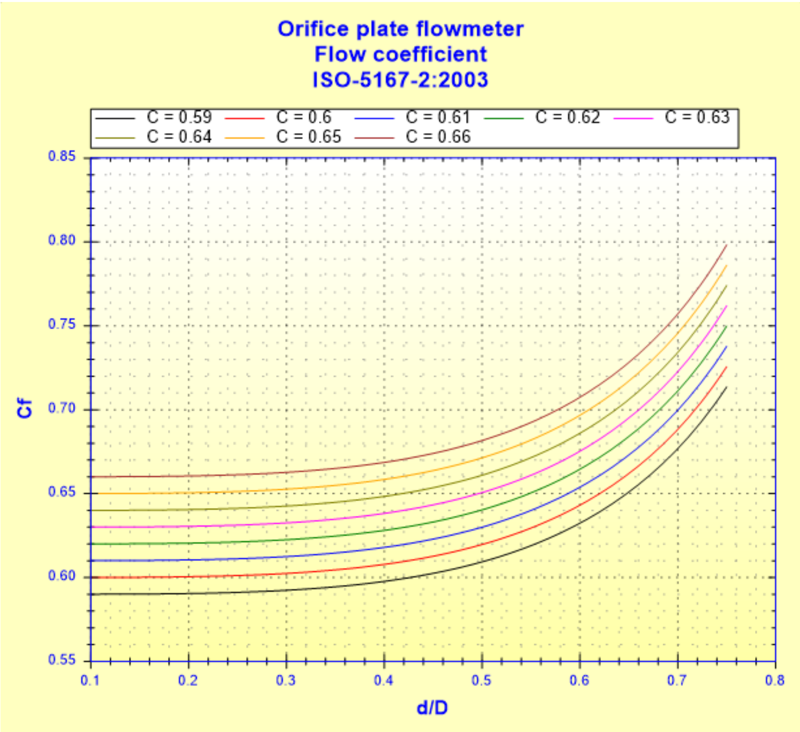
([1] §3.3.5)

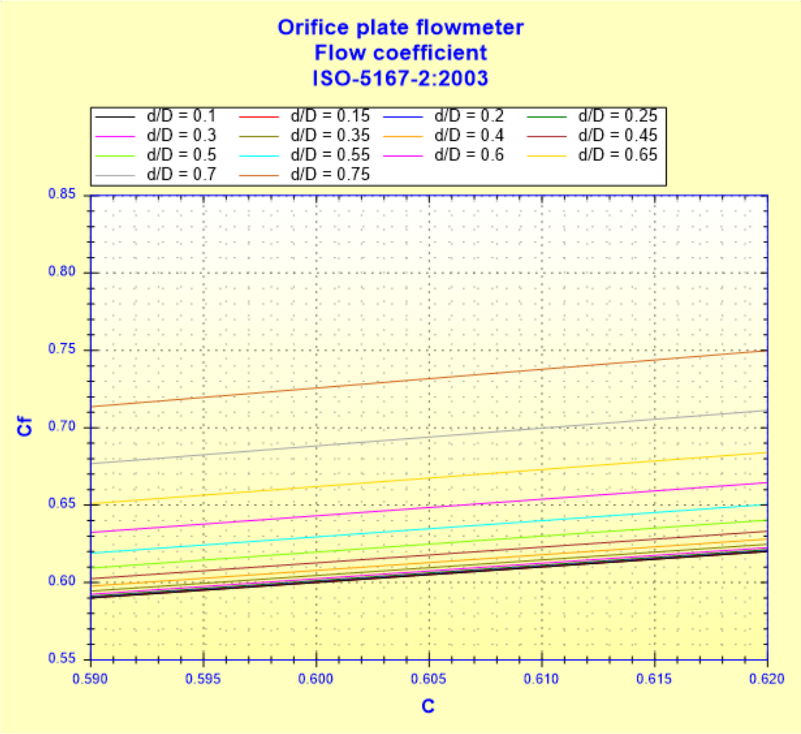


Flow coefficient:

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

([1] §3.3.5)





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

$$K = \left(\frac{\sqrt{1-\beta^4 \cdot \left(1-C^2\right)}}{C \cdot \beta^2} - 1 \right)^2$$

([2] § 5.4.3)

Net pressure loss (Pa):

$$\Delta\varpi = \frac{\sqrt{1-\beta^4 \cdot \left(1-C^2\right)} - C \cdot \beta^2}{\sqrt{1-\beta^4 \cdot \left(1-C^2\right)} + C \cdot \beta^2} \cdot \Delta p$$

