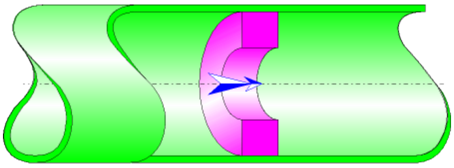
Thick-edged Orifice
Circular Cross-Section
(Pipe Flow - Guide)



Model description:

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

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

Pipe cross-sectional area (m²):

$$A = \pi \cdot \frac{d^2}{4}$$

Orifice cross-sectional area (m²):

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

Pipe velocity (m/s):

$$V = \frac{Q}{A}$$

Orifice velocity (m/s):

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

Mass flow rate (kg/s):

$$G = Q \cdot \rho$$

Reynolds number in pipe:

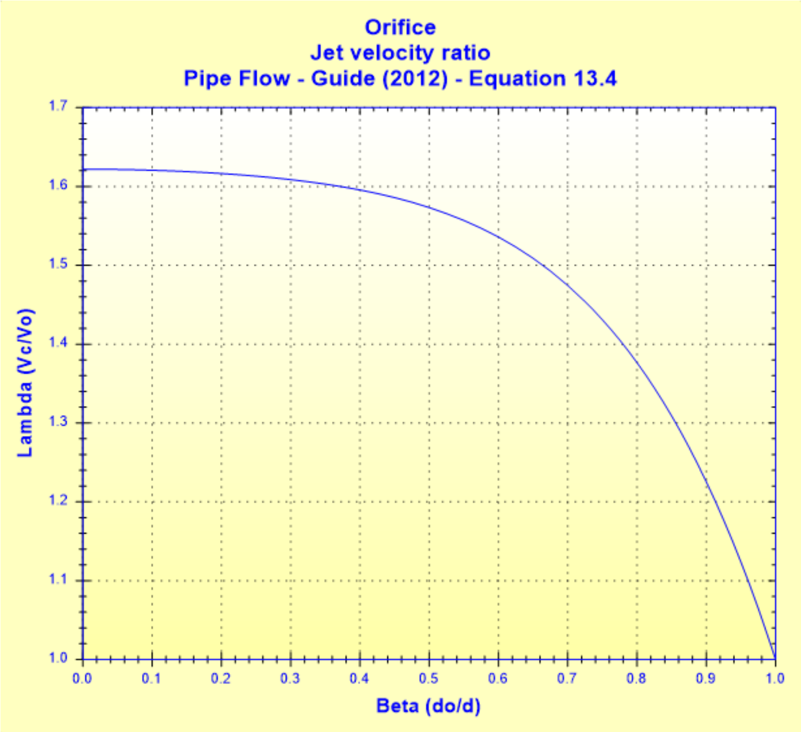
$$N_{Re} = \frac{V \cdot d}{\nu}$$

Reynolds number in orifice:

$$N_{Re_o} = \frac{V_o \cdot d_o}{\nu}$$

Jet velocity ratio:

$$\lambda = 1 + 0.622 \cdot \left(1 - 0.215\beta^2 - 0.785\beta^5\right)$$ ([1] equation 13.4)



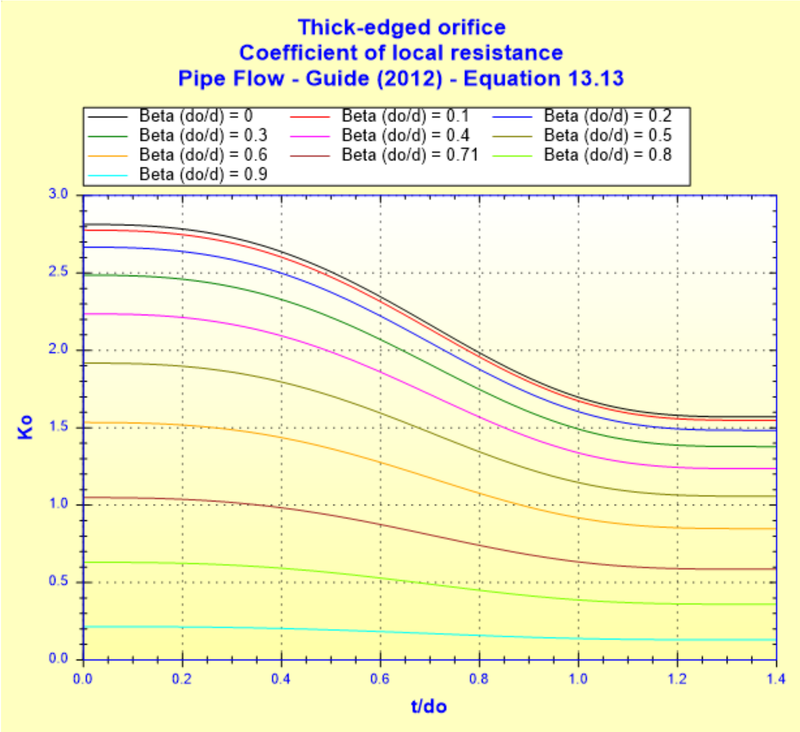
Velocity in vena contracta:

$$V_c = V_0 \cdot \lambda$$

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

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

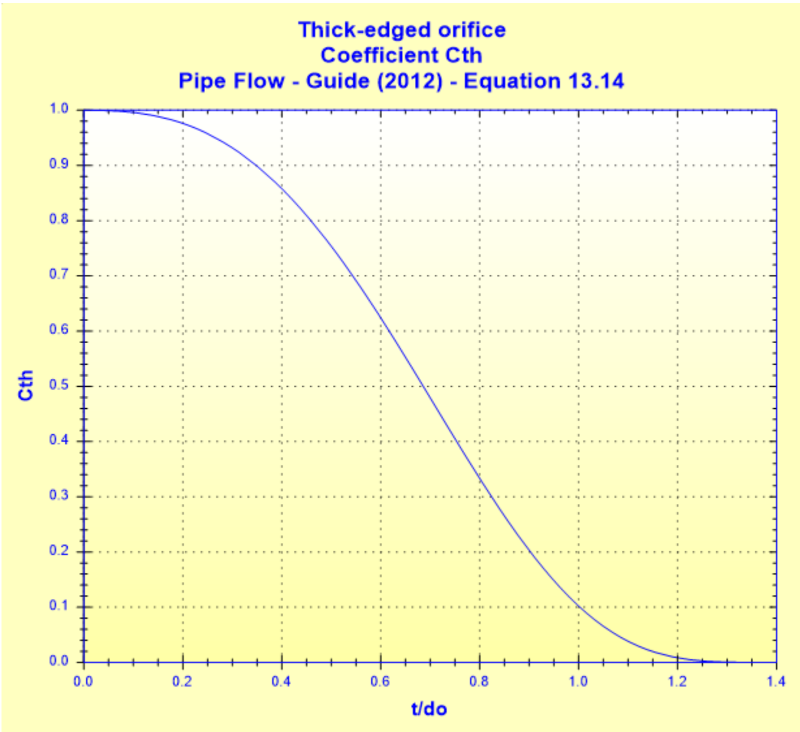
$$K_o = 0.0696 \cdot \left(1 - \beta^5\right) \cdot \lambda^2 + C_{th} \cdot \left(\lambda - \beta^2\right)^2 + \left(1 - C_{th}\right) \cdot \left[\left(\lambda - 1\right)^2 + \left(1 - \beta^2\right)^2\right]$$ ([1] equation 13.13)



with :

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

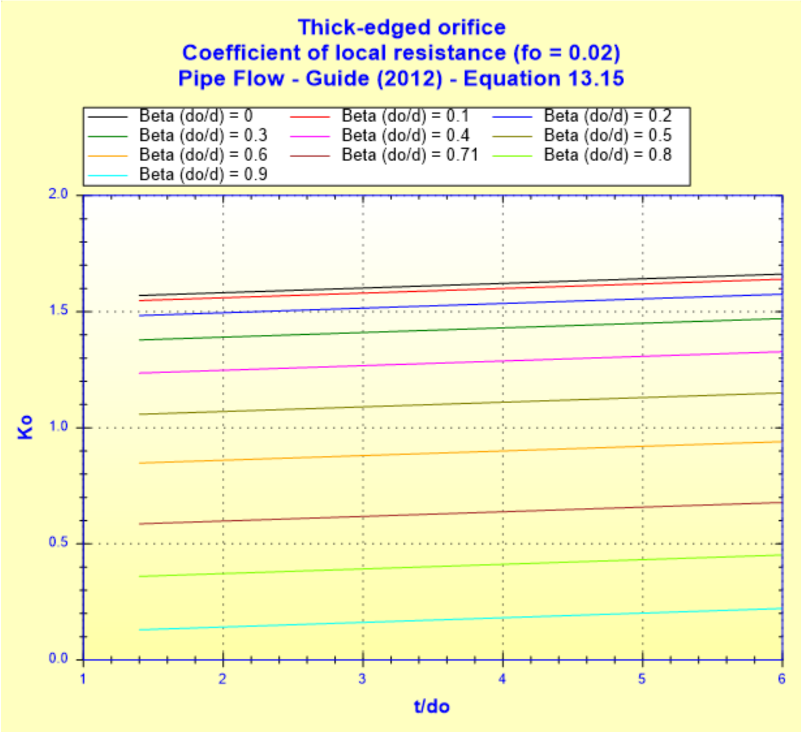
([1] equation 13.14)



