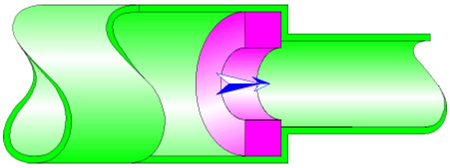
Thick-Edged Orifice (with Transition)
Circular Cross-Section
(IDELCHIK)



Model description:

This model of component calculates the minor head loss (pressure drop) generated by the flow in a thick-edged orifice installed in a straight pipe with transition. Moreover, the head loss due to friction of the fluid on the inner walls of the orifice is also taken into account in this component and is calculated with Darcy's formula.

The head loss by friction in the inlet and outlet piping is not taken into account in this component.

Model formulation:

Hydraulic diameter (m):

$$D_h = D_0$$

Major pipe cross-section area (m²):

$$F_1 = \pi \cdot \frac{D_1^{\,2}}{4}$$

Minor pipe cross-section area (m²):

$$F_2 = \pi \cdot \frac{D_2^{\,2}}{4}$$

Orifice cross-section area (m²):

$$F_0 = \pi \cdot \frac{D_0^{\,2}}{4}$$

Mean velocity in major pipe (m/s):

$$w_1 = \frac{Q}{F_1}$$

Mean velocity in minor pipe (m/s):

$$w_2 = \frac{Q}{F_2}$$

Mean velocity in orifice (m/s):

$$w_0 = \frac{Q}{F_0}$$

Mass flow rate (kg/s):

$$G = Q \cdot \rho$$

Reynolds number in major pipe:

$$\mathrm{Re}_1 = \frac{w_1 \cdot D_1}{\nu}$$

Reynolds number in minor pipe:

$$\mathrm{Re}_2 = \frac{w_2 \cdot D_2}{\nu}$$

Reynolds number in orifice:

$$\mathrm{Re}_0 = \frac{w_0 \cdot D_0}{\nu}$$

Relative roughness in orifice walls:

$$\overline{\Delta} = \frac{\Delta}{D_0}$$

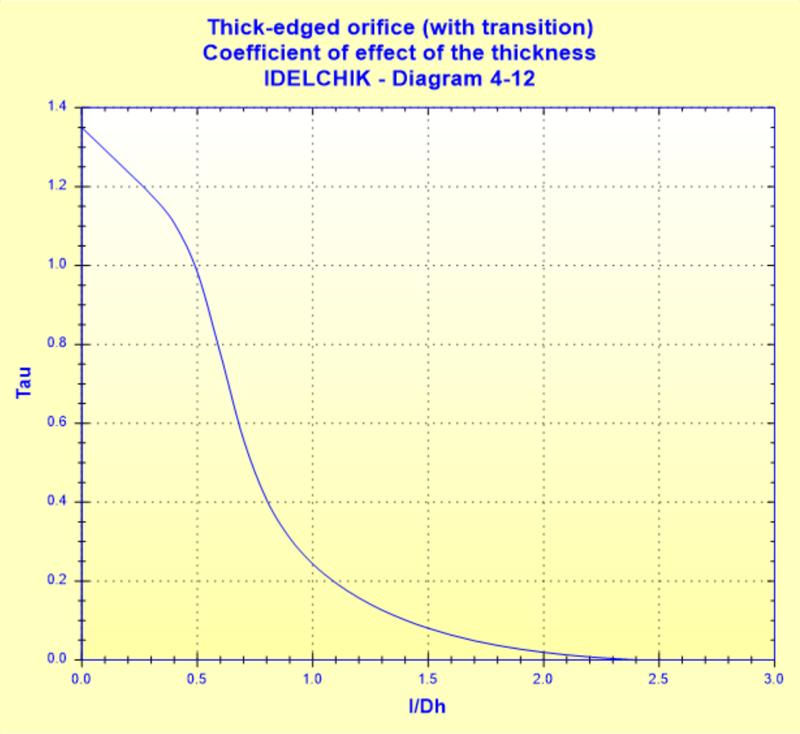
Coefficient of effect of the orifice thickness:

$$\tau = \left(2.4 - \frac{l}{D_h}\right) \cdot 10^{-\varphi\left(\frac{l}{D_h}\right)}$$

([1] diagram 4-12)

with:

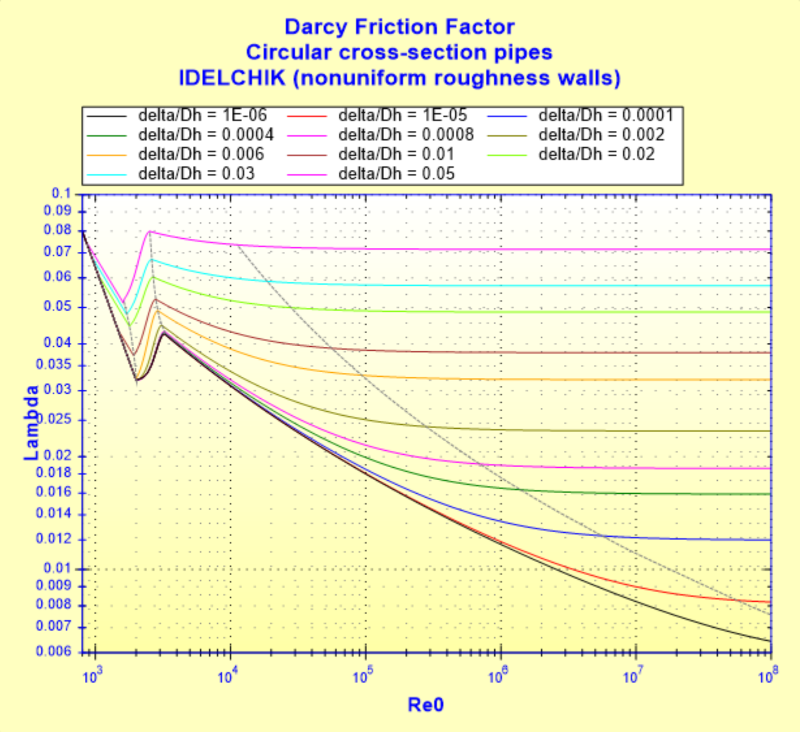
$$\varphi\left(\frac{l}{D_h}\right) = 0.25 + \frac{0.535 \cdot \left(\frac{l}{D_h}\right)^8}{0.05 \cdot \left(\frac{l}{D_h}\right)^7}$$



Darcy friction factor:

$$\lambda = f\left(\mathrm{Re}_0, \frac{\Delta}{D_h}\right)$$

See [Straight Pipe - Circular Cross-Section and Nonuniform Roughness Walls (IDELCHIK)]

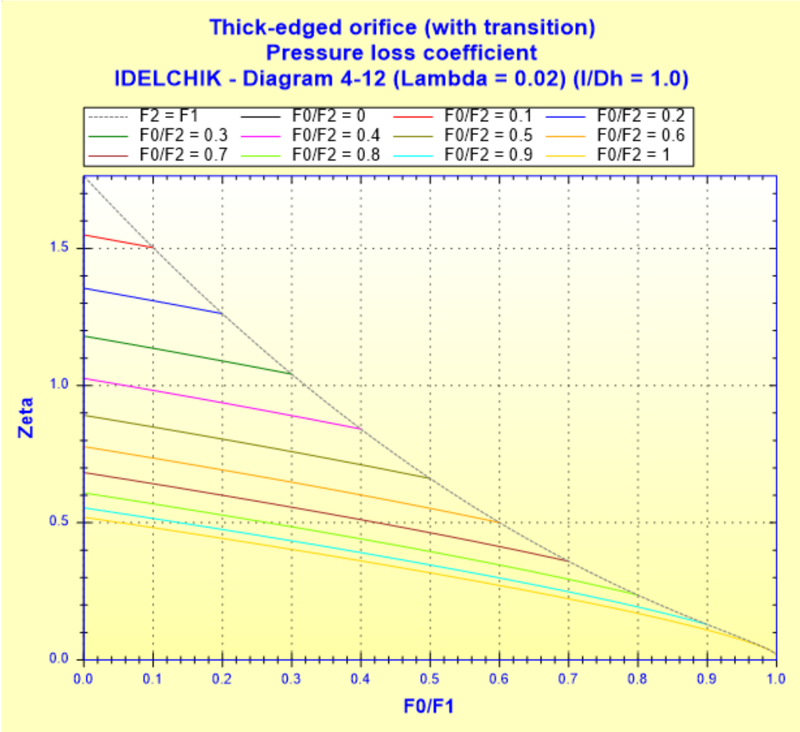


■ $\mathrm{Re}_0 \geq 10^5$

Local resistance coefficient:

$$\zeta = \left[0.5 \cdot \left(1 - \frac{F_0}{F_1}\right)^{0.75} + \left(1 - \frac{F_0}{F_2}\right)^{2} + \tau \cdot \left(1 - \frac{F_0}{F_1}\right)^{0.375} \cdot \left(1 - \frac{F_0}{F_2}\right) + \lambda \cdot \frac{l}{D_h}\right]$$

