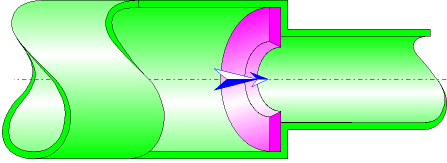




Bevel-Edged Orifice (with Transition) Circular Cross-Section (Pipe Flow - Guide)



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:

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

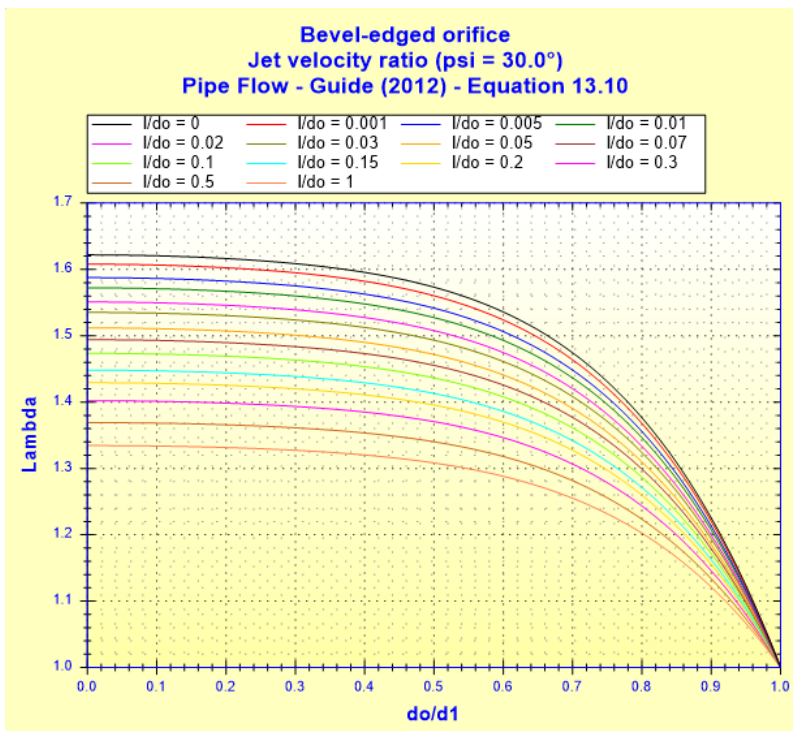
Reynolds number in orifice:

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

Jet velocity ratio:

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

([1] equation 13.10)

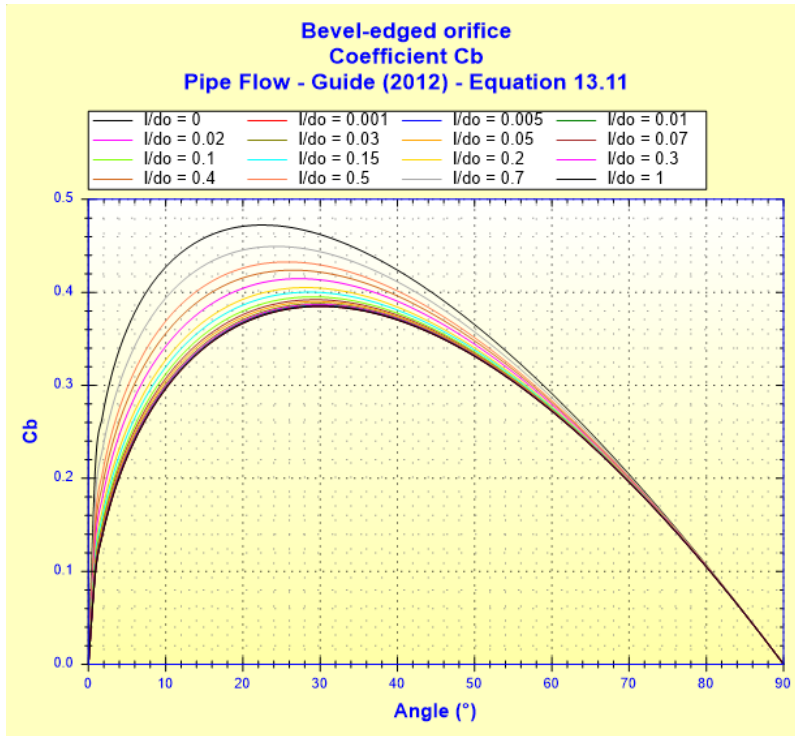


(with $\psi = 30^\circ$)

with:

Coefficient of effect of the bevel angle:

$$C_b = \left(1 - \frac{\Psi}{90}\right) \cdot \left(\frac{\Psi}{90}\right)^{\frac{1}{2 + l/d_0}} \quad ([1] \text{ equation } 13.11)$$



Velocity in vena contracta:

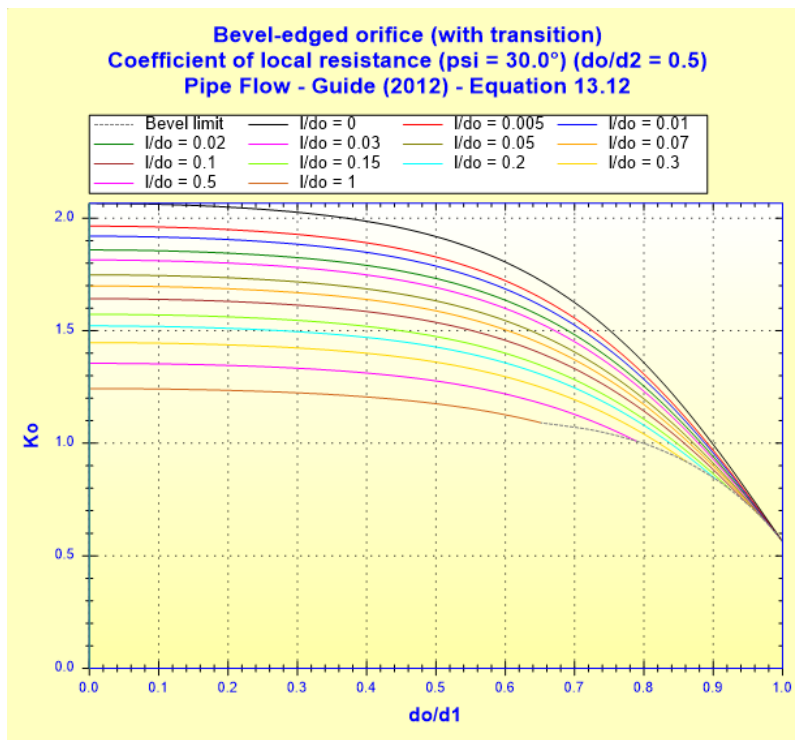
$$V_c = V_0 \cdot \lambda$$

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

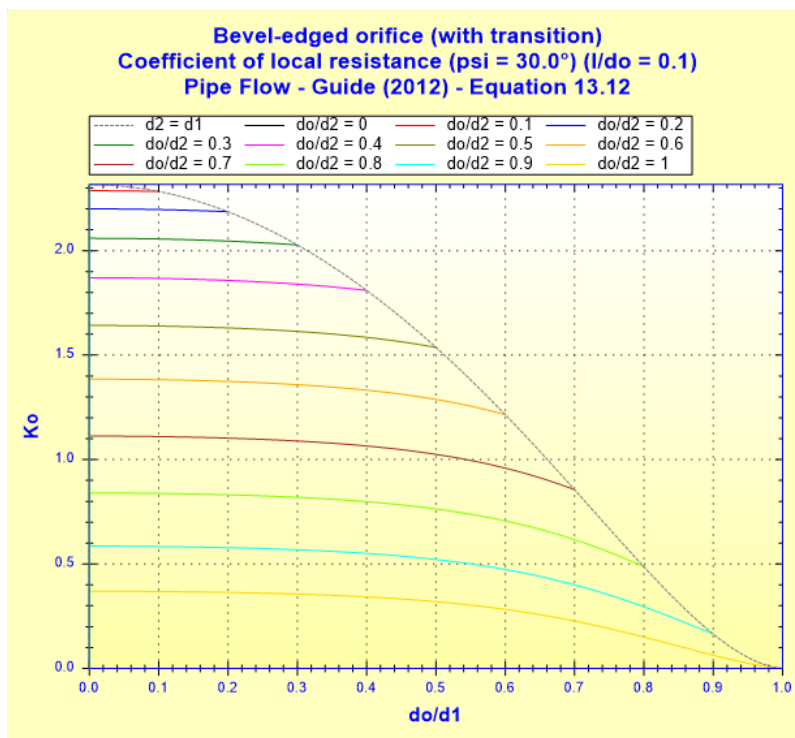
$$K_o = 0.0696 \cdot \left(1 - C_b \cdot \frac{l}{d_0}\right) \cdot \left(1 - 0.42 \cdot \sqrt{\frac{l}{d_0}} \cdot \beta^2\right) \cdot (1 - \beta^5) \cdot \lambda^2 + \left(\lambda - \left(\frac{d_0}{d_2}\right)^2\right)^2$$

