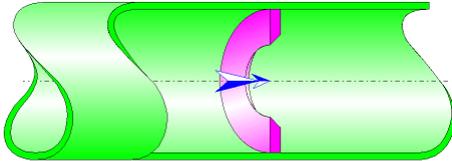




## Sharp-edged Orifice Circular Cross-Section (IDELCHIK)



### 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:

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Hydraulic diameter (m):

$$D_h = D_0$$

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Pipe cross-section area (m<sup>2</sup>):

$$F_1 = \pi \cdot \frac{D_1^2}{4}$$

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

$$F_0 = \pi \cdot \frac{D_0^2}{4}$$

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Mean velocity in pipe (m/s):

$$w_1 = \frac{Q}{F_1}$$

---

Mean velocity in orifice (m/s):

$$w_0 = \frac{Q}{F_0}$$

---

Mass flow rate (kg/s):

$$G = Q \cdot \rho$$

Reynolds number in pipe:

$$\text{Re}_1 = \frac{w_1 \cdot D_1}{\nu}$$

Reynolds number in orifice:

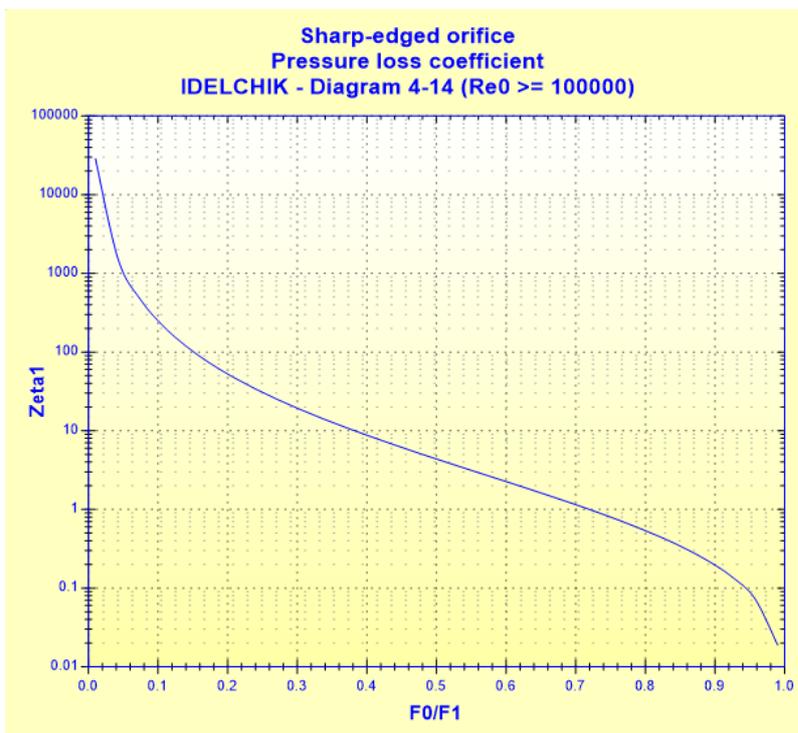
$$\text{Re}_0 = \frac{w_0 \cdot D_0}{\nu}$$

Pressure loss coefficient (based on the mean pipe velocity):

■  $\text{Re}_0 \geq 10^5$

$$\zeta_1 = \left[ \left( 1 - \frac{F_0}{F_1} \right) + 0.707 \cdot \left( 1 - \frac{F_0}{F_1} \right)^{0.375} \right]^2 \cdot \left( \frac{F_1}{F_0} \right)^2$$

([1] diagram 4.14)



■  $\text{Re}_0 \leq 10^5$

Quadratic pressure loss coefficient:

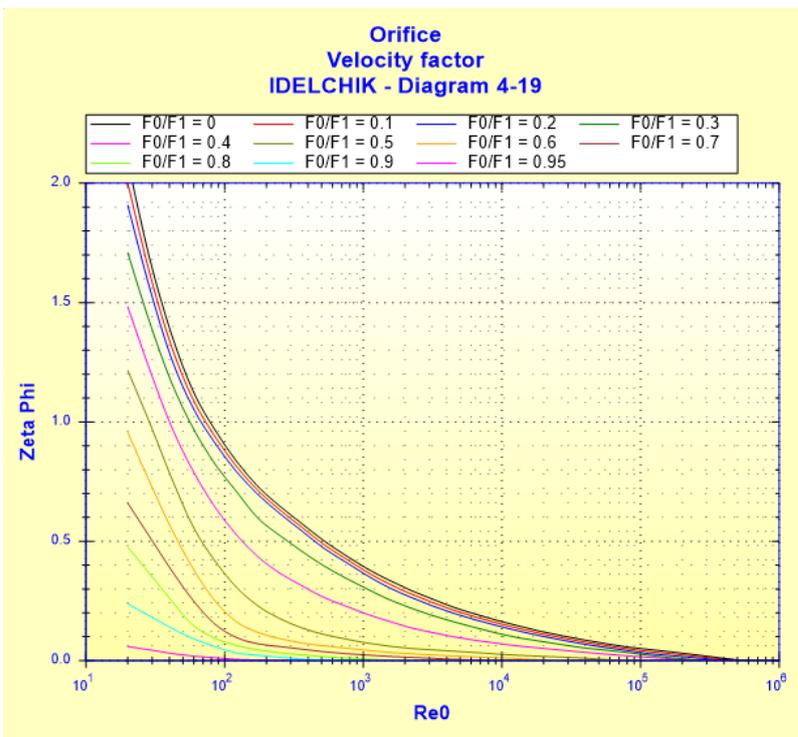
$$\zeta_{1quad} = \left[ \left( 1 - \frac{F_0}{F_1} \right) + 0.707 \cdot \left( 1 - \frac{F_0}{F_1} \right)^{0.375} \right]^2 \cdot \left( \frac{F_1}{F_0} \right)^2$$