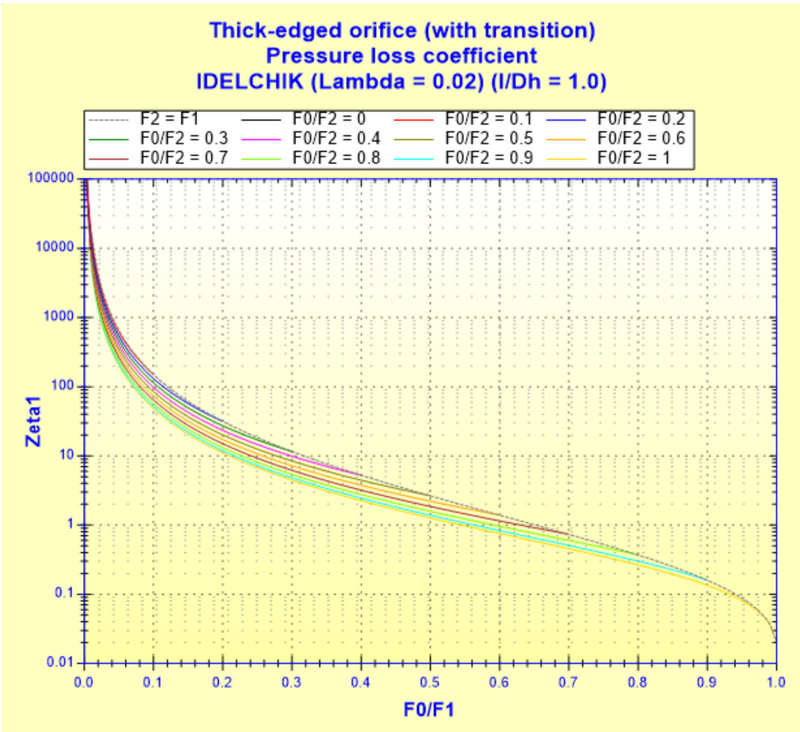
([1] diagram 4-12)



(with λ = 0.02 et l/D_h = 1)

Pressure loss coefficient (based on the major pipe velocity):

$$\zeta_1 = \zeta \cdot \left(\frac{F_1}{F_0}\right)^2$$



(with λ = 0.02 et l/D_h = 1)

■ $Re_0 < 10^5$

Quadratic local resistance coefficient:

$$\zeta_{quad} = \left[0.5 \cdot \left(1 - \frac{F_0}{F_1}\right)^{0.75} + \left(1 - \frac{F_0}{F_2}\right)^2 + \tau \cdot \left(1 - \frac{F_0}{F_1}\right)^{0.375} \cdot \left(1 - \frac{F_0}{F_2}\right) + \lambda \cdot \frac{l}{D_h}\right]$$

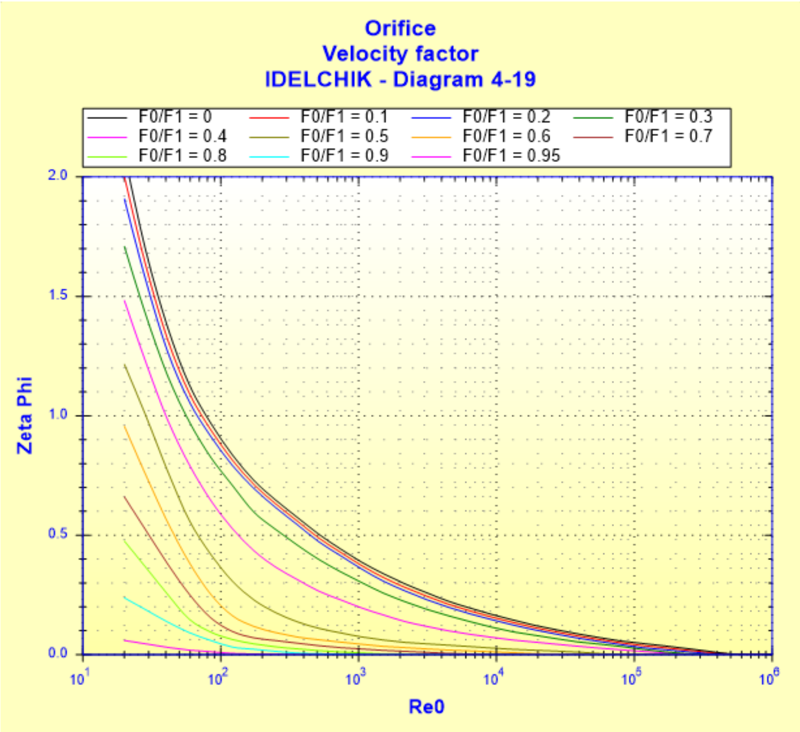
([1] diagram 4-12)

