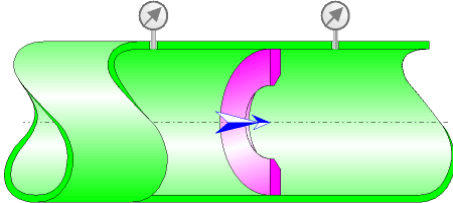




## Square-Edge Orifice Flowmeter D and D/2 pressure tapings (ISO 5167-2:2003)



### Model description:

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

### Model formulation:

Diameter ratio:

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

Orifice cross-sectional area (m<sup>2</sup>):

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

Pipe cross-sectional area (m<sup>2</sup>):

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

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:

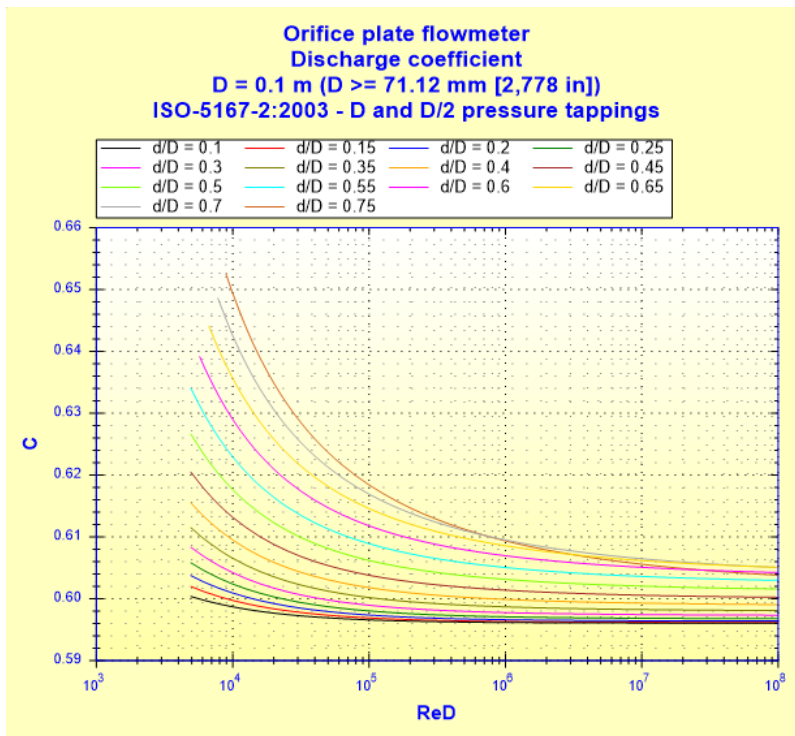
$$\text{Re}_D = \frac{V \cdot D}{\nu}$$

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)



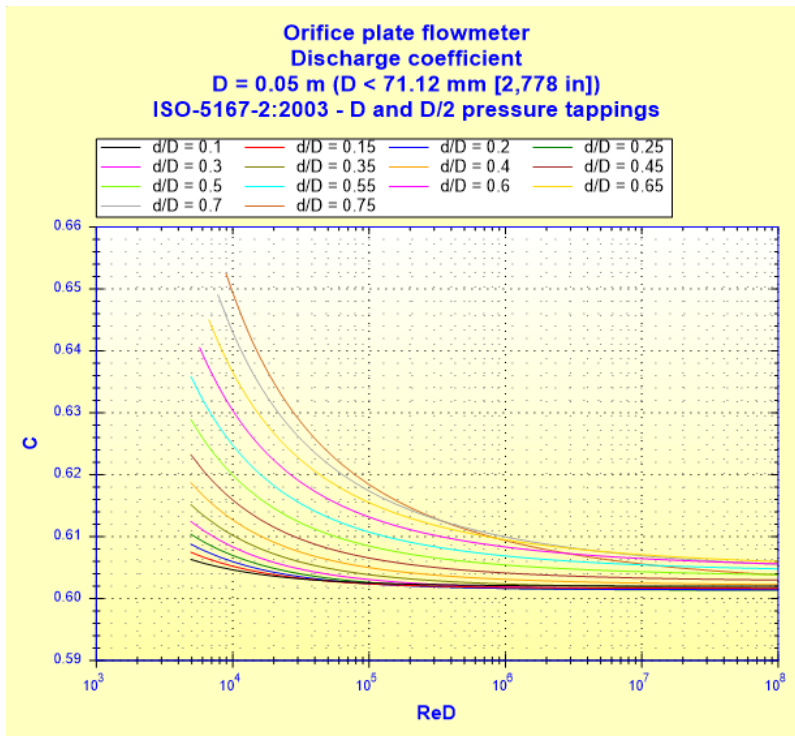
with  $D = 100 \text{ mm}$

■  $D < 71.12 \text{ mm (2.8 in)}$

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

([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:

$$L_1 = 1$$

$$L'_2 = 0.47$$

Expansibility factor:

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

Mass flow rate (kg/s):

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

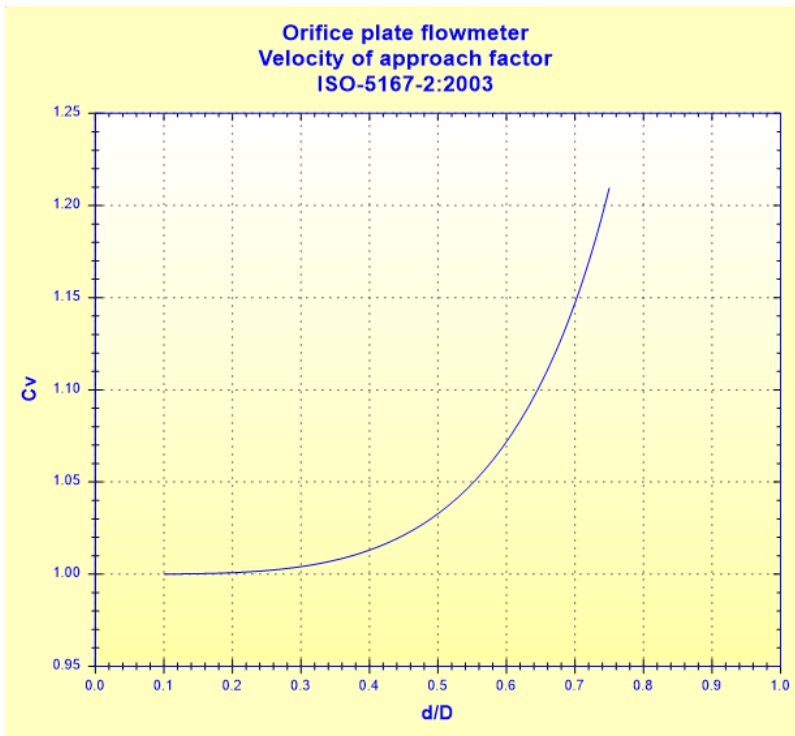
Volume flow rate ( $m^3/s$ ):

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

Velocity of approach factor:

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

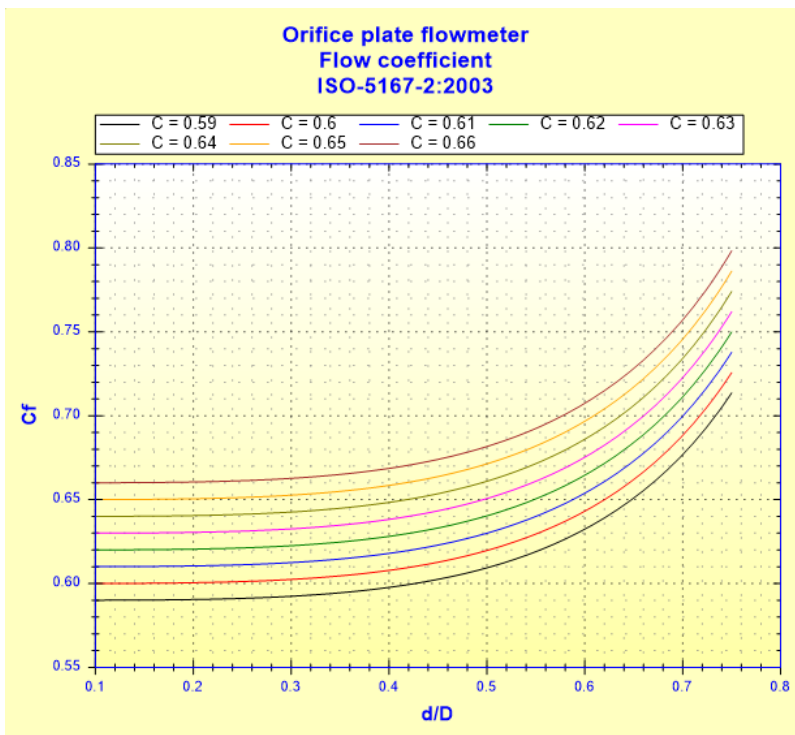
([1] §3.3.5)

