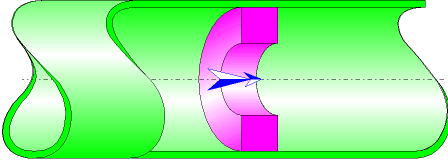




Thick-edged Orifice Circular Cross-Section (Pipe Flow - Guide)



Model description:

This model of component calculates the minor head loss (pressure drop) generated by the flow in a thick-Edged orifice. Moreover, when the thickness of the orifice is greater than 1.4 times the diameter of the orifice, the head loss due to friction in the orifice is also taken into account because it becomes significant.

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 diameters:

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

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:

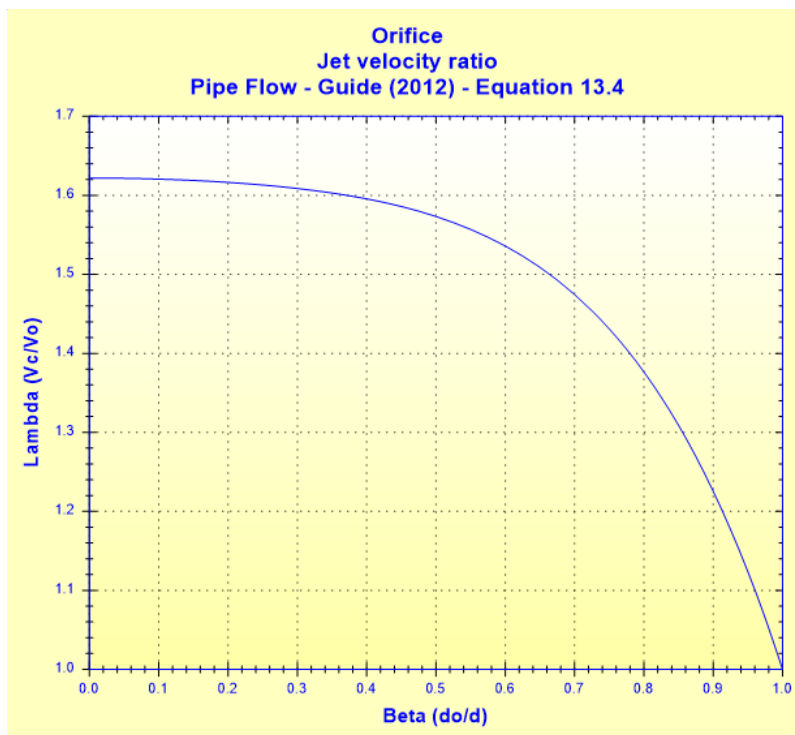
$$N_{Re} = \frac{V \cdot d}{\nu}$$

Reynolds number in orifice:

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

Jet velocity ratio:

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



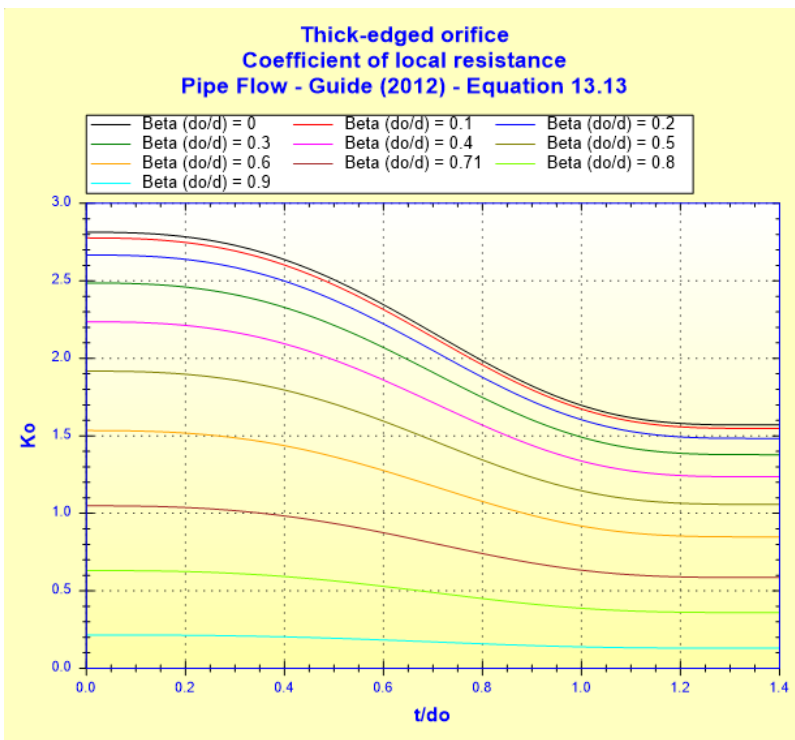
Velocity in vena contracta:

$$V_c = V_o \cdot \lambda$$

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

- Thickness to orifice diameter ratio ($t/d_o \leq 1.4$):

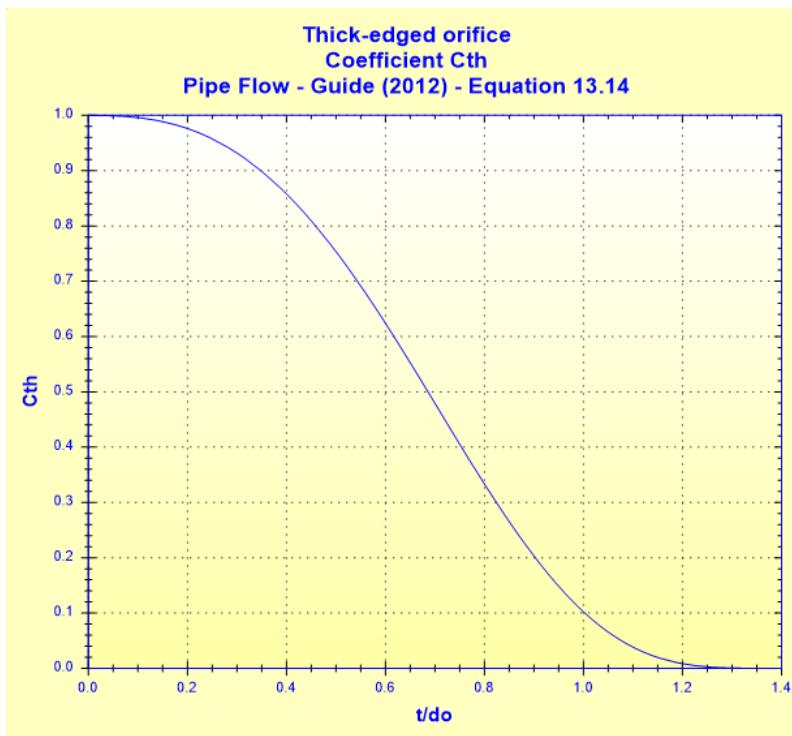
$$K_o = 0.0696 \cdot (1 - \beta^5) \cdot \lambda^2 + C_{th} \cdot (\lambda - \beta^2)^2 + (1 - C_{th}) \cdot [(\lambda - 1)^2 + (1 - \beta^2)^2] \quad ([1] \text{ equation } 13.13)$$



with :

$$C_{th} = \left[1 - 0.50 \cdot \left(\frac{t}{1.4d_o} \right)^{2.5} - 0.50 \cdot \left(\frac{t}{1.4d_o} \right)^3 \right]^{4.5}$$

