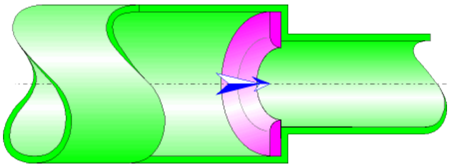
Round-Edged Orifice (with Transition)
Circular Cross-Section
(IDELCHIK)



Model description:

This model of component calculates the minor head loss (pressure drop) generated by the flow in a round-edged orifice installed in a straight pipe with transition.

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:

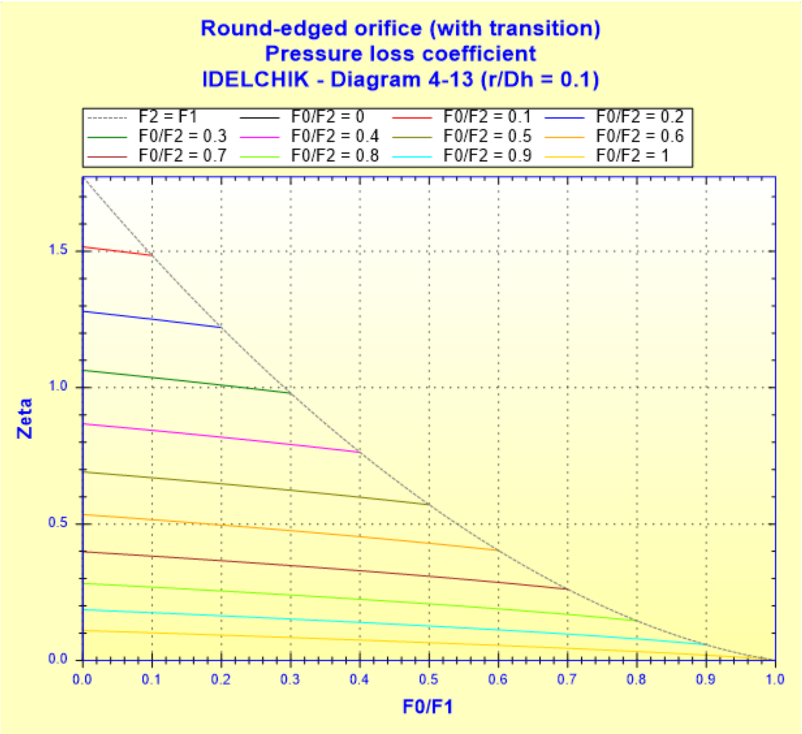
$$\mathrm{Re}_0 = \frac{w_0 \cdot D_0}{\nu}$$

■ $\mathrm{Re}_0 \geq 10^5$

Local resistance coefficient:

$$\zeta = \zeta' \cdot \left(1 - \frac{F_0}{F_1}\right)^{0.75} + \left(1 - \frac{F_0}{F_2}\right)^2 + 2 \cdot \sqrt{\zeta'} \cdot \left(1 - \frac{F_0}{F_1}\right)^{0.375} \cdot \left(1 - \frac{F_0}{F_2}\right)$$

([2] diagram 4-13)



