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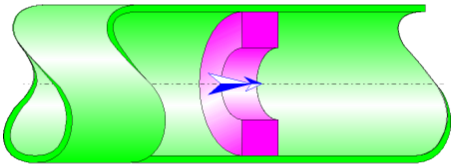
Thick-Edged Orifice
Circular Cross-Section
(IDELCHIK)



Model description:

This model of component calculates the minor head loss (pressure drop) generated by the flow in a thick-edged orifice. 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):

$$D_h = D_0$$

Pipe cross-section area (m²):

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

Orifice cross-section area (m²):

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

Mean velocity in pipe (m/s):

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

Mean velocity in orifice (m/s):

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

Mass flow rate (kg/s):

$$G = Q \cdot \rho$$

Reynolds number in pipe:

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

Reynolds number in orifice:

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

Relative roughness in orifice walls:

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

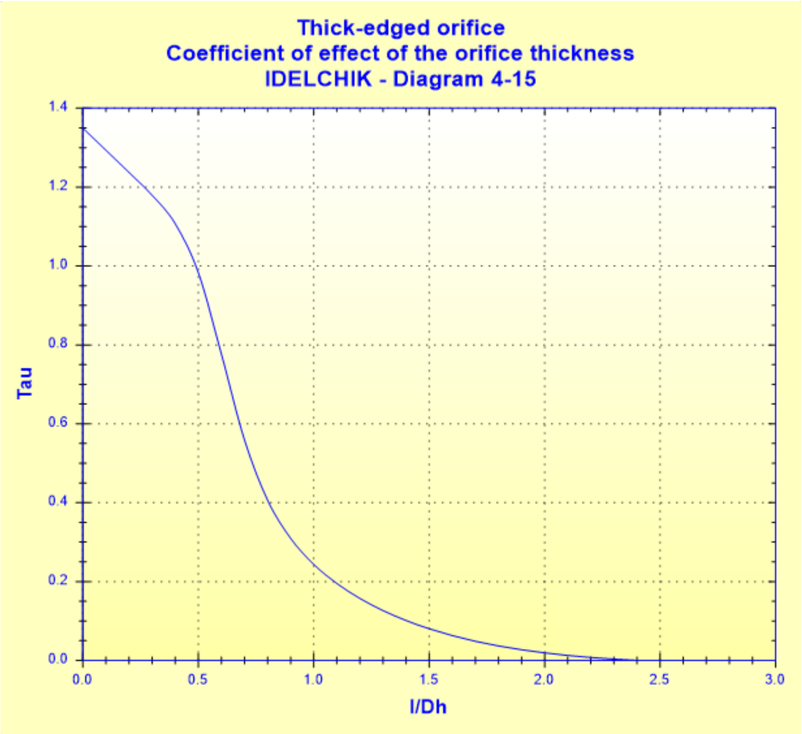
Coefficient of effect of the orifice thickness:

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

([1] diagram 4.15)

with:

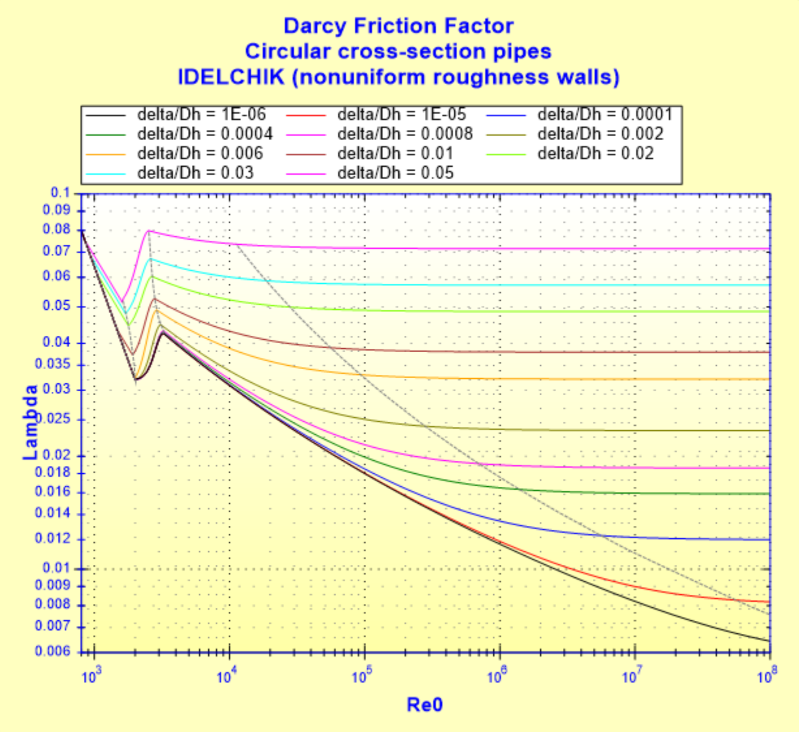
$$\varphi\left(\frac{l}{D_h}\right) = \frac{0.25 + 0.535 \cdot \left(\frac{l}{D_h}\right)^8}{0.05 + \left(\frac{l}{D_h}\right)^7}$$



