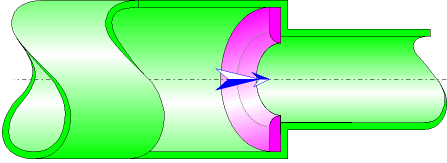




Round-Edged Orifice (with Transition) Circular Cross-Section (IDELCHIK)



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:

$$Re_1 = \frac{w_1 \cdot D_1}{\nu}$$

Reynolds number in minor pipe:

$$Re_2 = \frac{w_2 \cdot D_2}{\nu}$$

Reynolds number in orifice:

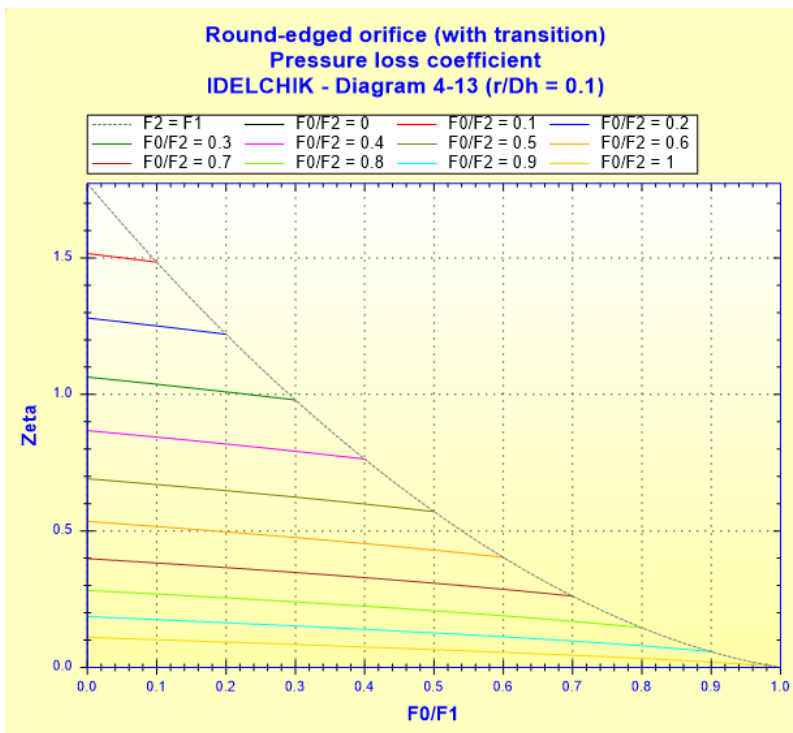
$$Re_0 = \frac{w_0 \cdot D_0}{\nu}$$

■ $Re_0 \geq 10^5$

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)