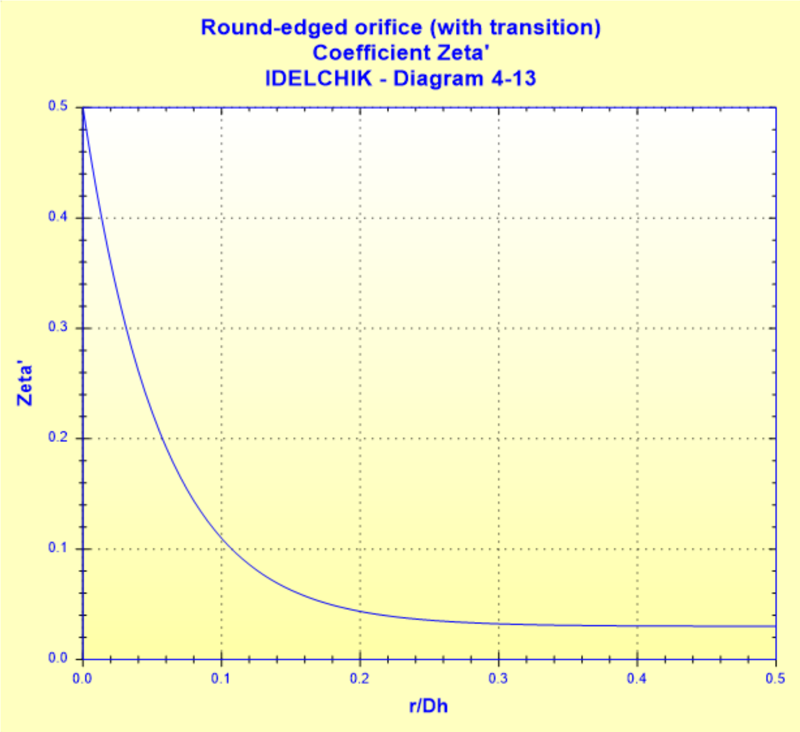
(with $r/D_h = 0.1$)

with :

Coefficient of effect of the round:

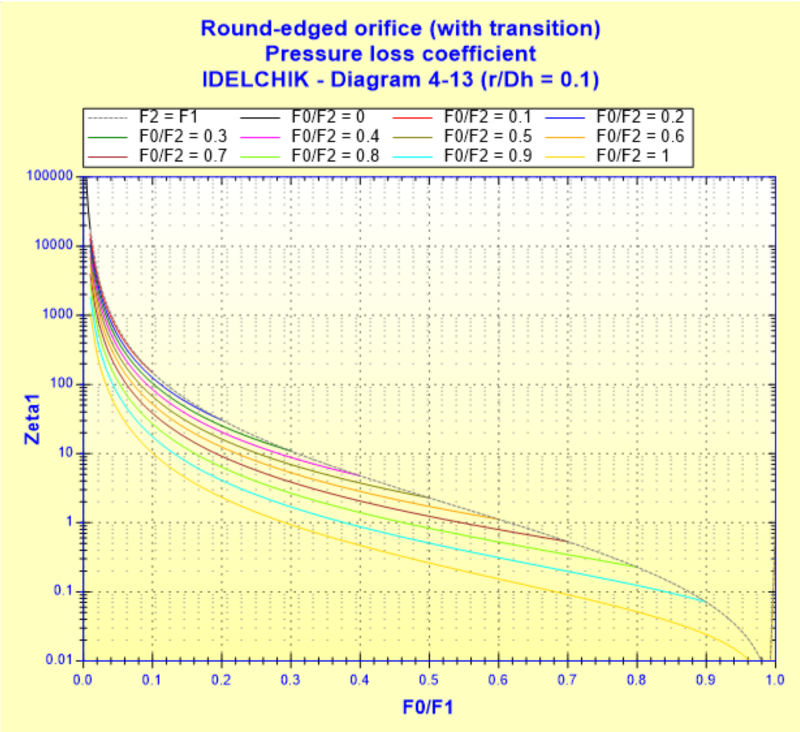
$$\zeta' = 0.03 + 0.47 \cdot 10^{-7.7 \cdot \frac{r}{D_h}}$$

([1] diagram 4-13)



Coefficient de perte de pression (basé sur la vitesse dans le grand tuyau) :

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



(with $r/D_h = 0.1$)

■ $Re_0 < 10^5$

Quadratic local resistance coefficient:

$$\zeta_{quad} = \left[\zeta' \cdot \left(1-\frac{F_0}{F_1}\right)^{0.75} + \left(1-\frac{F_0}{F_2}\right)^2 + 2\cdot\sqrt{\zeta'}\cdot\left(1-\frac{F_0}{F_1}\right)^{0.375} \cdot \left(1-\frac{F_0}{F_2}\right) \right]$$

