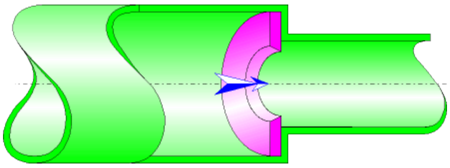
Bevel-Edged Orifice (with Transition)
Circular Cross-Section
(Pipe Flow - Guide)



Model description:

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

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):

$$G = Q \cdot \rho_m$$

Reynolds number in major pipe:

$$N_{Re1} = \frac{V_1 \cdot d_1}{\nu}$$

Reynolds number in minor pipe:

$$N_{Re2} = \frac{V_2 \cdot d_2}{\nu}$$

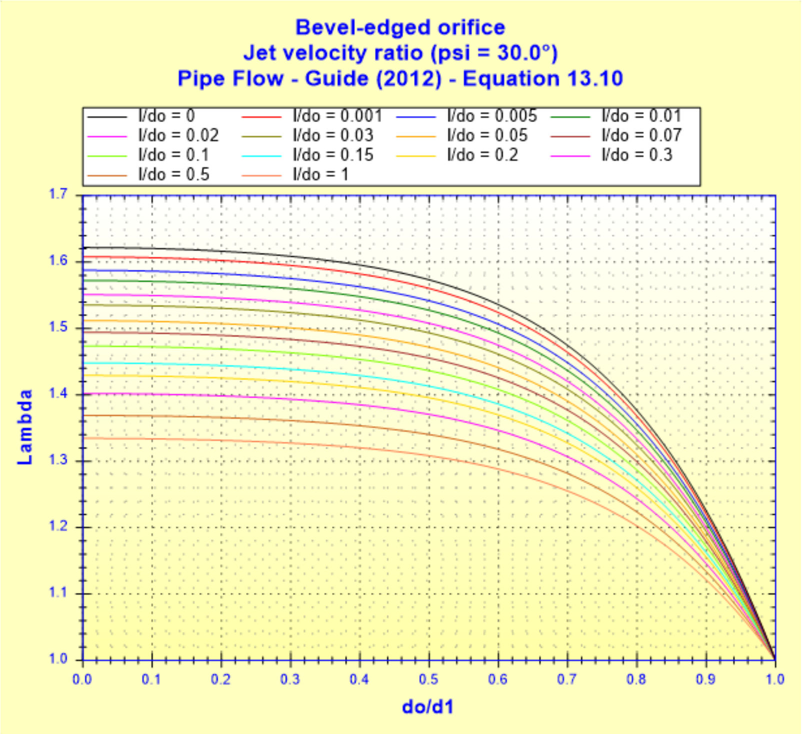
Reynolds number in orifice:

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

Jet velocity ratio:

$$\lambda = 1 + 0.622 \cdot \left[1 - C_b \cdot \left(\frac{l}{d_0} \right)^{\frac{1-\sqrt[4]{l/d_0}}{2}} \right] \cdot \left(1 - 0.215 \cdot \beta^2 - 0.785 \cdot \beta^5 \right)$$

([1] equation 13.10)



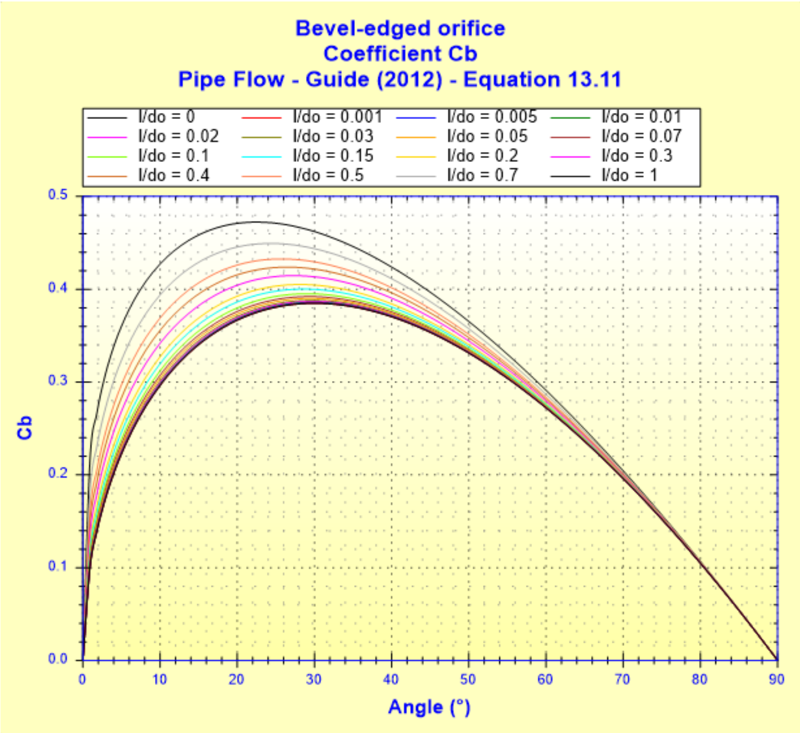
(with ψ = 30°)