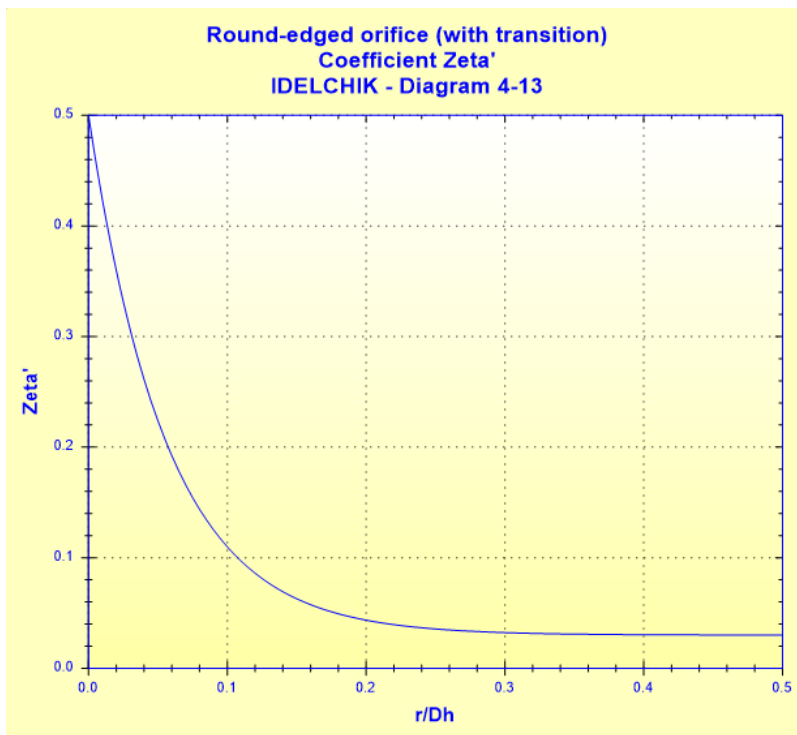


(with r/ Dh = 0.1)

with :

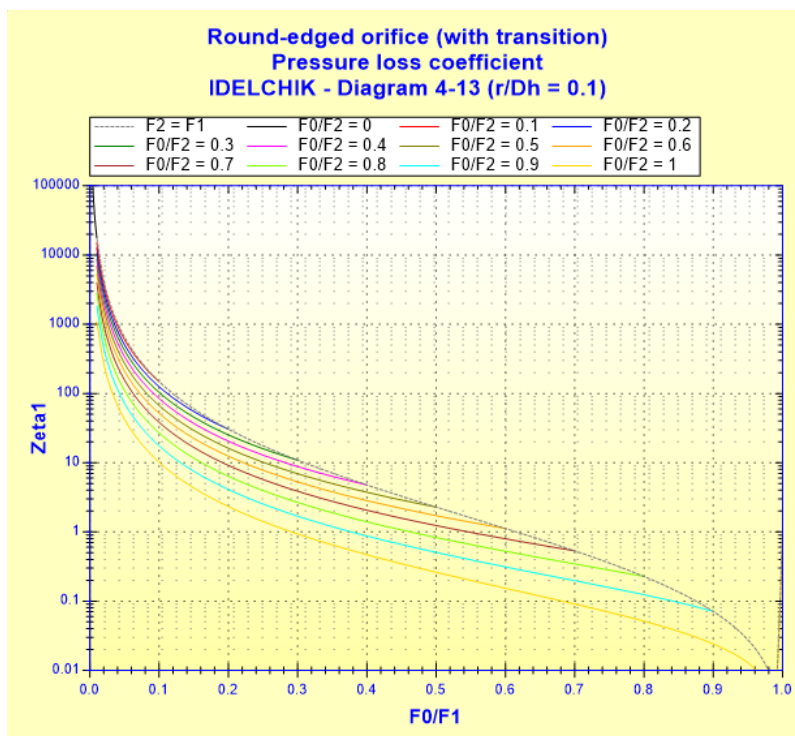
Coefficient of effect of the round:

$$\zeta' = 0.03 + 0.47 \cdot 10^{-7.7 \cdot \frac{r}{D_h}} \quad ([1] \text{ diagram 4-13})$$



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/ Dh = 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 :

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

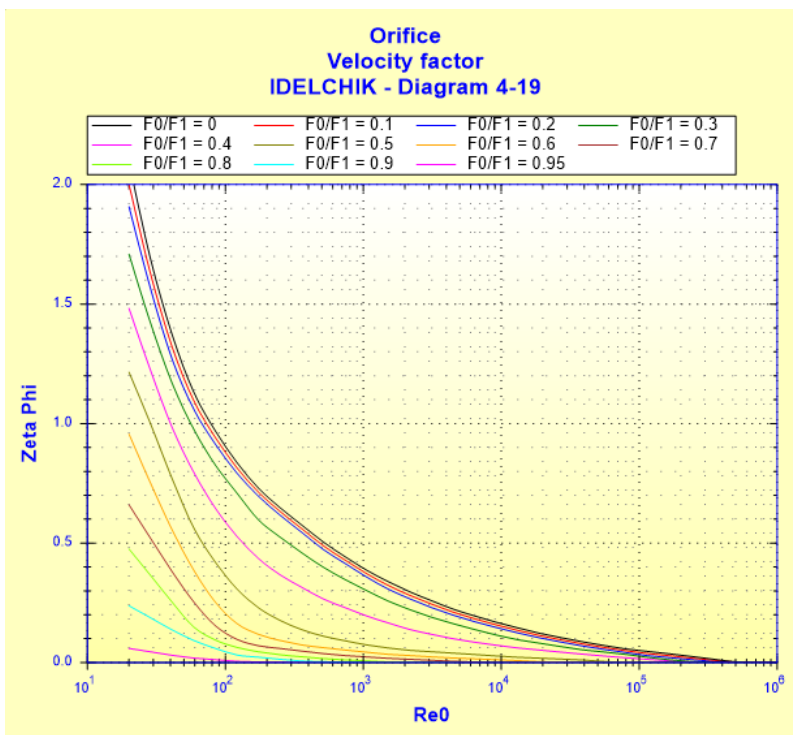
([1] diagram 4-13)