Darcy friction factor:

$$\lambda = f\left(Re_0, \frac{\Delta}{D_h}\right)$$

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

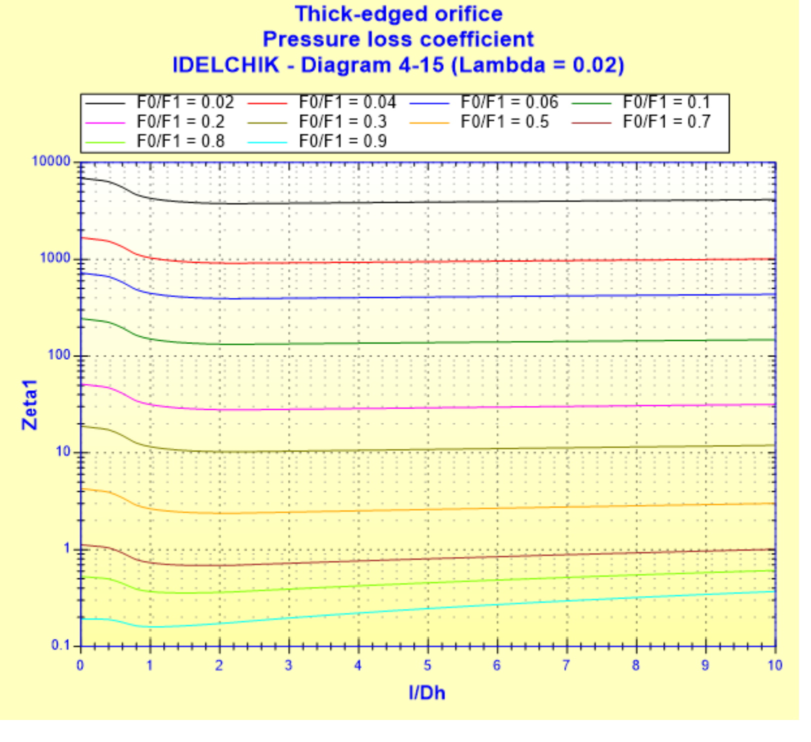


Pressure loss coefficient (based on the mean pipe velocity):

- $Re_0 \geq 10^5$

$$\zeta_1 = \left[0.5 \cdot \left(1 - \frac{F_0}{F_1}\right)^{0.75} + \tau \cdot \left(1 - \frac{F_0}{F_1}\right)^{1.375} + \left(1 - \frac{F_0}{F_1}\right)^2 + \lambda \cdot \frac{l}{D_h}\right] \cdot \left(\frac{F_1}{F_0}\right)^2$$

([1] diagram 4.15)



([1] diagram 4.15 with λ = 0.02)

- $Re_0 \leq 10^5$

Quadratic pressure loss coefficient:

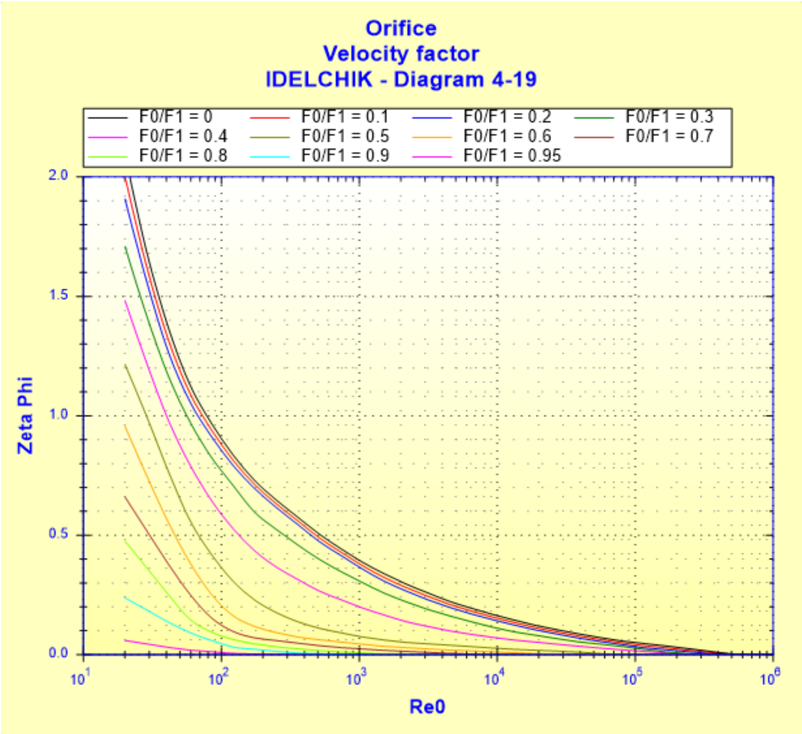
$$\zeta_{1quad} = \left[0.5 \cdot \left(1 - \frac{F_0}{F_1}\right)^{0.75} + \tau \cdot \left(1 - \frac{F_0}{F_1}\right)^{1.375} + \left(1 - \frac{F_0}{F_1}\right)^{2} + \lambda \cdot \frac{l}{D_h}\right] \cdot \left(\frac{F_1}{F_0}\right)^{2}$$

([1] diagram 4.15)

Velocity factor:

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

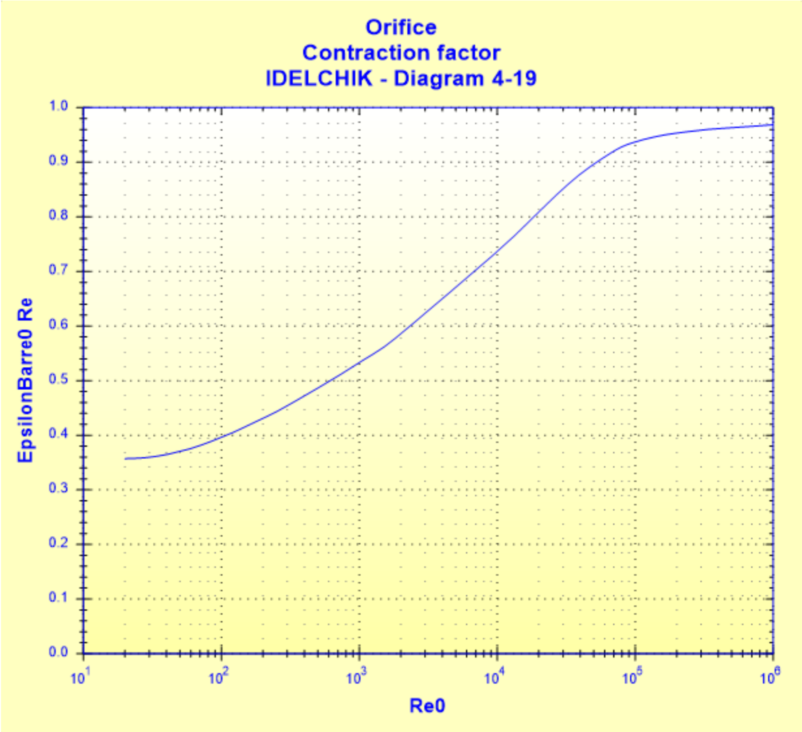
([1] diagram 4.19)



Contraction factor:

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

([1] diagram 4.19)



Pressure loss coefficient (based on the mean 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)