([1] equation

13.12)



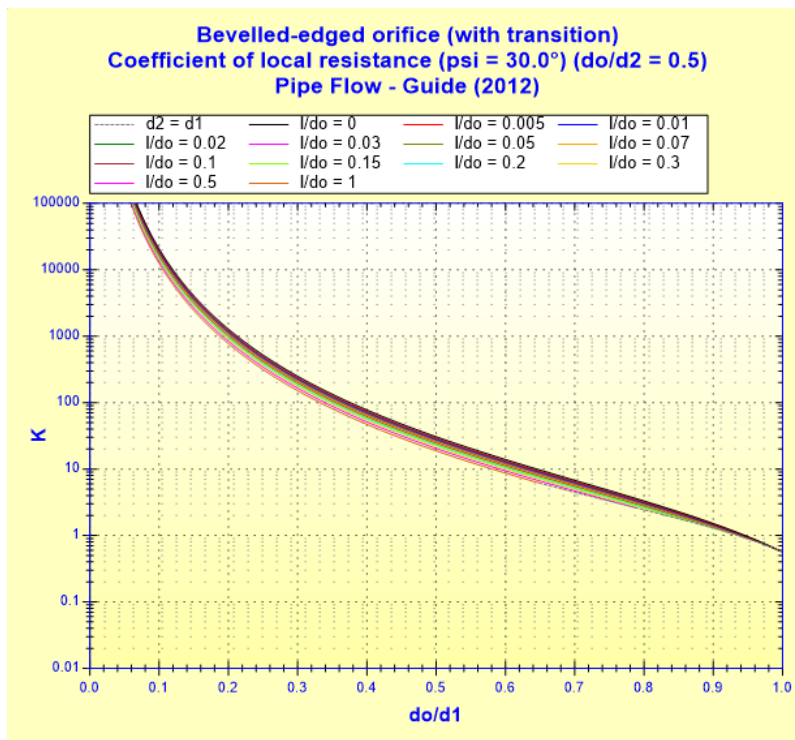
(with $\psi = 30^\circ$ and $d_o/d_2 = 0.5$)



(with $\psi = 30^\circ$ and $l/d_o = 0.1$)

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

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



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)
W_h	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
- bevel angle less than or equal to: $\psi \leq \text{tg}^{-1}((d_1 - d_o) / (2 l))$

Example of application:

The screenshot shows the HydrCalc 2020b software interface for a bevelled-edged orifice calculation. The fluid is Water @ 1 atm [HC] with a temperature of 20 °C and pressure of 1.013 bar. The orifice has a diameter ratio of 0.4978663 and a thickness to orifice diameter ratio of 0.2. The calculated pressure loss is 0.09270793 bar, and the total head loss is 0.9471 m of fluid.

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

Geometrical characteristics:

- Major diameter: $d_1 = 0.0703$ m
- Minor diameter: $d_2 = 0.0431$ m
- Orifice diameter: $d_o = 0.035$ m
- Thickness: $l = 0.007$ m
- Bevel angle: $\psi = 45^\circ$
- Upstream velocity: $V_1 = 1.288$ m/s (Turbulent)
- Velocity in vena contracta: $V_c = 7.345876$ m/s
- Downstream velocity: $V_2 = 3.427$ m/s (Turbulent)

Complementary results:

Designation	Symbol	Value	Unit
Diameters ratio	d_o/d_1	0.4978663	
Diameters ratio	d_o/d_2	0.812065	
Minor cross-section area	A_2	0.001458963	m ²
Major cross-section area	A_1	0.003881508	m ²
Orifice cross-section area	A_0	0.0009621127	m ²
Thickness to orifice diameter ratio	l/d_o	0.2	
Pipe Reynolds number	NRe_1	90251	
Pipe Reynolds number	NRe_2	147207.5	
Orifice Reynolds number	NRe_0	181275.6	
Jet section	A_c	0.000680654	m ²
Velocity in vena contracta	V_c	7.345876	m/s
Coefficient of effect of the angle (Equation 13.11)	C_b	0.36487	
Jet velocity ratio (Equation 13.10)	λ	1.413512	
Coefficient of local resistance (Equation 13.12)	K_0	0.6877627	
Pressure loss coefficient (based on the mean pipe velocity)	K	11.19406	
Hydraulic power loss	W_h	46.35396	W

References:

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

HydrauCalc
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