([2] diagram 4-13)

with :

$$\zeta' = 0.03 + 0.47 \cdot 10^{-7.7\cdot\frac{r}{D_h}}$$

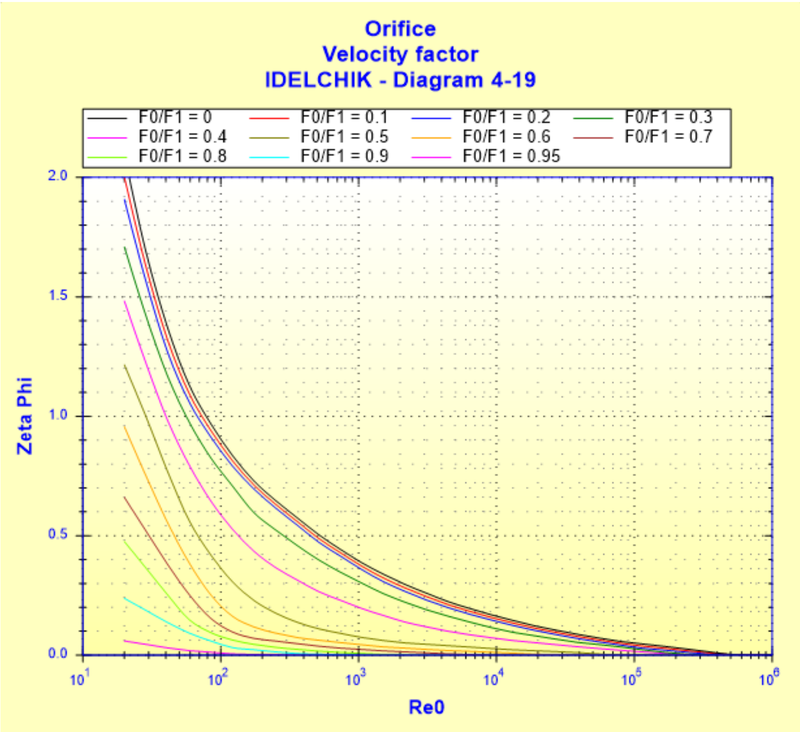
([1] diagram 4-13)

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

Velocity factor:

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

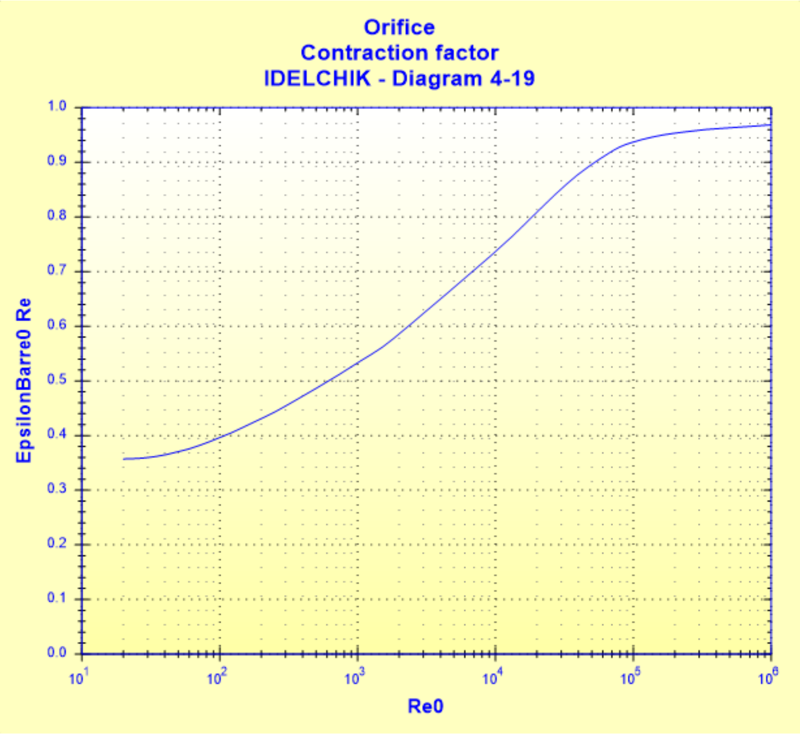
([1] diagram 4-19)