with:

Coefficient of effect of the bevel angle:

$$C_b = \left(1 - \frac{\Psi}{90}\right) \cdot \left(\frac{\Psi}{90}\right)^{\frac{1}{2+l/d_0}}$$

([1] equation 13.11)



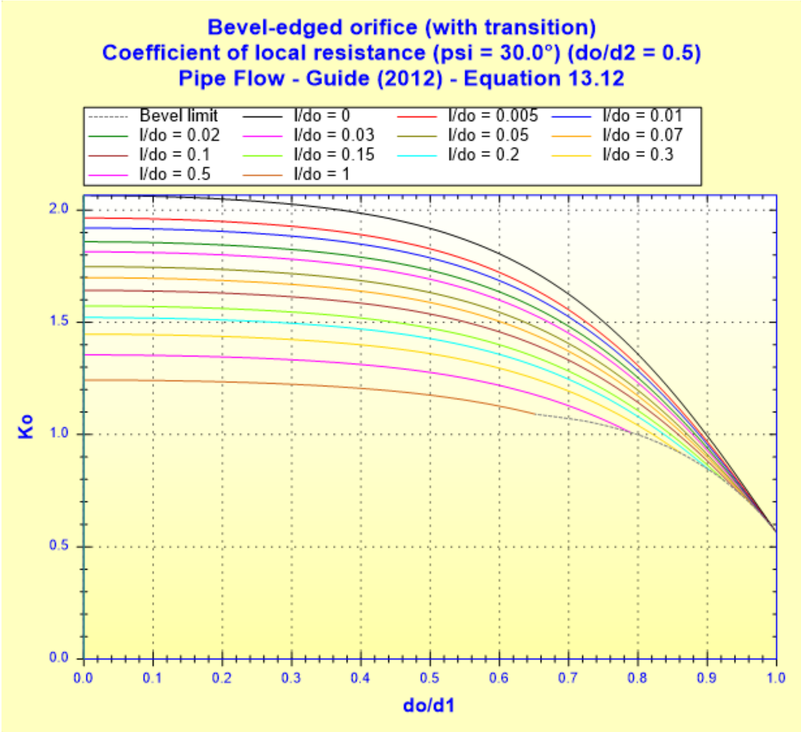
Velocity in vena contracta:

$$V_c = V_0 \cdot \lambda$$

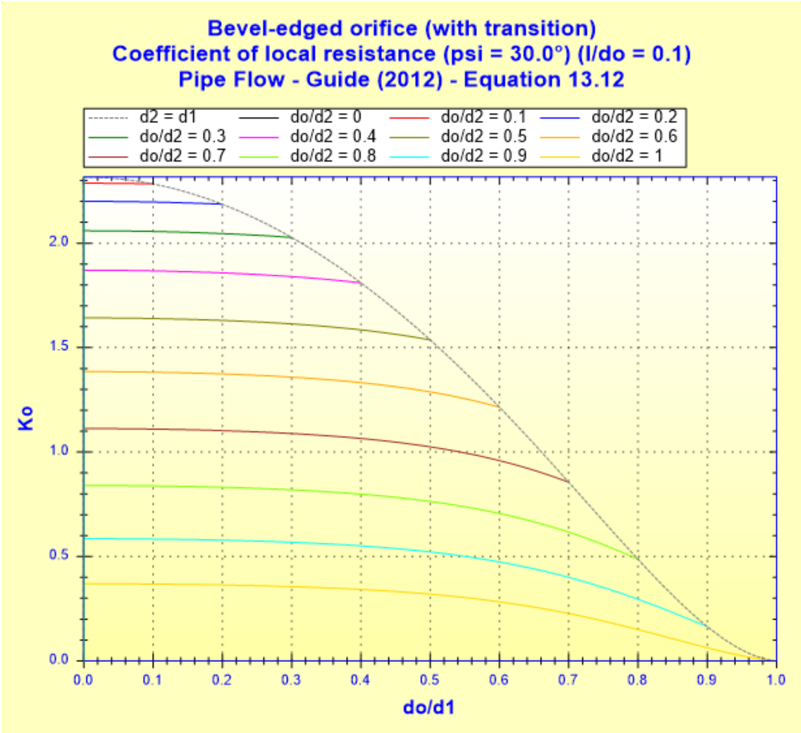
Coefficient of local resistance ($NRe_o \geq 10^4$):

