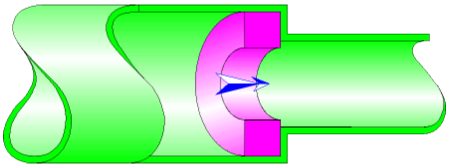
Thick-Edged Orifice (with Transition)
Circular Cross-Section
(Pipe Flow - Guide)



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, when the thickness of the orifice is greater than 1.4 times the diameter of the orifice, the head loss due to friction in the orifice is also taken into account because it becomes significant.

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

Model formulation:

Ratio of orifice to major pipe diameters:

$$\beta = \frac{d_o}{d_1}$$

Major pipe cross-sectional area (m²):

$$A_1 = \pi \cdot \frac{d_1^2}{4}$$

Minor pipe cross-sectional area (m²):

$$A_2 = \pi \cdot \frac{d_2^2}{4}$$

Orifice cross-sectional area (m²):

$$A_o = \pi \cdot \frac{d_o^2}{4}$$

Major pipe velocity (m/s):

$$V_1 = \frac{Q}{A_1}$$

Minor pipe velocity (m/s):

$$V_2 = \frac{Q}{A_2}$$

Orifice velocity (m/s):

$$V_o = \frac{Q}{A_o}$$

Mass flow rate (kg/s):

$$G = Q \cdot \rho$$

Reynolds number in major pipe:

$$N_{\mathrm{Re}1} = \frac{V_1 \cdot d_1}{\nu}$$

Reynolds number in minor pipe:

$$N_{\mathrm{Re}2} = \frac{V_2 \cdot d_2}{\nu}$$

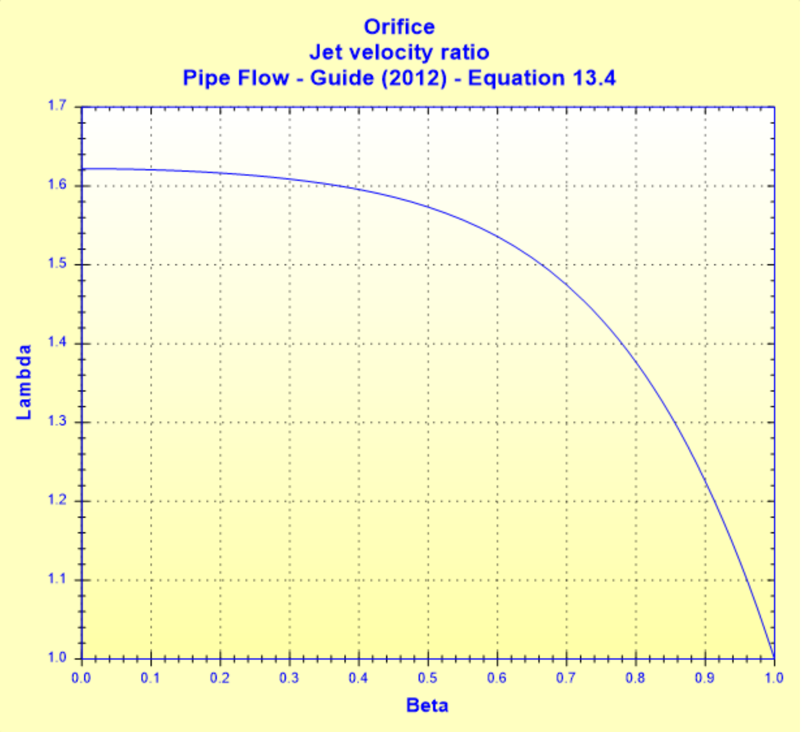
Reynolds number in orifice:

$$N_{\mathrm{Re}0} = \frac{V_o \cdot d_o}{\nu}$$

Jet velocity ratio:

$$\lambda = 1 + 0.622 \cdot \left(1 - 0.215\beta^2 - 0.785\beta^5\right)$$

([1] equation 13.4)



Velocity in vena contracta:

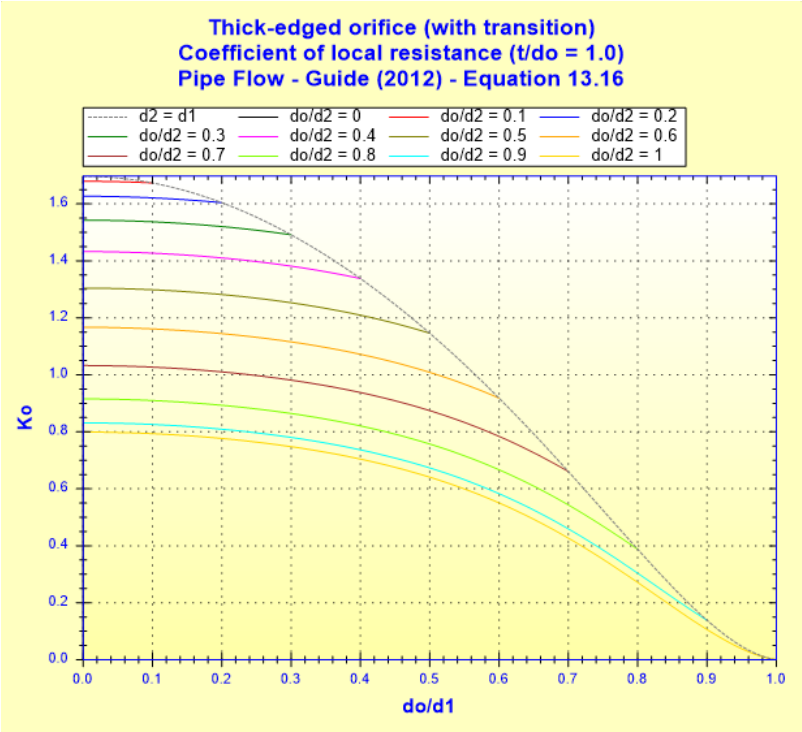
$$V_c = V_0 \cdot \lambda$$

Coefficient of local resistance ($NRe_o \geq 10^4$):

- Thickness to orifice diameter ratio (t/d_o) $\leq$ 1.4:

$$K_o = 0.0696 \cdot (1-\beta^5) \cdot \lambda^2 + C_{th} \cdot \left(\lambda - \left(\frac{d_0}{d_2}\right)^2\right)^2 + (1-C_{th}) \cdot \left[(\lambda-1)^2 + \left(1-\left(\frac{d_0}{d_2}\right)^2\right)^2\right]$$

([1] equation 13.16)

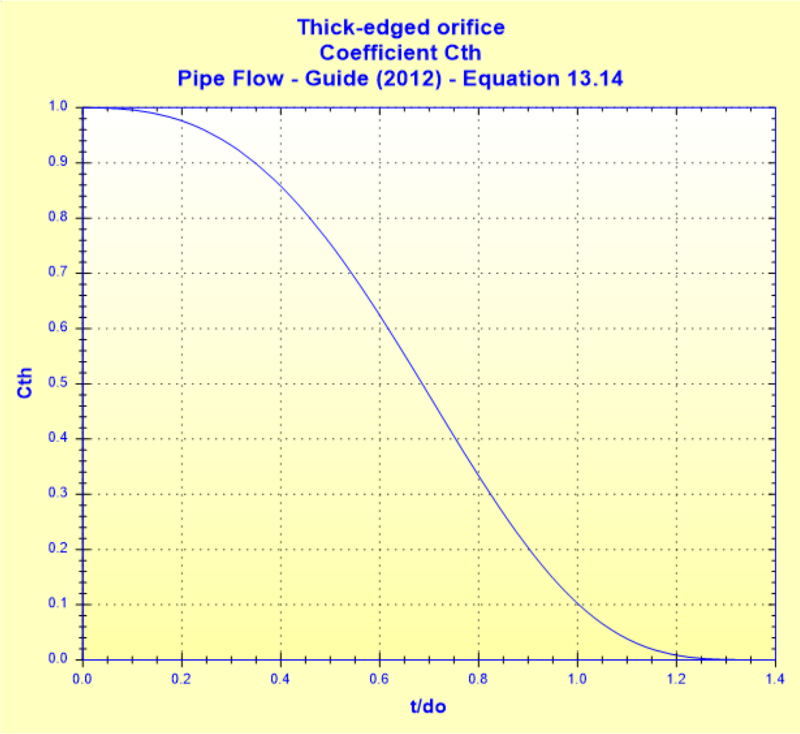


(with $t/d_0 = 1$)

with:

$$C_{th} = \left[1 - 0.50 \cdot \left(\frac{t}{1.4 d_o}\right)^{2.5} - 0.50 \cdot \left(\frac{t}{1.4 d_o}\right)^{3}\right]^{4.5}$$