([2] § 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:

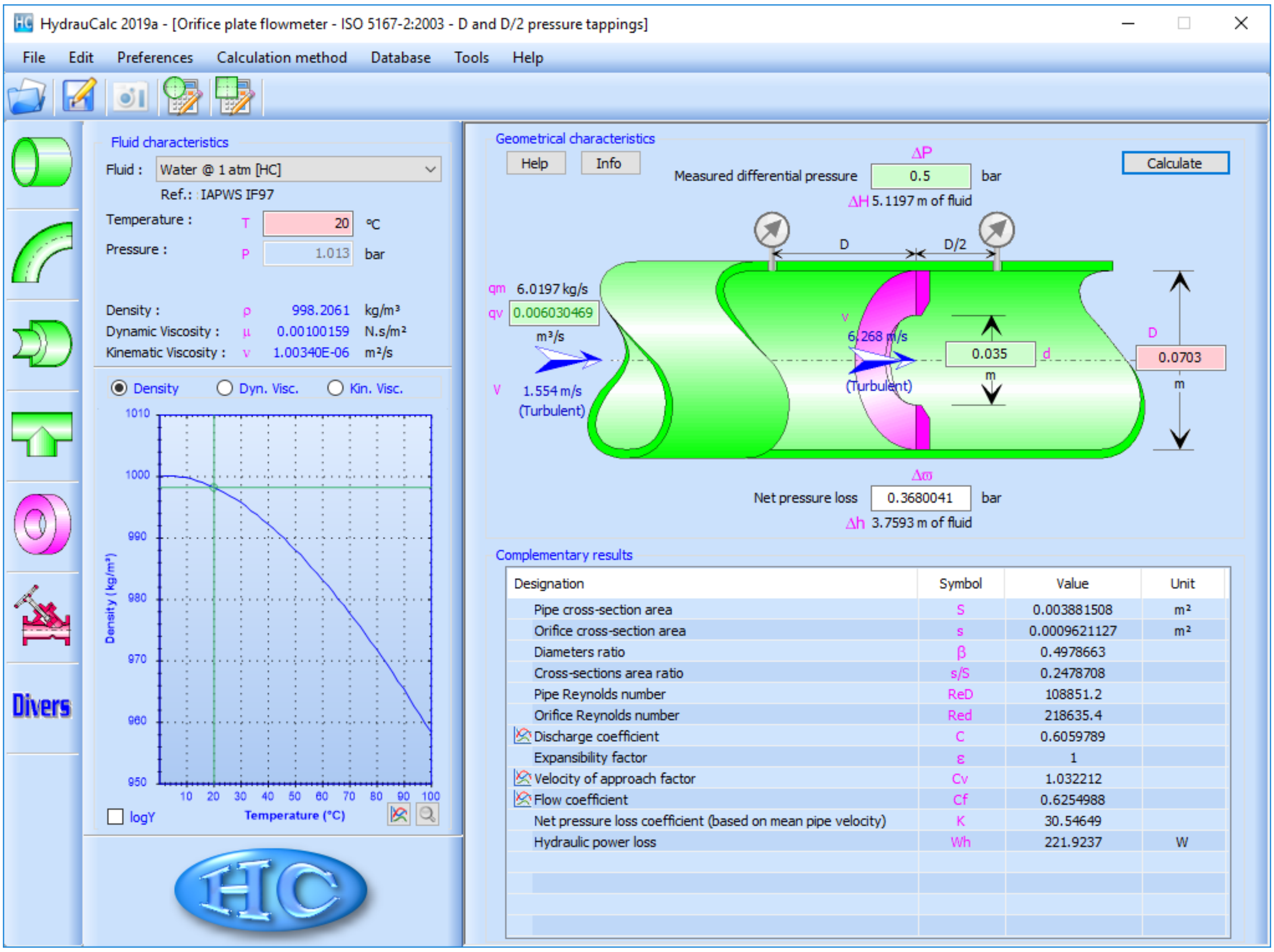
d	Orifice diameter (m)
D	Internal pipe diameter (m)
β	Diameter ratio ()
s	Orifice cross-sectional area (m²)

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 ()
$\Delta\varpi$	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:

- $d \geq 12.5$ mm
- $50 \text{ mm} \leq D \leq 1\,000 \text{ mm}$
- $0.1 \leq \beta \leq 0.75$
- $Re_D \geq 5\,000$ for $0.1 \leq \beta \leq 0.559$
- $Re_D \geq 16\,000\,\beta^2$ for $\beta > 0.559$

Example of application:



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