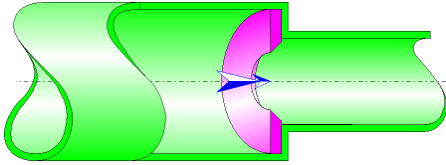




## Sharp-Edged Orifice (with Transition) Circular Cross-Section (Pipe Flow - Guide)



### Model description:

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

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Ratio of orifice to major pipe diameters:

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

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Major pipe cross-sectional area (m<sup>2</sup>):

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

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Minor pipe cross-sectional area (m<sup>2</sup>):

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

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Orifice cross-sectional area (m<sup>2</sup>):

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

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Major pipe velocity (m/s):

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

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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:

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

Reynolds number in minor pipe:

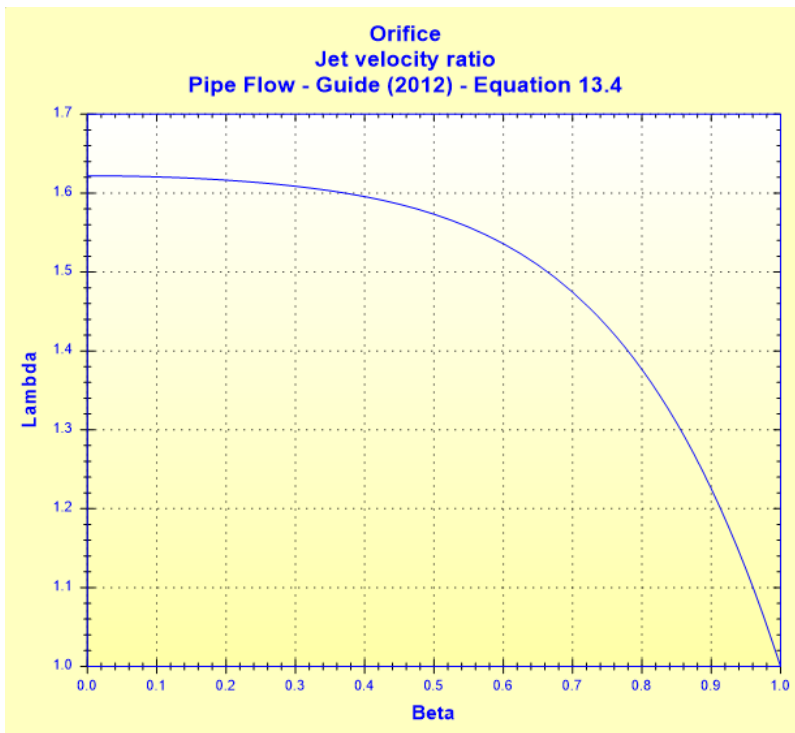
$$N_{Re2} = \frac{V_2 \cdot d_2}{\nu}$$

Reynolds number in orifice:

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

Jet velocity ratio:

$$\lambda = 1 + 0.622 \cdot (1 - 0.215\beta^2 - 0.785\beta^5) \quad ([1] \text{ equation 13.4})$$



Velocity in vena contracta (m/s):

$$V_c = V_o \cdot \lambda$$

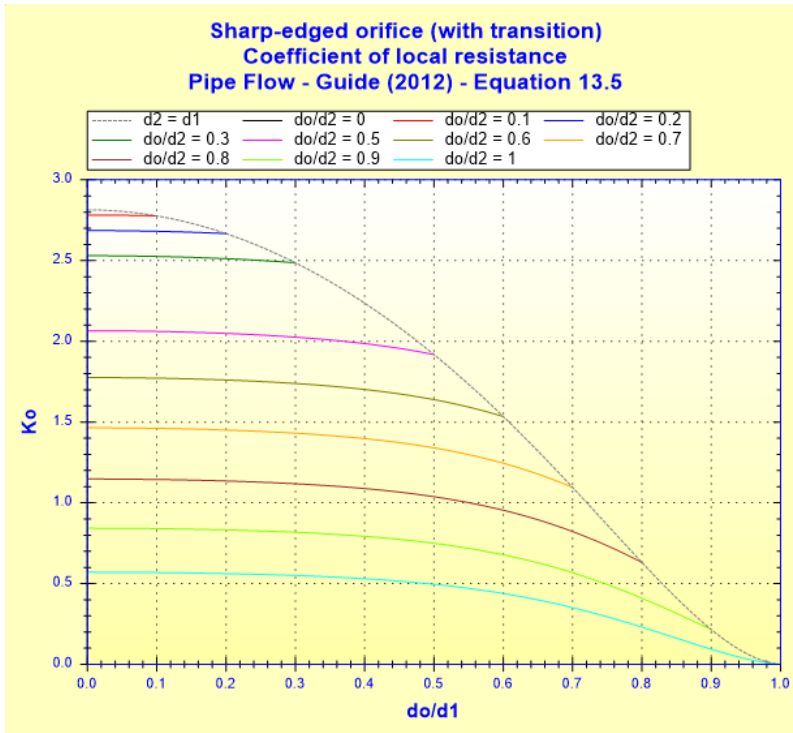
Vena contracta cross-sectional area (m<sup>2</sup>):