([1] diagram 4.14)

Velocity factor:

$$\zeta_\varphi = f \left( \text{Re}_0, \frac{F_0}{F_1} \right)$$

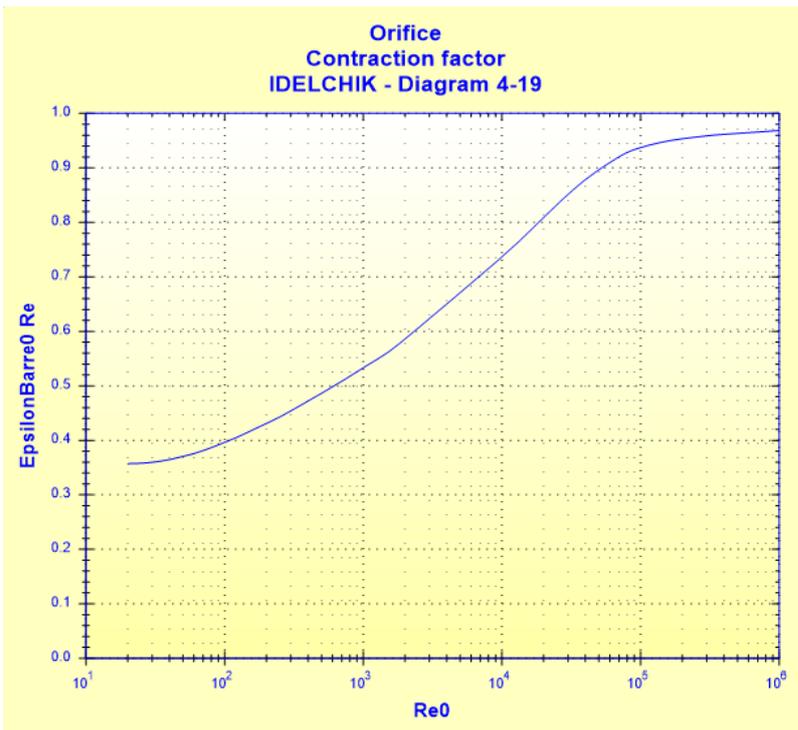
([1] diagram 4.19)



Contraction factor:

$$\bar{\epsilon}_{0Re} = f(Re_0)$$

([1] diagram 4.19)



Pressure loss coefficient (based on the mean pipe velocity):

- $30 < Re_0 < 10^5$

$$\zeta_1 = \zeta_\varphi \cdot \left(\frac{F_1}{F_0}\right)^2 + \bar{\epsilon}_{0Re} \cdot \zeta_{1quad}$$

([1] diagram 4.19)

- $10 < Re_0 \leq 30$

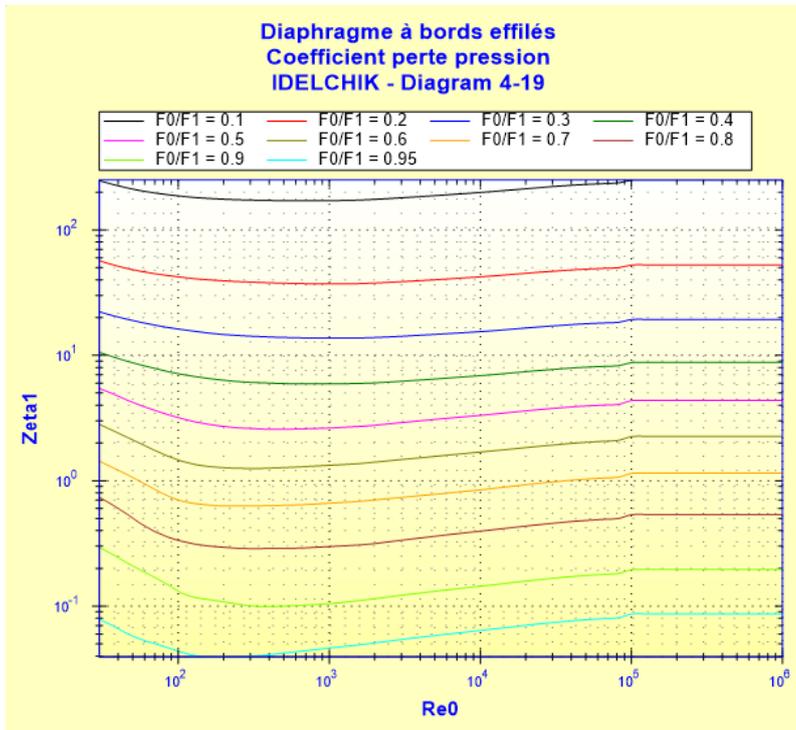
$$\zeta_1 = \frac{33}{Re_0} \cdot \left( \frac{F_1}{F_0} \right)^2 + \bar{\varepsilon}_0 Re \cdot \zeta_{1quad}$$