Contraction factor:

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

([1] diagram 4-19)



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

- $30 < Re_0 < 10^5$

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

([1] diagram 4-19)

- $10 < Re_0 \le 30$

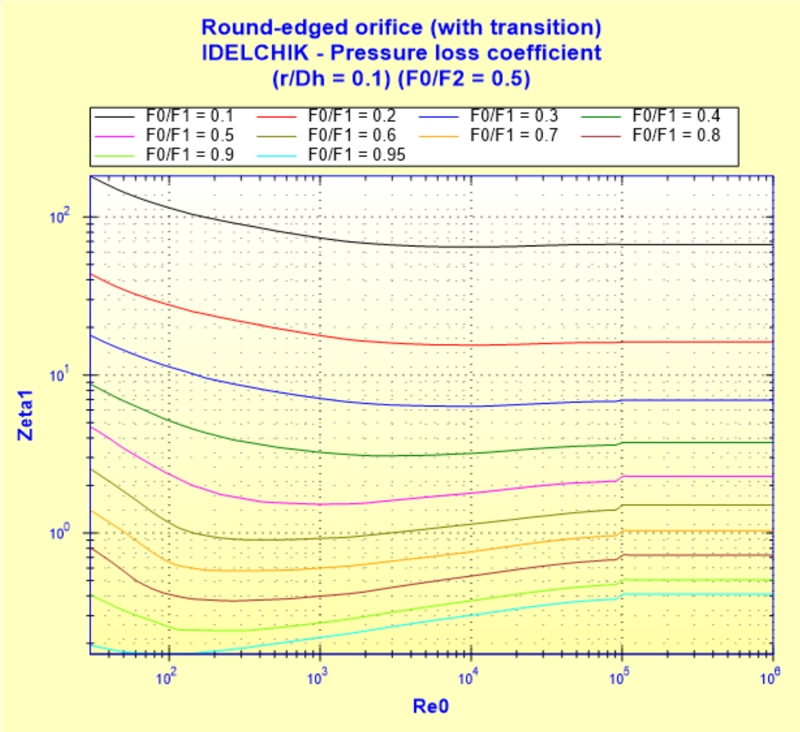
$$\zeta_1 = \frac{33}{Re_0} \cdot \left(\frac{F_1}{F_0}\right)^2 + \bar{\varepsilon}_{0Re} \cdot \zeta_{1quad}$$

([1] diagram 4-19)

- $Re_0 \le 10$

$$\zeta_1 = \frac{33}{Re_0} \cdot \left(\frac{F_1}{F_0}\right)^2$$

([1] diagram 4-19)



(with r/ D_h = 0.1 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:

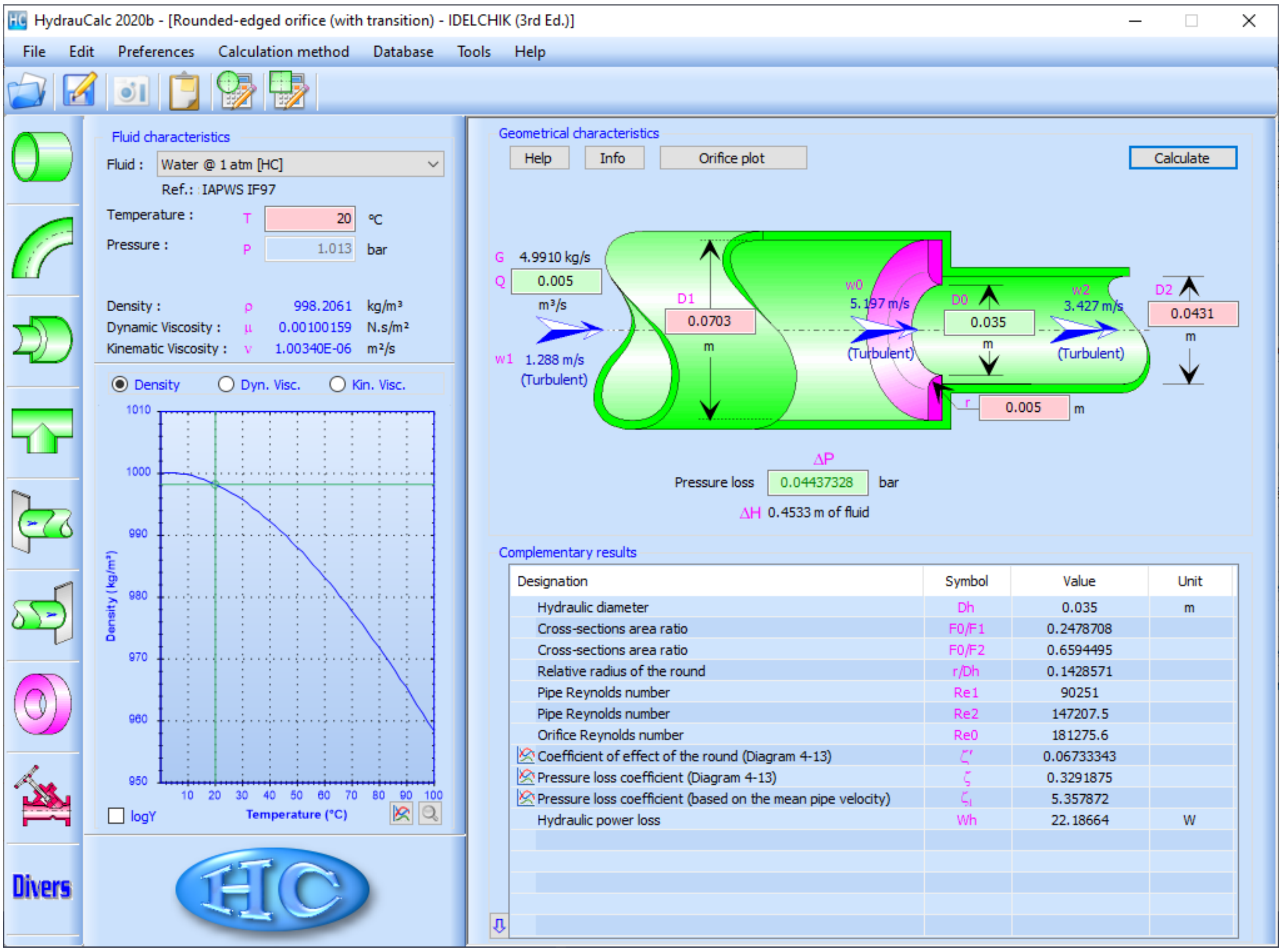
D_h	Hydraulic diameter (m)
D_1	Major pipe internal diameter (m)
D_2	Minor pipe internal diameter (m)
D_0	Orifice diameter (m)
F_1	Major pipe cross-sectional area (m^2)
F_2	Minor pipe cross-sectional area (m^2)
F_0	Orifice cross-sectional area (m^2)
Q	Volume flow rate (m^3/s)
G	Mass flow rate (kg/s)
w_1	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 ()

r	Radius of the round (m)
ζ'	Coefficient of effect of the round ()
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/m³)
ν	Fluid kinematic viscosity (m²/s)
g	Gravitational acceleration (m/s²)

Validity range:

- any flow regime: laminar and turbulent
- stabilized flow upstream of the orifice
- round radius less than the radius difference ($r < (D_1/2 - D_0/2)$)

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 local resistance coefficients ζ and ζ_{quad} is that of the original reference document [2] which differs from that of the translated document [1]

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