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

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

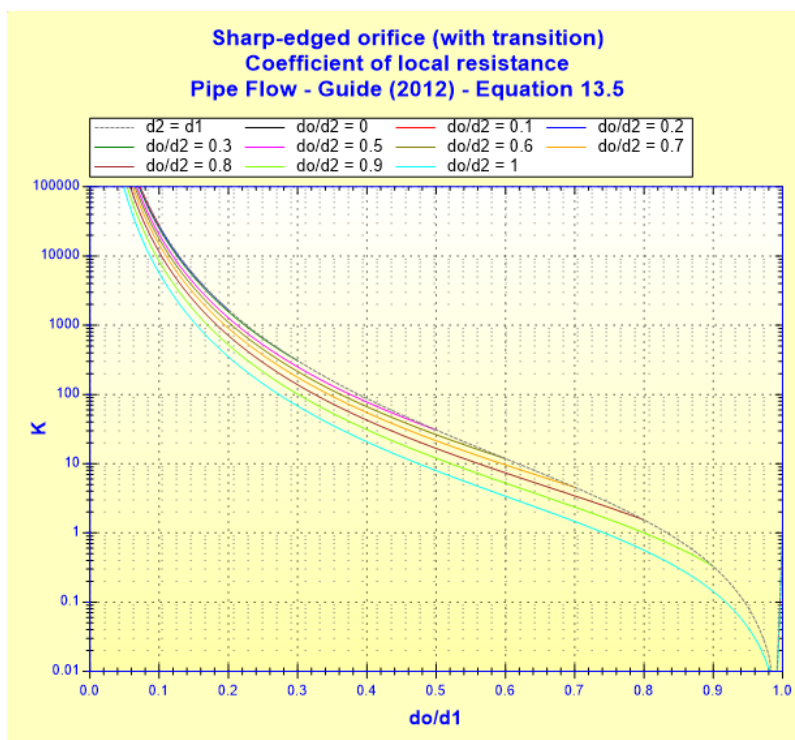
$$K_o = 0.0696 \cdot (1 - \beta^5) \cdot \lambda^2 + \left( \lambda - \left( \frac{d_o}{d_2} \right)^2 \right)^2$$

([1] equation 13.5)



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:**

$d_o$	Orifice diameter (m)
$d_1$	Internal major pipe diameter (m)
$d_2$	Internal minor pipe diameter (m)
$\beta$	Ratio of orifice to major pipe diameters ( )
$A_o$	Orifice cross-sectional area (m <sup>2</sup> )
$A_1$	Major pipe cross-sectional area (m <sup>2</sup> )
$A_2$	Minor pipe cross-sectional area (m <sup>2</sup> )
$Q$	Volume flow rate (m <sup>3</sup> /s)
$G$	Mass flow rate (kg/s)
$V_o$	Mean velocity in orifice (m/s)
$V_1$	Mean velocity in major pipe (m/s)
$V_2$	Mean velocity in minor pipe (m/s)
$NR_{e0}$	Reynolds number in orifice ( )
$NR_{e1}$	Reynolds number in major pipe ( )
$NR_{e2}$	Reynolds number in minor pipe ( )
$\lambda$	Jet velocity ratio ( )

$V_c$	Mean velocity in vena contracta (m/s)
$K_0$	Coefficient of local resistance ( )
$K$	Total pressure loss coefficient (based on the major pipe velocity) ( )
$\Delta P$	Total pressure loss (Pa)
$\Delta H$	Total head loss of fluid (m)
$Wh$	Hydraulic power loss (W)
$\rho_m$	Fluid density (kg/m <sup>3</sup> )
$\nu$	Fluid kinematic viscosity (m <sup>2</sup> /s)
$g$	Gravitational acceleration (m/s <sup>2</sup> )

### Validity range:

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

### Example of application:

The screenshot displays the HydraulCalc 2020b interface for a sharp-edged orifice flow calculation. The software is set to calculate the flow of water at 1 atm and 20°C. The pipe diameter is 0.0703 m and the orifice diameter is 0.035 m. The flow is turbulent, with a pressure loss of 0.1352534 bar and a head loss of 1.3817 m of fluid.

**Fluid characteristics:**

- Fluid: Water @ 1 atm [HC]
- Temperature: 20 °C
- Pressure: 1.013 bar
- Density: 998.2061 kg/m<sup>3</sup>
- Dynamic Viscosity: 0.00100159 N.s/m<sup>2</sup>
- Kinematic Viscosity: 1.00340E-06 m<sup>2</sup>/s

**Geometrical characteristics:**

- Major diameter (d1): 0.0703 m
- Orifice diameter (d2): 0.0431 m
- Major velocity (V1): 1.288 m/s (Turbulent)
- Orifice velocity (V0): 5.197 m/s (Turbulent)
- Jet velocity (V2): 3.427 m/s (Turbulent)

**Complementary results:**

Designation	Symbol	Value	Unit
Diameters ratio	do/d1	0.4978663	
Diameters ratio	do/d2	0.812065	
Minor cross-section area	A2	0.001458963	m <sup>2</sup>
Major cross-section area	A1	0.003881508	m <sup>2</sup>
Orifice cross-section area	A0	0.0009621127	m <sup>2</sup>
Cross-sections area ratio	A0/A1	0.2478708	
Cross-sections area ratio	A0/A2	0.6594495	
Pipe Reynolds number	NRe1	90251	
Pipe Reynolds number	NRe2	147207.5	
Orifice Reynolds number	NRe0	181275.6	
Jet section	Ac	0.0006112857	m <sup>2</sup>
Velocity in vena contracta	Vc	8.179481	m/s
Jet velocity ratio (Equation 13.4)	$\lambda$	1.573917	
Coefficient of local resistance (Equation 13.5)	Ko	1.00339	
Pressure loss coefficient (based on the mean pipe velocity)	K	16.33123	
Hydraulic power loss	Wh	67.62667	W

### References:

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