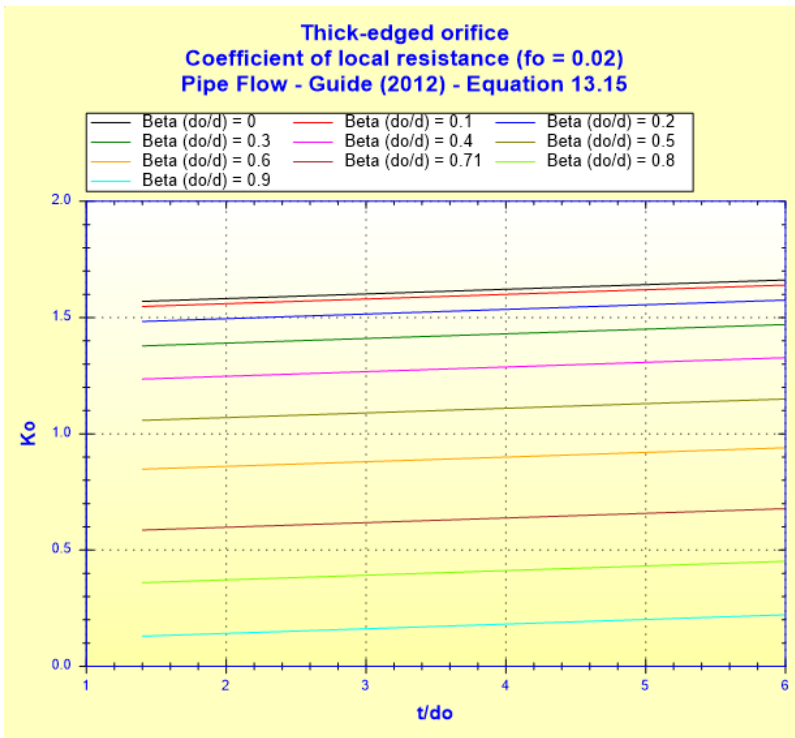
([1] equation 13.14)



■ Thickness to orifice diameter ratio (t/d_o) > 1.4:

$$K_o = 0.0696 \cdot (1 - \beta^5) \cdot \lambda^2 + (\lambda - 1)^2 + (1 - \beta^2)^2 + f_o \cdot \left(\frac{t}{d_o} - 1.4 \right)$$

([1] equation 13.15)



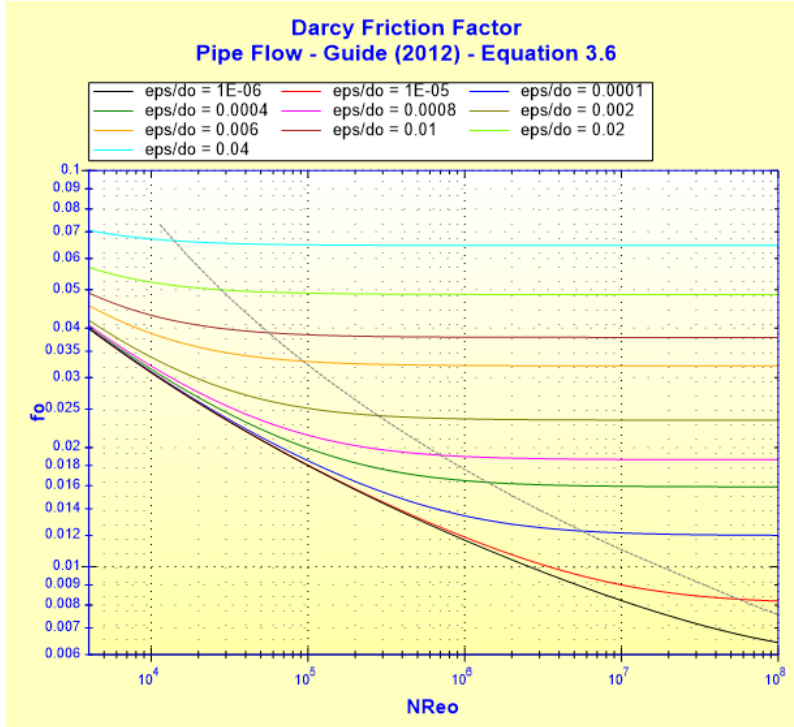
$f_o = 0,02$)