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

Velocity factor:

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

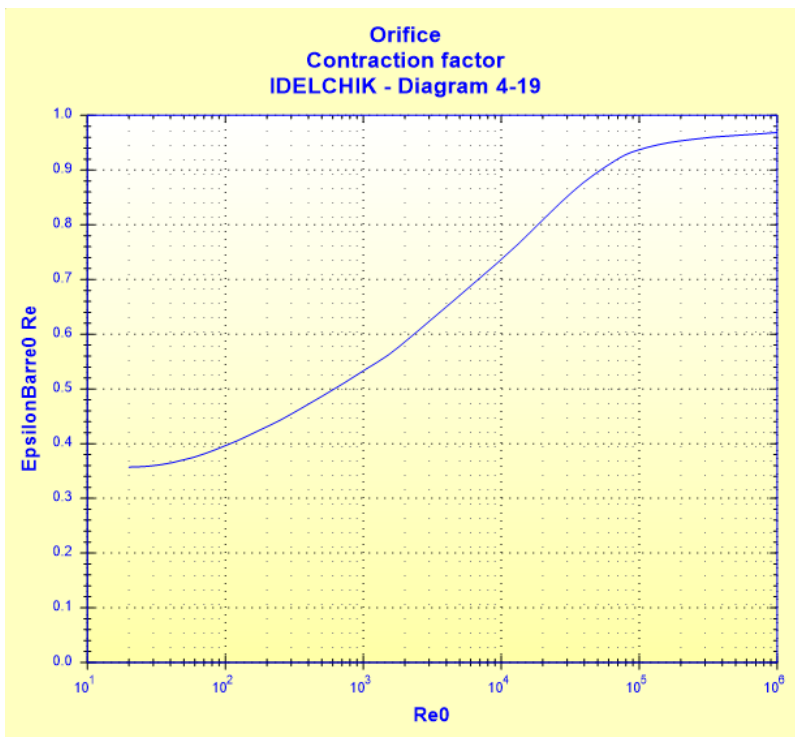
([1] diagram 4-19)



Contraction factor:

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

([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)

