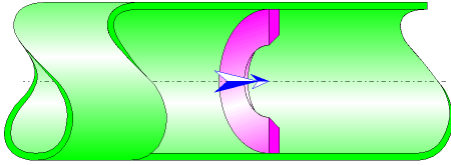




Sharp-edged Orifice Circular Cross-Section (Pipe Flow - Guide)



Model description:

This model of component calculates the minor head loss (pressure drop) generated by the flow in a sharp-edged orifice installed in a straight pipe.

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 diameter:

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

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:

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

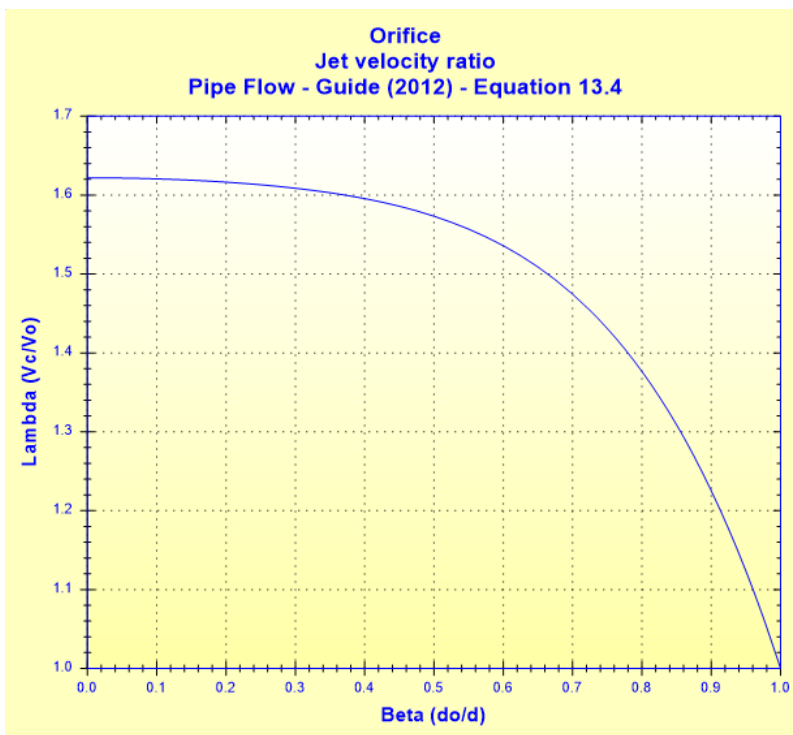
Reynolds number in orifice:

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

Jet velocity ratio:

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

([1] equation 13.4)



Velocity in vena contracta (m/s):

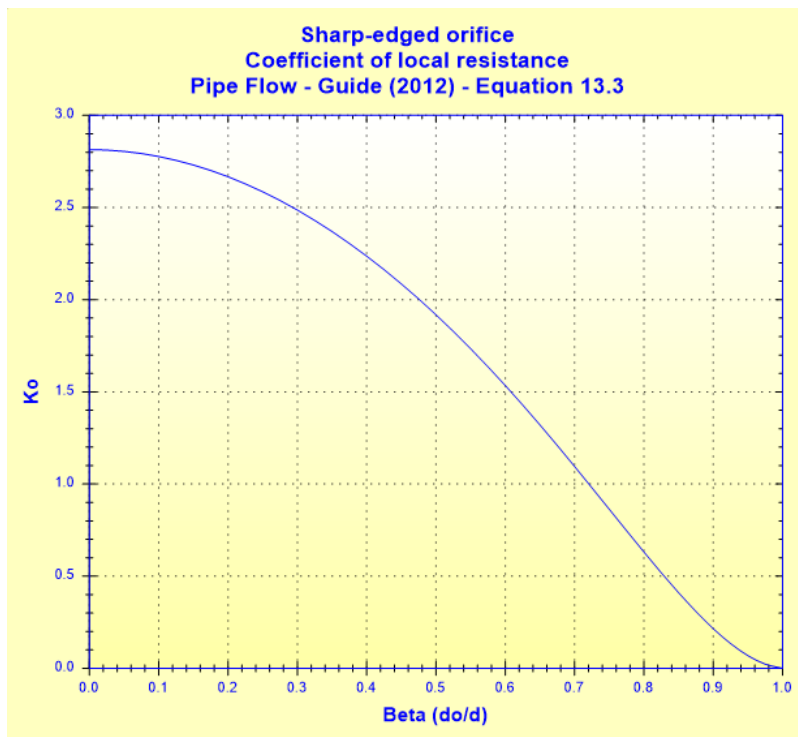
Vena contracta cross-sectional area (m²):

$$A_c = \frac{Q}{V_c}$$

Coefficient of local resistance ($N_{Re_o} \geq 10^4$):

$$K_o = 0.0696 \cdot (1 - \beta^5) \cdot \lambda^2 + (\lambda - \beta^2)^2$$

([1] equation 13.3)



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

$$K = K_0 \cdot \left(\frac{A}{A_0} \right)^2$$

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_0	Orifice diameter (m)
d	Internal pipe diameter (m)
β	Ratio of orifice to pipe diameter ()
A_0	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_0	Mean velocity in orifice diameter (m/s)
V	Mean velocity in pipe diameter (m/s)
NRe_0	Reynolds number in orifice ()
NRe	Reynolds number in pipe ()

λ	Jet velocity ratio ()
V_c	Mean velocity in vena contracta (m/s)
K_o	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/m ³)
ν	Fluid kinematic viscosity (m ² /s)
g	Gravitational acceleration (m/s ²)

Validity range:

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

Example of application:

The screenshot shows the HydraulCalc 2018a software interface for a sharp-edged orifice flow calculation. The main window is titled "HydrauCalc 2018a - [Sharp-edged orifice - Pipe Flow - Guide (2012)]".

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:

- Mass flow rate: Q = 4.9910 kg/s
- Volume flow rate: $Q_v = 0.005$ m³/s
- Mean pipe velocity: V = 1.288 m/s (Turbulent)
- Vena contracta velocity: $V_o = 5.197$ m/s (Turbulent)
- Orifice diameter: $d_o = 0.035$ m
- Pipe diameter: d = 0.0703 m
- Pressure loss: $\Delta P = 0.2595555$ bar
- Head loss: $\Delta H = 2.6515$ m of fluid

Complementary results:

Designation	Symbol	Value	Unit
Pipe cross-section area	A	0.003881508	m ²
Orifice cross-section area	Ao	0.0009621127	m ²
Diameters ratio (do/d)	β	0.4978663	
Cross-sections area ratio	Ao/A	0.2478708	
Pipe Reynolds number	NRe	90251	
Orifice Reynolds number	NReo	181275.6	
Jet section	Ac	0.0006112857	m ²
Velocity in vena contracta	Vc	8.179481	m/s
Jet velocity ratio (Equation 13.4)	λ	1.573917	
Coefficient of local resistance (Equation 13.3)	Ko	1.925537	
Pressure loss coefficient (based on the mean pipe velocity)	K	31.34015	
Hydraulic power loss	Wh	129.7777	W

References:

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