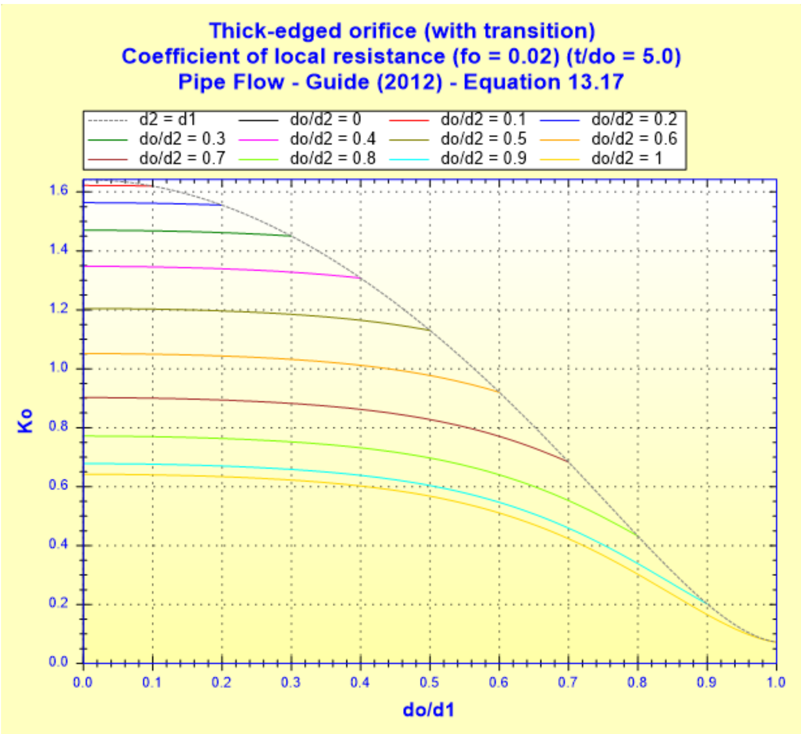
([1] equation 13.14)



■ Thickness to orifice diameter ratio $(t/d_o) > 1.4$:

$$K_o = 0.0696 \cdot (1-\beta^5) \cdot \lambda^2 + (\lambda - 1)^2 + \left[1 - \left(\frac{d_0}{d_2}\right)^2\right]^2 + f_o \cdot \left(\frac{t}{d_o} - 1.4\right)$$

([1] equation 13.17)

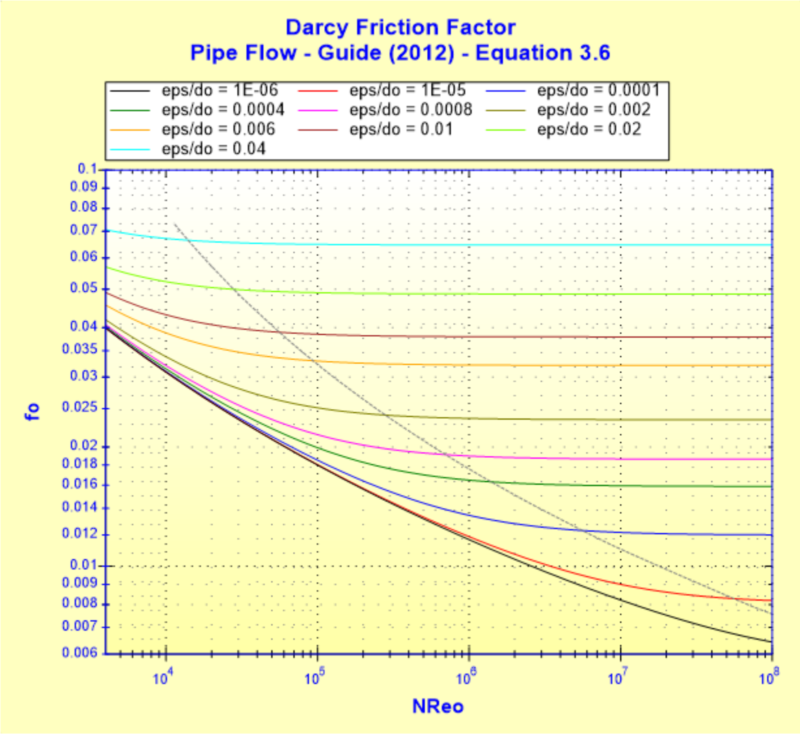


(with f_0 = 0.02 and t/d_0 = 5)