$$K_o = 0.0696 \cdot \left(1 - C_b \cdot \frac{l}{d_0}\right) \cdot \left(1 - 0.42 \cdot \sqrt{\frac{l}{d_0}} \cdot \beta^2\right) \cdot \left(1 - \beta^5\right) \cdot \lambda^2 + \left(\lambda - \left(\frac{d_0}{d_2}\right)^2\right)^2$$

([1] equation 13.12)



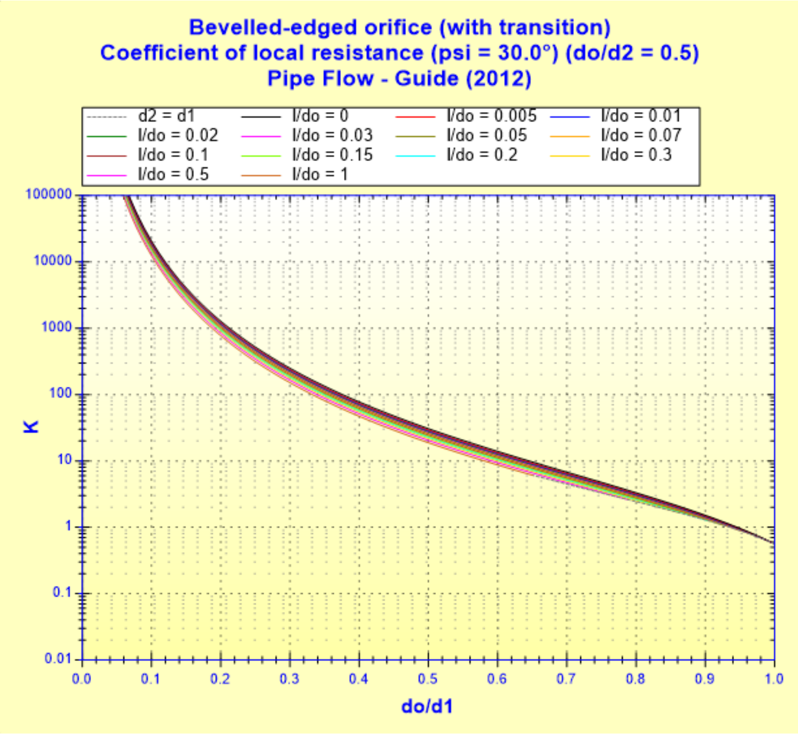
(with ψ = 30° and d_0/d_2 = 0.5)



(with ψ = 30° and l/d_0 = 0.1)

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

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



(with ψ = 30° and d_0/d_2 = 0.5)

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:

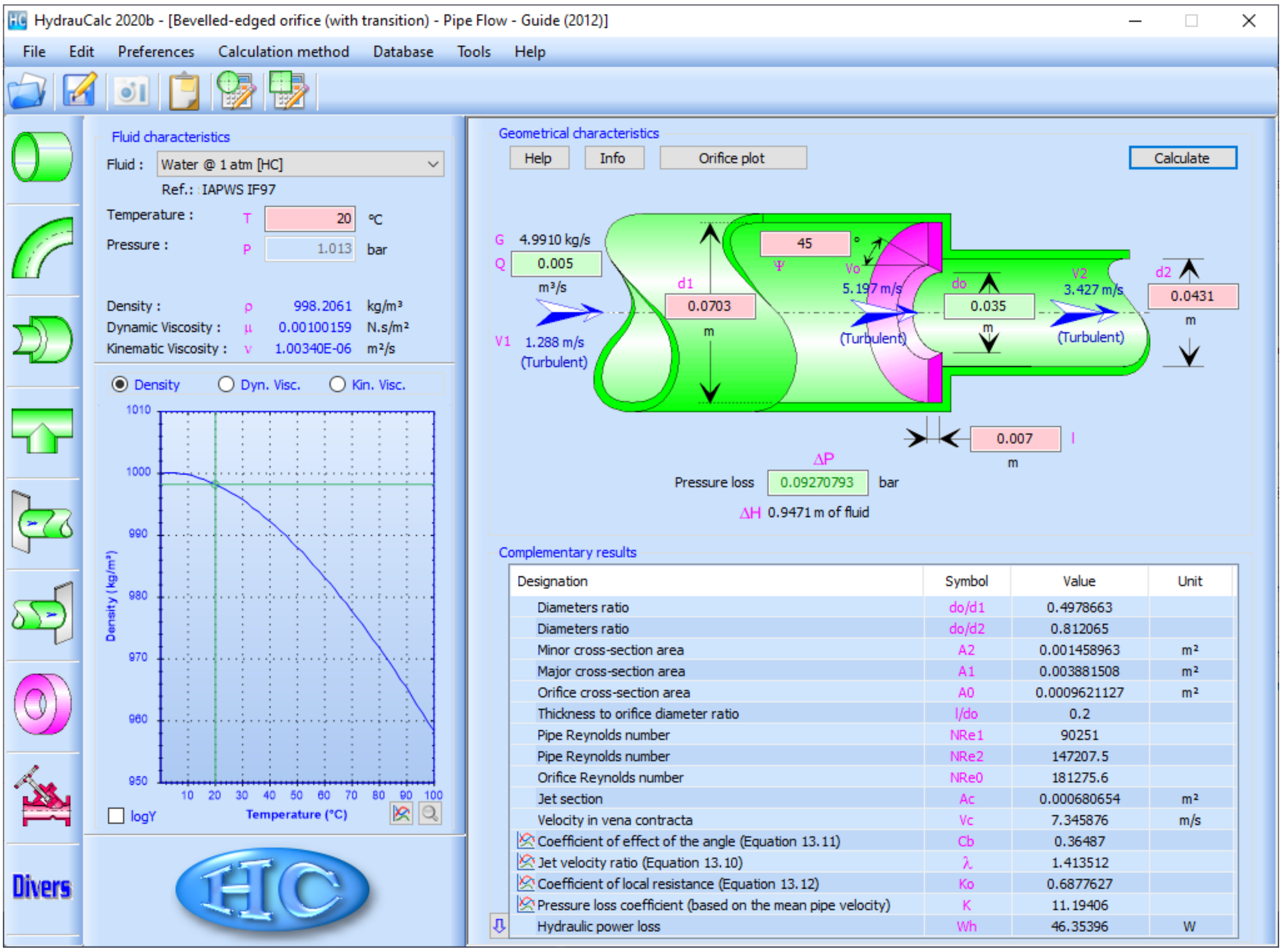
d_0	Orifice diameter (m)
d_1	Internal major pipe diameter (m)
d_2	Internal minor pipe diameter (m)
β	Ratio of orifice to major pipe diameters ()
A_0	Orifice cross-sectional area (m^2)
A_1	Major pipe cross-sectional area (m^2)
A_2	Minor pipe cross-sectional area (m^2)
Q	Volume flow rate (m^3/s)
G	Mass 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 ()
l	Orifice thickness (m)

ψ	Bevel angle (°)
λ	Jet velocity ratio ()
V_c	Mean velocity in vena contracta (m/s)
C_b	Coefficient of effect of the bevel angle ()
K_0	Coefficient of local resistance ()
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/m³)
ν	Fluid kinematic viscosity (m²/s)
g	Gravitational acceleration (m/s²)

Validity range:

- turbulent flow regime in orifice ($NRe_0 \geq 10^4$)
- stabilized flow upstream of the orifice
- bevel angle less than or equal to: $\psi \leq tg^{-1}((d_1 - d_0) / (2\ l))$

Example of application:



References:

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