- $10 < Re_0 \leq 30$

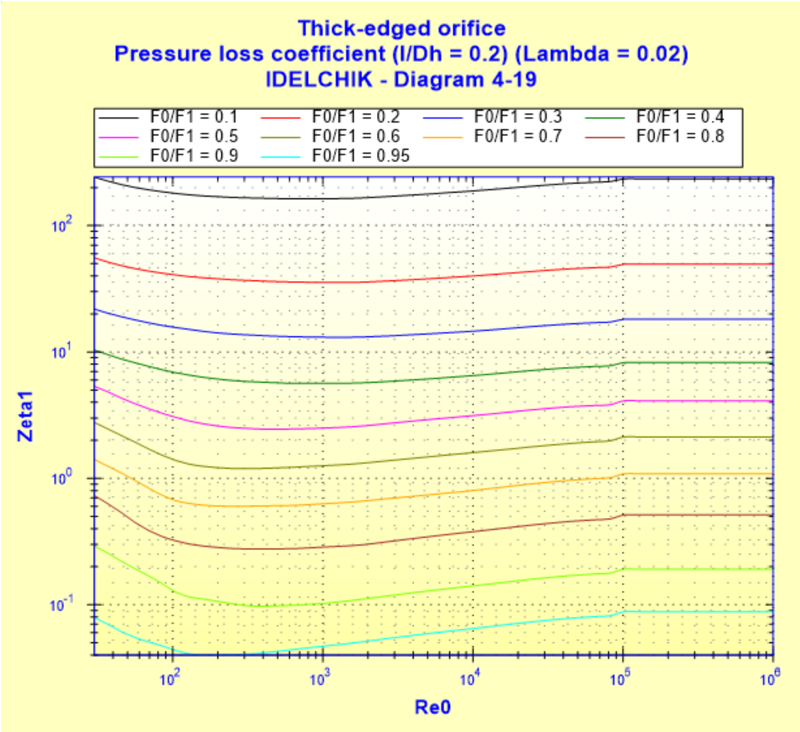
$$\zeta_1 = \frac{33}{Re_0} \cdot \left(\frac{F_1}{F_0}\right)^2 + \bar{\varepsilon}_{0Re} \cdot \zeta_{1quad}$$

([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)



([1] diagram 4.19 with l/Dh = 0.2 and λ = 0.02)

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):