$$\zeta_{1quad} = \zeta_{quad} \cdot \left(\frac{F_1}{F_0}\right)^2$$

Velocity factor:

$$\zeta_{\varphi} = f\left(\mathrm{Re}_0, \frac{F_0}{F_1}\right)$$

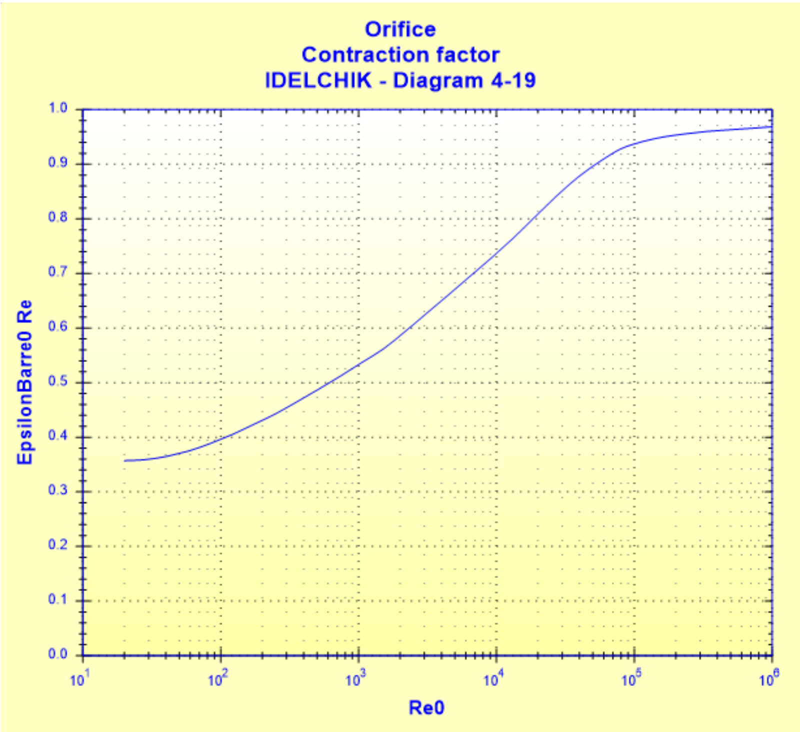
([1] diagram 4-19)



Contraction factor:

$$\bar{\varepsilon}_{0\mathrm{Re}} = f(\mathrm{Re}_0)$$

([1] diagram 4-19)



Pressure loss coefficient (based on the major pipe velocity):

- $30 < Re_0 < 10^5$

$$\zeta_1 = \zeta_\varphi \cdot \left(\frac{F_1}{F_0}\right)^2 + \bar{\varepsilon}_{0\mathrm{Re}} \cdot \zeta_{1quad}$$

([1] diagram 4-19)