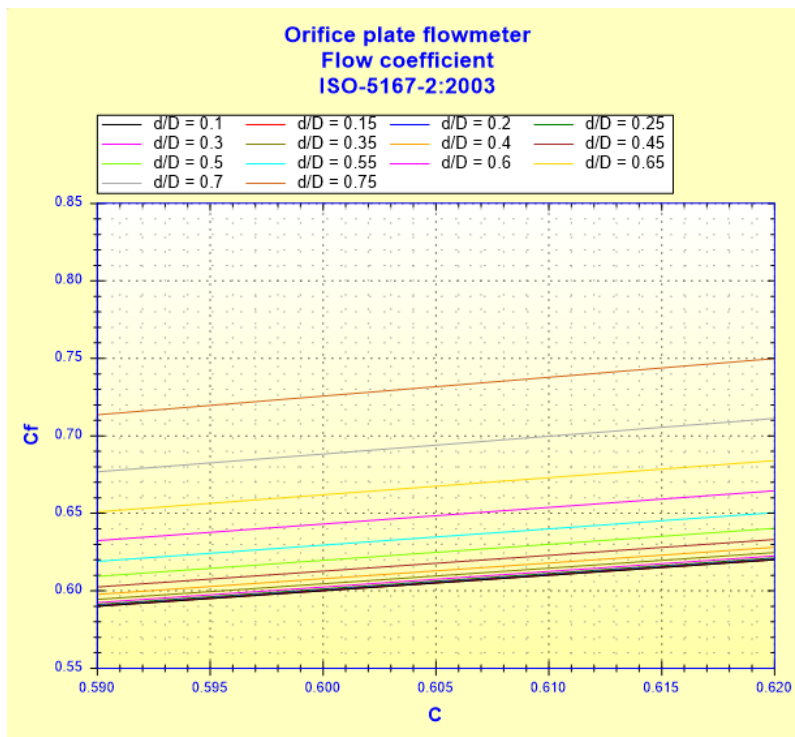


Flow coefficient:

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

([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)
- $\beta$  Diameter ratio ( )
- s Orifice cross-sectional area (m<sup>2</sup>)

S	Pipe cross-sectional area (m <sup>2</sup> )
q <sub>v</sub>	Volume flow rate (m <sup>3</sup> /s)
v	Mean velocity in orifice (m/s)
V	Mean velocity in pipe (m/s)
Re <sub>d</sub>	Reynolds number referred to orifice ( )
Re <sub>D</sub>	Reynolds number referred to pipe ( )
C	Discharge coefficient ( )
L <sub>1</sub>	Upstream relative pressure tapping spacing from the upstream face ( )
L' <sub>2</sub>	Downstream relative pressure tapping spacing from the downstream face ( )
ε	Expansibility factor ( )
q <sub>m</sub>	Mass flow rate (kg/s)
C <sub>v</sub>	Velocity of approach factor ( )
C <sub>f</sub>	Flow coefficient ( )
K	Pressure loss coefficient of orifice ( )
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 <sup>3</sup> )
ν	Fluid kinematic viscosity (m <sup>2</sup> /s)
g	Gravitational acceleration (m/s <sup>2</sup> )

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#### Limit of use:

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

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#### Example of application:

HydrauCalc 2019a - [Orifice plate flowmeter - ISO 5167-2:2003 - D and D/2 pressure tapings]

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Fluid characteristics  
 Fluid : Water @ 1 atm [HC]  
 Ref.: IAPWS IF97  
 Temperature : T 20 °C  
 Pressure : P 1.013 bar  
 Density :  $\rho$  998.2061 kg/m<sup>3</sup>  
 Dynamic Viscosity :  $\mu$  0.00100159 N.s/m<sup>2</sup>  
 Kinematic Viscosity :  $\nu$  1.00340E-06 m<sup>2</sup>/s  
 Density  Dyn. Visc.  Kn. Visc.

Geometrical characteristics  
 Measured differential pressure  $\Delta P$  0.5 bar  
 $\Delta H$  5.1197 m of fluid  
 Net pressure loss  $\Delta p$  0.3680041 bar  
 $\Delta h$  3.7593 m of fluid

Complementary results

Designation	Symbol	Value	Unit
Pipe cross-section area	S	0.003881508	m <sup>2</sup>
Orifice cross-section area	s	0.0009621127	m <sup>2</sup>
Diameters ratio	$\beta$	0.4978663	
Cross-sections area ratio	s/S	0.2478708	
Pipe Reynolds number	ReD	108851.2	
Orifice Reynolds number	Red	218635.4	
Discharge coefficient	C	0.6059789	
Expansibility factor	$\epsilon$	1	
Velocity of approach factor	Cv	1.032212	
Flow coefficient	Cf	0.6254988	
Net pressure loss coefficient (based on mean pipe velocity)	K	30.54649	
Hydraulic power loss	Wh	221.9237	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