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

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

([1] equation 13.15)

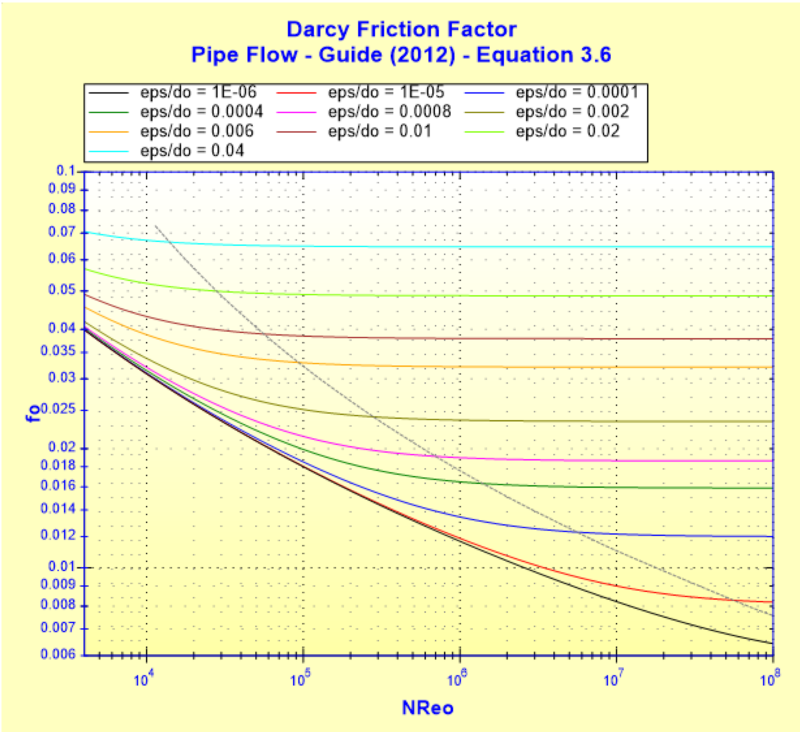


([1] equation 13.15 with fo = 0,02)

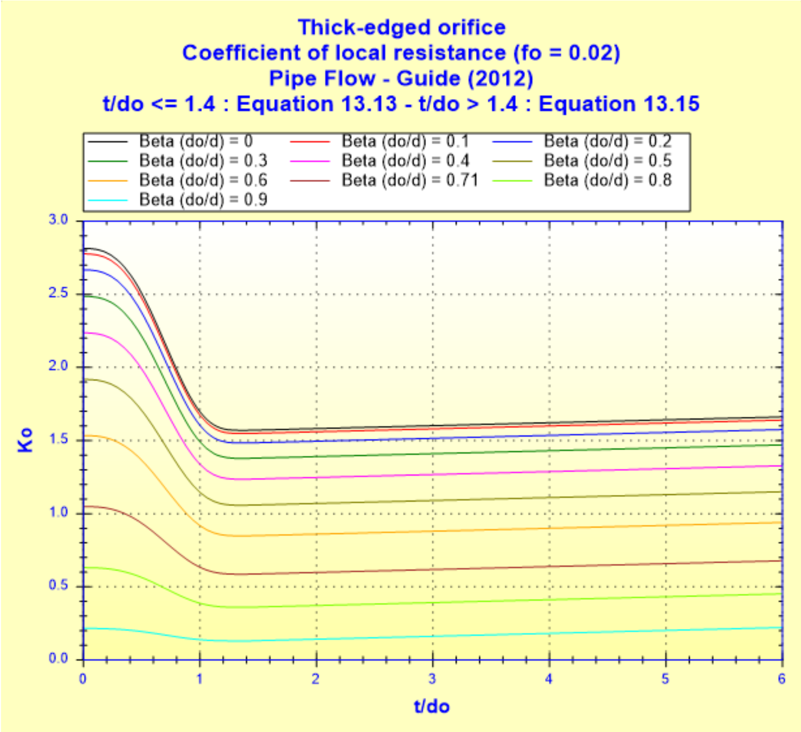
with :

$$f_o = \frac{1}{\left[2 \cdot \log\left(\frac{\varepsilon}{3.7 \cdot d_o} + \frac{2.51}{NRe_0 \cdot \sqrt{f_o}}\right)\right]^2}$$

Colebrook-White equation ([1] equation 3.6)



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



([1] equations 13.13 and 13.15 with fo = 0.02)

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

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

Total pressure loss (Pa):

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

Total head loss of fluid (m):

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

Hydraulic power loss (W):

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

Symbols, Definitions, SI Units:

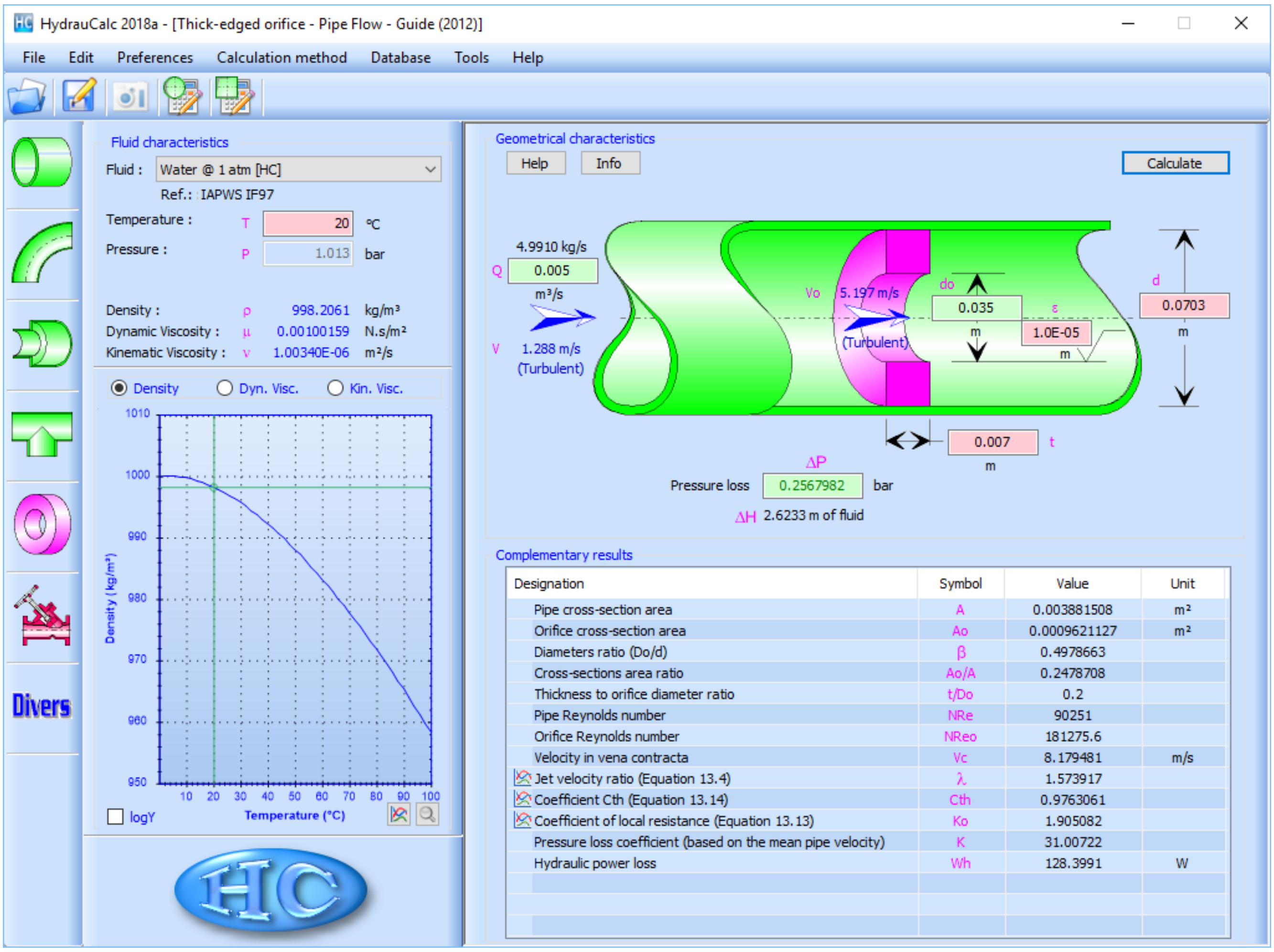
d_o	Orifice diameter (m)
d	Internal pipe diameter (m)
β	Ratio of orifice to pipe diameters ()
A_o	Orifice cross-sectional area (m^2)
A	Pipe cross-sectional area (m^2)
Q	Volume flow rate (m^3/s)
G	Mass flow rate (kg/s)
V_o	Mean velocity in orifice (m/s)
V	Mean velocity in pipe (m/s)
NRe_o	Reynolds number in orifice ()

NRe	Reynolds number in pipe ()
λ	Jet velocity ratio ()
V_c	Mean velocity in vena contracta (m/s)
t	Thickness orifice (m)
K_o	Coefficient of local resistance ()
Cth	Coefficient ()
f_o	Friction factor ()
K	Total 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_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)