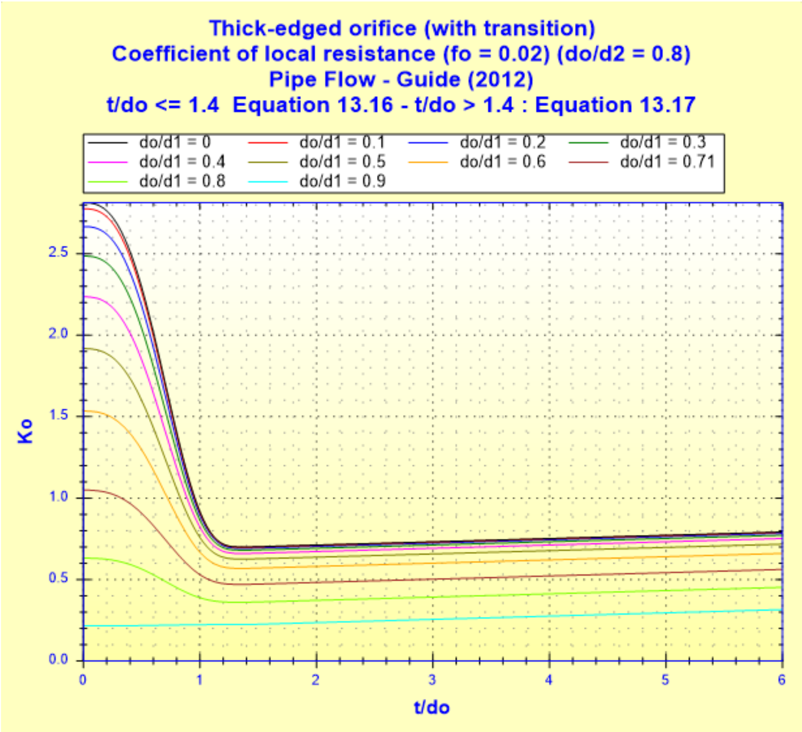
with:

$$f_o = \frac{1}{\left[2 \cdot \log\left(\frac{\varepsilon}{3.7 \cdot d_o} + \frac{2.51}{N\mathrm{Re}_0 \cdot \sqrt{f_o}}\right)\right]^2}$$

Colebrook-White equation ([1] equation 3.6)



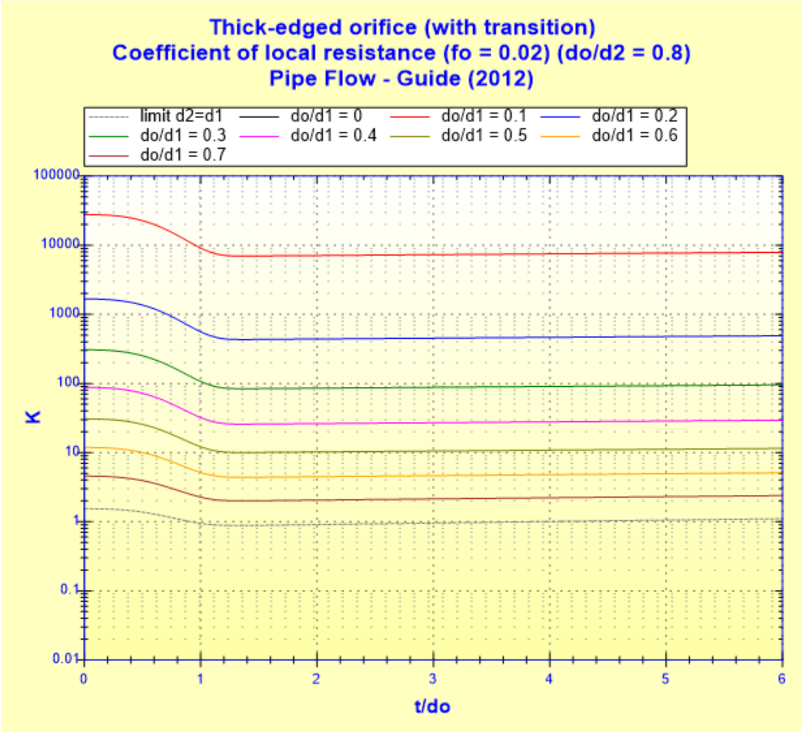
■ All thickness to orifice diameter ratios (t/d_o):