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

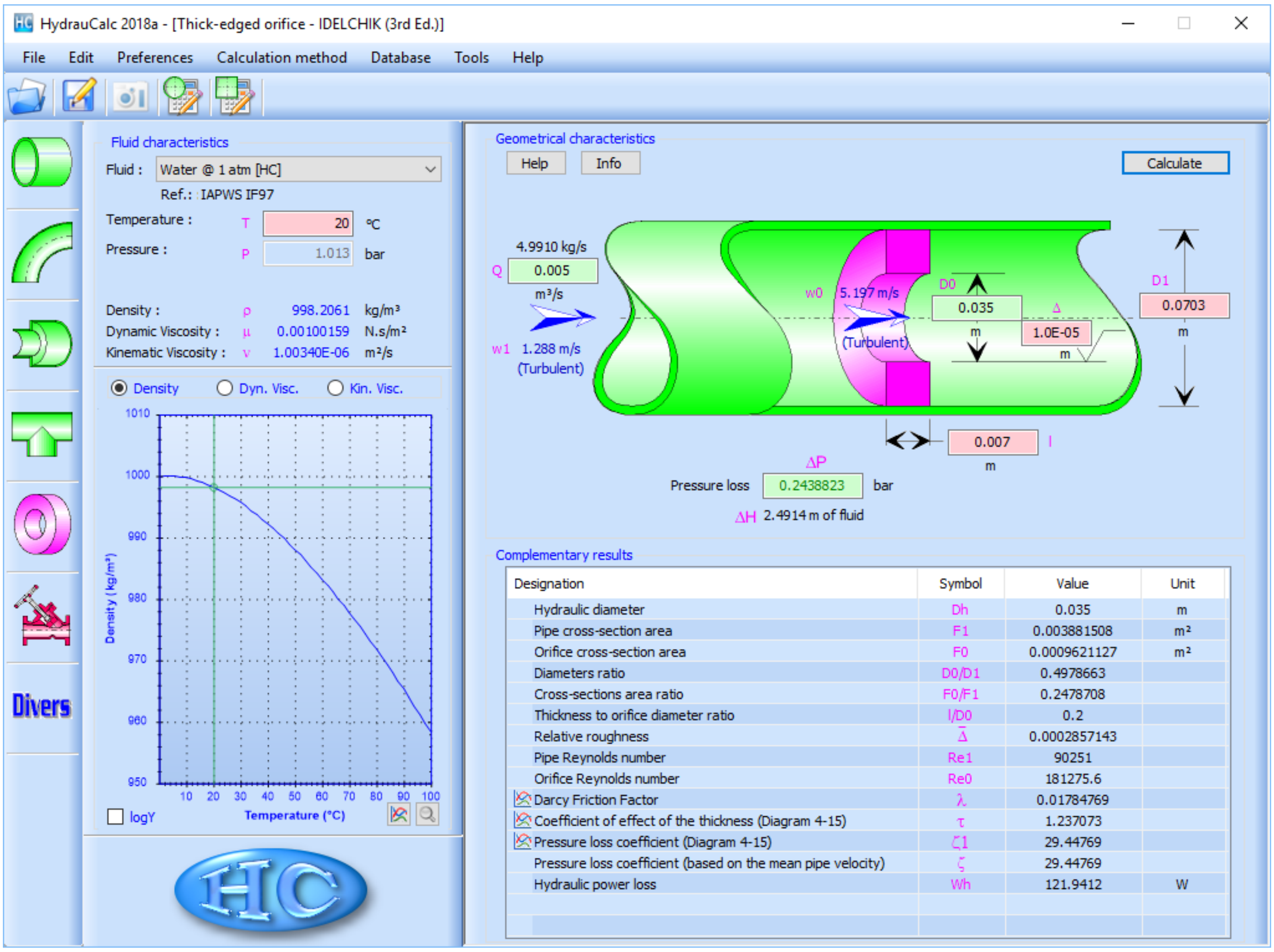
Symbols, Definitions, SI Units:

D_h	Hydraulic diameter (m)
D_1	Pipe internal diameter (m)
D_0	Orifice diameter (m)
F_1	Pipe cross-sectional area (m²)
F_0	Orifice cross-sectional area (m²)
Q	Volume flow rate (m³/s)
G	Mass flow rate (kg/s)
w_1	Mean velocity in pipe (m/s)
w_0	Mean velocity in orifice (m/s)
l	Orifice thickness (m)
Re_1	Reynolds number in pipe ()
Re_0	Reynolds number in orifice ()
Δ	Absolute roughness of orifice walls (m)
$\overline{\Delta}$	Relative roughness of orifice walls ()
τ	Coefficient of effect of the orifice thickness ()
λ	Darcy friction coefficient in orifice ()
ζ_{1quad}	Quadratic pressure loss coefficient determined as Re = 10^5 ()
ζ_φ	Velocity factor ()
$\overline{\varepsilon}_{0Re}$	Contraction factor ()
ζ_1	Pressure loss coefficient (based on the mean 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
- thickness to orifice diameter ratio (l/D_0) greater than 0.015

Example of application:



Designation	Symbol	Value	Unit
Hydraulic diameter	Dh	0.035	m
Pipe cross-section area	F1	0.003881508	m²
Orifice cross-section area	F0	0.0009621127	m²
Diameters ratio	D0/D1	0.4978663	
Cross-sections area ratio	F0/F1	0.2478708	
Thickness to orifice diameter ratio	l/D0	0.2	
Relative roughness	$\bar{\Delta}$	0.0002857143	
Pipe Reynolds number	Re1	90251	
Orifice Reynolds number	Re0	181275.6	
Darcy Friction Factor	λ	0.01784769	
Coefficient of effect of the thickness (Diagram 4-15)	τ	1.237073	
Pressure loss coefficient (Diagram 4-15)	ζ1	29.44769	
Pressure loss coefficient (based on the mean pipe velocity)	ζ	29.44769	
Hydraulic power loss	Wh	121.9412	W

References:

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