([1] equation 13.15 with

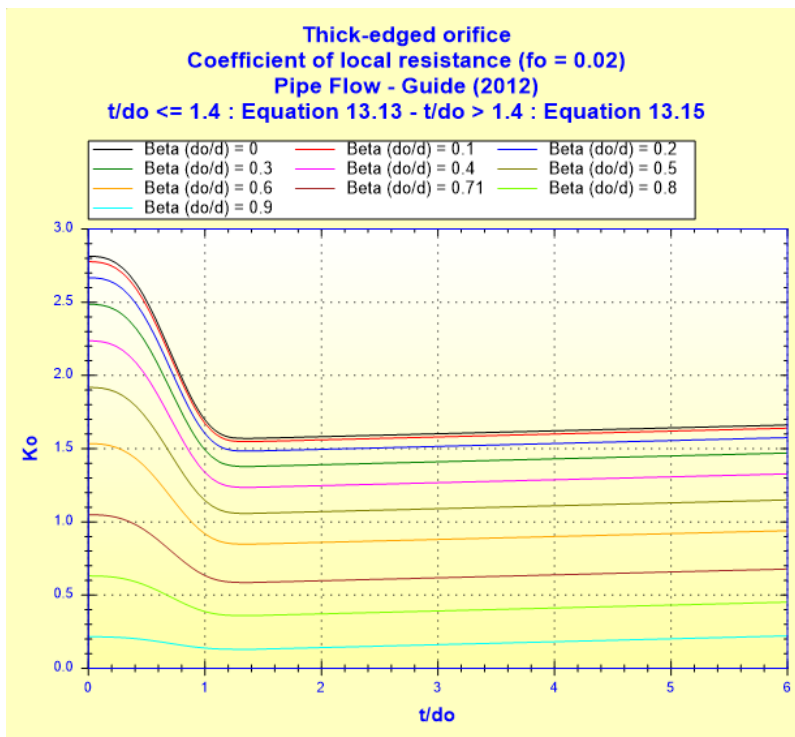
with :

$$f_o = \frac{1}{\left[2 \cdot \log \left(\frac{\varepsilon}{3.7 \cdot d_o} + \frac{2.51}{NRe_0 \cdot \sqrt{f_o}} \right) \right]^2}$$

Colebrook-White equation ([1] equation 3.6)



■ All thickness to orifice diameter ratios (t/d_o):



([1] equations 13.13 and

13.15 with fo = 0.02)

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

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

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 _o	Orifice diameter (m)
d	Internal pipe diameter (m)
β	Ratio of orifice to pipe diameters ()
A _o	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 _o	Mean velocity in orifice (m/s)
V	Mean velocity in pipe (m/s)
NRe _o	Reynolds number in orifice ()

NRe	Reynolds number in pipe ()
λ	Jet velocity ratio ()
V_c	Mean velocity in vena contracta (m/s)
t	Thickness orifice (m)
K_o	Coefficient of local resistance ()
C_{th}	Coefficient ()
f_o	Friction factor ()
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

Example of application:

The screenshot shows the HydraulCalc 2018a software interface for a thick-edged orifice flow calculation. The window title is "HydraulCalc 2018a - [Thick-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/m^3
- Dynamic Viscosity: $\mu = 0.00100159$ N.s/m^2
- Kinematic Viscosity: $\nu = 1.00340E-06$ m^2/s

Geometrical characteristics:

- Mass flow rate: $Q = 4.9910$ kg/s
- Volume flow rate: $Q = 0.005$ m^3/s
- Mean velocity: $V = 1.288$ m/s (Turbulent)
- Jet velocity: $V_o = 5.197$ m/s (Turbulent)
- Orifice diameter: $d_o = 0.035$ m
- Orifice thickness: $t = 0.007$ m
- Orifice diameter ratio: $\beta = 0.4978663$
- Orifice diameter: $d = 0.0703$ m
- Pressure loss: $\Delta P = 0.2567982$ bar
- Head loss: $\Delta H = 2.6233$ m of fluid

Complementary results:

Designation	Symbol	Value	Unit
Pipe cross-section area	A	0.003881508	m^2
Orifice cross-section area	A_o	0.0009621127	m^2
Diameters ratio (Do/d)	β	0.4978663	
Cross-sections area ratio	A_o/A	0.2478708	
Thickness to orifice diameter ratio	t/D_o	0.2	
Pipe Reynolds number	NRe	90251	
Orifice Reynolds number	NRe_o	181275.6	
Velocity in vena contracta	V_c	8.179481	m/s
Jet velocity ratio (Equation 13.4)	λ	1.573917	
Coefficient C_{th} (Equation 13.14)	C_{th}	0.9763061	
Coefficient of local resistance (Equation 13.13)	K_o	1.905082	
Pressure loss coefficient (based on the mean pipe velocity)	K	31.00722	
Hydraulic power loss	W_h	128.3991	W

References:

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

HydrauCalc
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