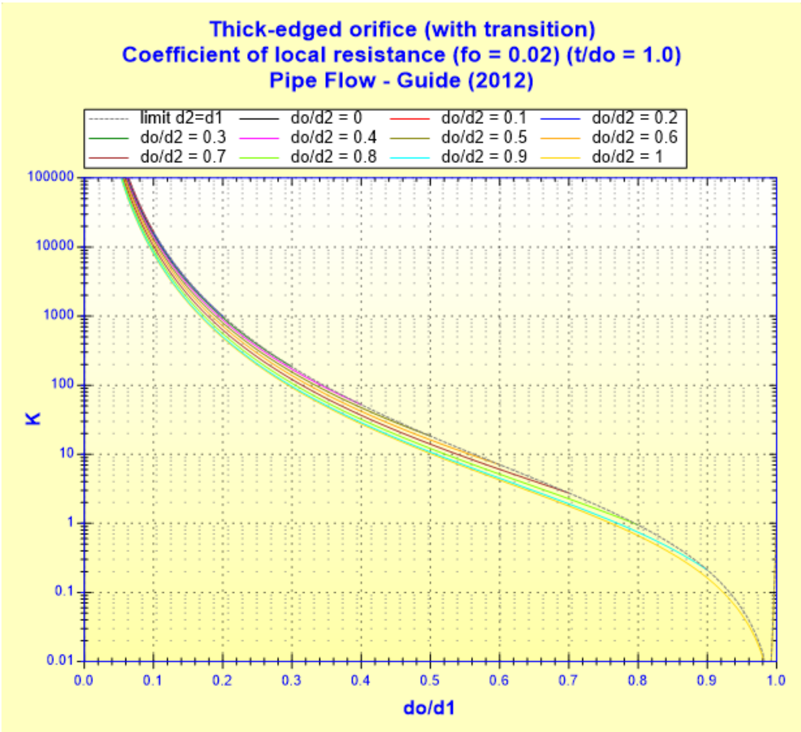
(with f_0 = 0.02 and d_0/d_2 = 0.8)

Total pressure loss coefficient (based on the major pipe velocity):

$$K = K_o \cdot \left(\frac{A_1}{A_o}\right)^2$$



(with f_0 = 0.02 and d_0/d_2 = 0.8)



(with f_0 = 0.02 and t/d_0 = 1)

Total pressure loss (Pa):

$$\Delta P = K \cdot \frac{\rho_m \cdot V_1^2}{2}$$

Total head loss of fluid (m):

$$\Delta H = K \cdot \frac{V_1^2}{2 \cdot g}$$

Hydraulic power loss (W):