- $10 < Re_0 \leq 30$

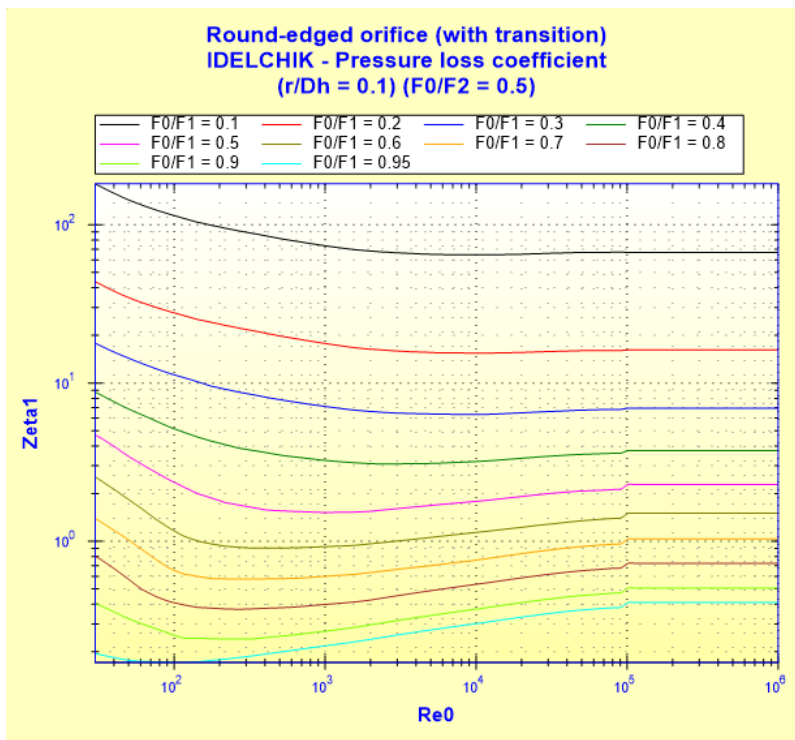
$$\zeta_1 = \frac{33}{Re_0} \cdot \left(\frac{F_1}{F_0}\right)^2 + \bar{\varepsilon}_{0Re} \cdot \zeta_{1quad}$$

([1] diagram 4-19)

- $Re_0 \leq 10$

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

([1] diagram 4-19)



(with $r/D_h = 0.1$ and $F_0/F_2 = 0.5$)

= 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_{lquad}	Quadratic local resistance coefficient (based on the major pipe velocity) ()
ζ_{φ}	Velocity factor ()
ε_{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
- round radius less than the radius difference ($r < (D_1/2 - D_0/2)$)

Example of application:

The screenshot shows the HydraulCalc 2020b software interface. The main window is titled "HydraulCalc 2020b - [Rounded-edged orifice (with transition) - IDELCHIK (3rd Ed.)]". The interface is divided into several panels:

- Fluid characteristics:**
 - Fluid: Water @ 1 atm [HC]
 - Ref.: IAPWS IF97
 - Temperature: T = 20 °C
 - Pressure: P = 1.013 bar
 - Density: $\rho = 998.2061$ kg/m³
 - Dynamic Viscosity: $\mu = 0.00100159$ N.s/m²
 - Kinematic Viscosity: $\nu = 1.00340E-06$ m²/s
 - Graph: Density (kg/m³) vs Temperature (°C) showing a decreasing trend from 1000 at 0°C to approximately 950 at 100°C.
- Geometrical characteristics:**
 - Help, Info, Orifice plot, Calculate buttons.
 - Diagram of a rounded-edged orifice with dimensions:
 - Major diameter: $D_1 = 0.0703$ m
 - Minor diameter: $D_0 = 0.035$ m
 - Round radius: $r = 0.005$ m
 - Flow velocity upstream: $w_1 = 1.288$ m/s (Turbulent)
 - Flow velocity through orifice: $w_0 = 5.197$ m/s (Turbulent)
 - Flow velocity downstream: $w_2 = 3.427$ m/s (Turbulent)
 - Mass flow rate: $G = 4.9910$ kg/s, $Q = 0.005$ m³/s
 - Pressure loss: $\Delta P = 0.04437328$ bar
 - Head loss: $\Delta H = 0.4533$ m of fluid
- Complementary results:**

Designation	Symbol	Value	Unit
Hydraulic diameter	D_h	0.035	m
Cross-sections area ratio	F_0/F_1	0.2478708	
Cross-sections area ratio	F_0/F_2	0.6594495	
Relative radius of the round	r/D_h	0.1428571	
Pipe Reynolds number	Re_1	90251	
Pipe Reynolds number	Re_2	147207.5	
Orifice Reynolds number	Re_0	181275.6	
Coefficient of effect of the round (Diagram 4-13)	ζ'	0.06733343	
Pressure loss coefficient (Diagram 4-13)	ζ	0.3291875	
Pressure loss coefficient (based on the mean pipe velocity)	ζ_1	5.357872	
Hydraulic power loss	Wh	22.18664	W

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]

HydrauCalc

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