([1] diagram 4.19)

- $Re_0 \leq 10$

$$\zeta_1 = \frac{33}{Re_0} \cdot \left( \frac{F_1}{F_0} \right)^2$$

([1] diagram 4.19)



([1] diagramme 4.19)

Total pressure loss (Pa):

$$\Delta P = \zeta_1 \cdot \frac{\rho \cdot w_1^2}{2}$$

Total head loss of fluid (m):

$$\Delta H = \zeta_1 \cdot \frac{w_1^2}{2 \cdot g}$$

Hydraulic power loss (W):

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

**Symbols, Definitions, SI Units:**

$D_h$	Hydraulic diameter (m)
$D_1$	Pipe internal diameter (m)
$F_1$	Pipe cross-sectional area (m <sup>2</sup> )
$D_0$	Orifice diameter (m)
$F_0$	Orifice cross-sectional area (m <sup>2</sup> )
$Q$	Volume flow rate (m <sup>3</sup> /s)
$G$	Mass flow rate (kg/s)
$w_1$	Mean velocity in pipe (m/s)

$w_0$	Mean velocity in orifice (m/s)
$l$	Orifice thickness (m)
$Re_1$	Reynolds number in pipe ( )
$Re_0$	Reynolds number in orifice ( )
$\zeta_{1quad}$	Quadratic pressure loss coefficient determined as $Re = 10^5$ ( )
$\zeta_{\rho}$	Velocity factor ( )
$\varepsilon_{0Re}$	Contraction factor ( )
$\zeta_1$	Pressure loss coefficient (based on the mean pipe velocity) ( )
$\Delta P$	Total pressure loss (Pa)
$\Delta H$	Total head loss of fluid (m)
$Wh$	Hydraulic power loss (W)
$\rho$	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:

- any flow regime: laminar and turbulent
- stabilized flow upstream of the orifice
- thickness to orifice diameter ratio ( $l/D_0$ ) lower than or equal to 0.015

### Example of application:

The screenshot shows the HydraulCalc 2018a software interface for a sharp-edged orifice flow calculation. The window title is "HydrauCalc 2018a - [Sharp-edged orifice - IDELCHIK (3rd Ed.)]".

**Fluid characteristics:**

- Fluid: Water @ 1 atm [HC]
- Ref.: IAPWS IF97
- Temperature: T = 20 °C
- Pressure: P = 1.013 bar
- Density:  $\rho = 998.2061$  kg/m<sup>3</sup>
- Dynamic Viscosity:  $\mu = 0.00100159$  N.s/m<sup>2</sup>
- Kinematic Viscosity:  $\nu = 1.00340E-06$  m<sup>2</sup>/s

**Geometrical characteristics:**

- Mass flow rate:  $Q = 4.9910$  kg/s
- Volume flow rate:  $Q = 0.005$  m<sup>3</sup>/s
- Upstream velocity:  $w_1 = 1.288$  m/s (Turbulent)
- Orifice diameter:  $D_0 = 0.035$  m
- Orifice thickness:  $D_1 = 0.0703$  m
- Orifice velocity:  $w_0 = 5.197$  m/s (Turbulent)
- Pressure loss:  $\Delta P = 0.2595051$  bar
- Head loss:  $\Delta H = 2.6510$  m of fluid

**Complementary results:**

Designation	Symbol	Value	Unit
Hydraulic diameter	Dh	0.0703	m
Pipe cross-section area	F1	0.003881508	m <sup>2</sup>
Orifice cross-section area	F0	0.0009621127	m <sup>2</sup>
Diameters ratio	D0/D1	0.4978663	
Cross-sections area ratio	F0/F1	0.2478708	
Pipe Reynolds number	Re1	90251	
Orifice Reynolds number	Re0	181275.6	
Pressure loss coefficient (Diagram 4-14)	$\zeta_1$	31.33406	
Pressure loss coefficient (based on the mean pipe velocity)	$\zeta$	31.33406	
Hydraulic power loss	Wh	129.7525	W

The software also includes a graph of Density (kg/m<sup>3</sup>) vs Temperature (°C) for water, showing a decrease in density as temperature increases from 10°C to 100°C.

## References:

[1] Handbook of Hydraulic Resistance, 3rd Edition, I.E. Idelchik

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HydrauCalc

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