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

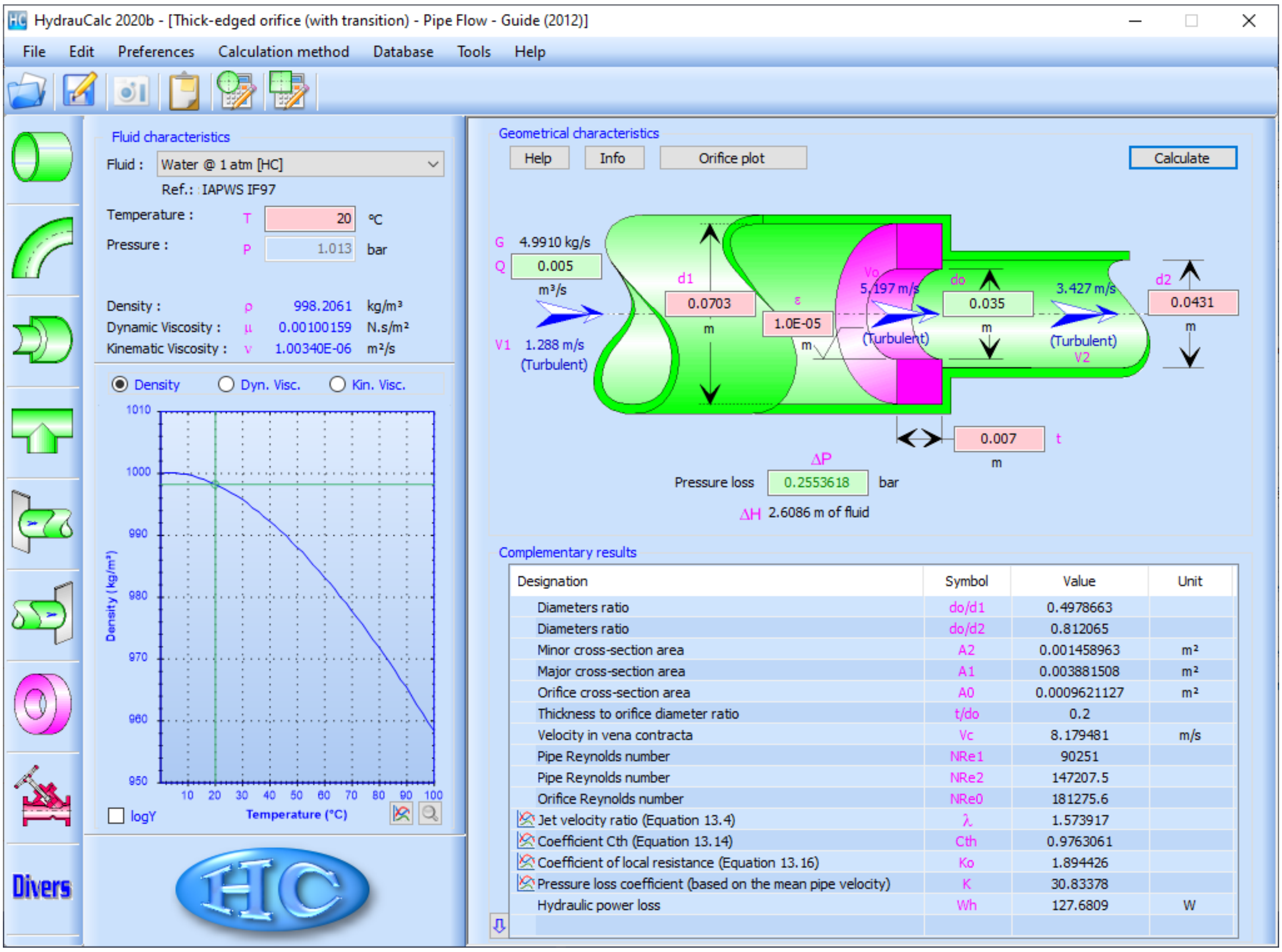
Symbols, Definitions, SI Units:

d_0	Orifice diameter (m)
d_1	Internal major pipe diameter (m)
d_2	Internal minor pipe diameter (m)
β	Ratio of orifice to major pipe diameters ()
A_0	Orifice cross-sectional area (m^2)
A_1	Major pipe cross-sectional area (m^2)
A_2	Minor pipe cross-sectional area (m^2)
Q	Volume flow rate (m^3/s)
G	Mass flow rate (kg/s)
V_0	Mean velocity in orifice (m/s)
V_1	Mean velocity in major pipe (m/s)
V_2	Mean velocity in minor pipe (m/s)
NRe_0	Reynolds number in orifice ()
NRe_1	Reynolds number in major pipe ()
NRe_2	Reynolds number in minor pipe ()
λ	Jet velocity ratio ()
V_c	Mean velocity in vena contracta (m/s)
t	Thickness orifice (m)
K_0	Coefficient of local resistance ()
Cth	Coefficient ()
f_o	Friction factor ()
K	Total 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_m	Fluid density (kg/m^3)
ν	Fluid kinematic viscosity (m^2/s)
g	Gravitational acceleration (m/s^2)

Validity range:

- turbulent flow regime in orifice ($NRe_o \geq 10^4$)
- stabilized flow upstream of the orifice

Example of application:



References:

[1] Pipe Flow: A Practical and Comprehensive Guide. Donald C. Rennels and Hobart M. Hudson. (2012)