- $10 < Re_0 \le 30$

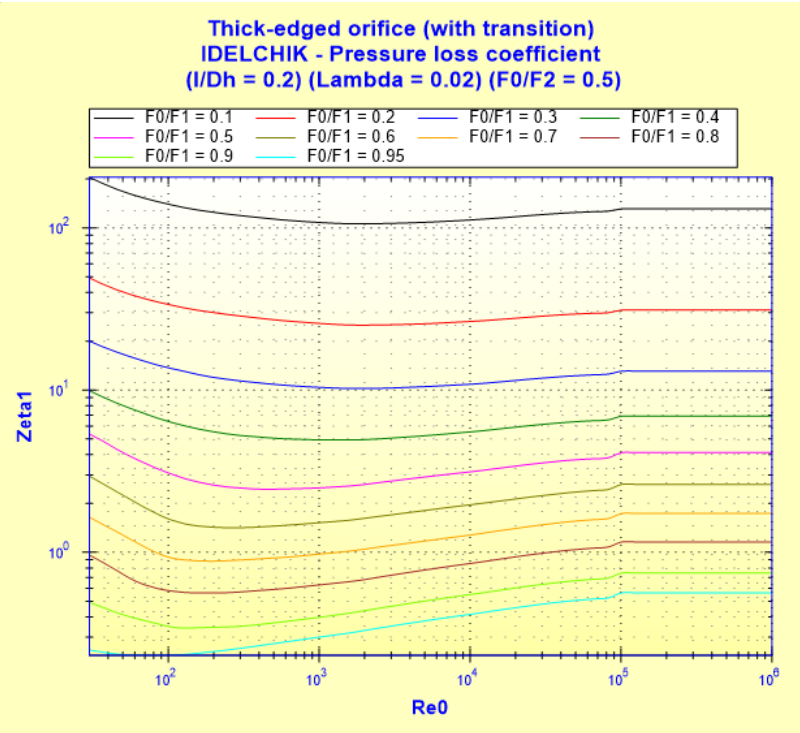
$$\zeta_1 = \frac{33}{\mathrm{Re}_0} \cdot \left(\frac{F_1}{F_0}\right)^2 + \bar{\varepsilon}_{0\mathrm{Re}} \cdot \zeta_{1quad}$$

([1] diagram 4-19)

- $Re_0 \le 10$

$$\zeta_1 = \frac{33}{\mathrm{Re}_0} \cdot \left(\frac{F_1}{F_0}\right)^2$$

([1] diagram 4-19)



(with $l/D_h = 0.2$, $\lambda = 0.02$ and $F_0/F_2 = 0.5$)

Total pressure loss (Pa):

$$\Delta P = \zeta_1 \cdot \frac{\rho \cdot w_1^2}{2}$$

Total head loss of fluid (m):

$$\Delta H = \zeta_1 \cdot \frac{w_1^2}{2 \cdot g}$$

Hydraulic power loss (W):

$$Wh = \Delta P \cdot Q$$

Symbols, Definitions, SI Units:

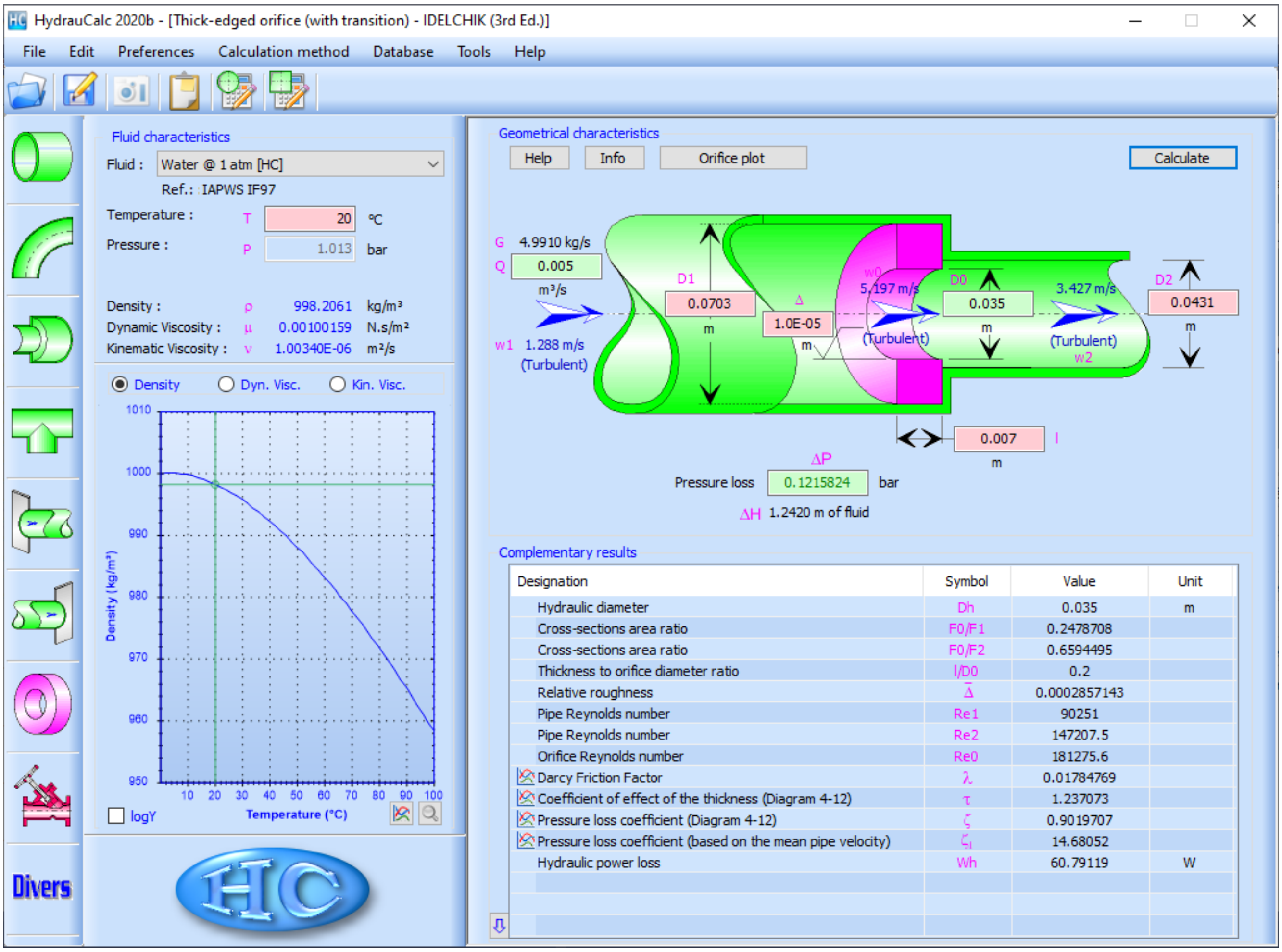
D_h Hydraulic diameter (m)

D_1	Major pipe internal diameter (m)
D_2	Minor pipe internal diameter (m)
D_0	Orifice diameter (m)
F_1	Major pipe cross-sectional area (m^2)
F_2	Minor pipe cross-sectional area (m^2)
F_0	Orifice cross-sectional area (m^2)
Q	Volume flow rate (m^3/s)
G	Mass flow rate (kg/s)
w_1	Mean velocity in major pipe (m/s)
w_2	Mean velocity in minor pipe (m/s)
w_0	Mean velocity in orifice (m/s)
Re_1	Reynolds number in major pipe ()
Re_2	Reynolds number in minor pipe ()
Re_0	Reynolds number in orifice ()
Δ	Absolute roughness of orifice walls (m)
$\overline{\Delta}$	Relative roughness of orifice walls ()
l	Orifice thickness (m)
τ	Coefficient of effect of the orifice thickness ()
λ	Darcy friction coefficient in orifice ()
ζ	Local resistance coefficient (based on the orifice velocity) ()
ζ_{quad}	Quadratic local resistance coefficient (based on the orifice velocity) ()
ζ_{1quad}	Quadratic local resistance coefficient (based on the major pipe velocity) ()
ζ_{φ}	Velocity factor ()
$\overline{\varepsilon}_{0Re}$	Contraction factor ()
ζ_1	Pressure loss coefficient (based on the major pipe velocity) ()
ΔP	Total pressure loss (Pa)
ΔH	Total head loss of fluid (m)
Wh	Hydraulic power loss (W)
ρ	Fluid density (kg/m^3)
ν	Fluid kinematic viscosity (m^2/s)
g	Gravitational acceleration (m/s^2)

Validity range:

- any flow regime: laminar and turbulent
- stabilized flow upstream of the orifice
- thickness to orifice diameter ratio (l/D_0) greater than 0.015

Example of application:



References:

[1] Handbook of Hydraulic Resistance, 3rd Edition, I.E. Idelchik

[2] Идельчик.И.Е.Справочник по гидравлическим сопротивлениям.1992 (original document in Russian language)

Note: The formulation used for the calculation of the coefficient $\varphi\left(\frac{l}{D_h}\right)$ is that of the original reference document [2] which differs from that of the translated document [1]