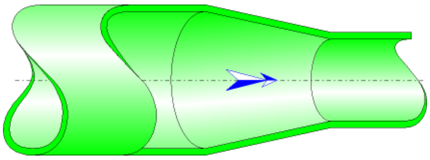
Gradual Contraction
Circular Cross-Section
(Pipe Flow - Guide)



Model description:

This model of component calculates the head loss (pressure drop) generated by the flow in a gradual contraction. The head loss by friction in the gradual contraction is also taken into account.

The head loss by friction in the inlet and outlet piping is not taken into account in this component.

Model formulation:

Ratio of small to large diameter:

$$\boxed{\beta = \frac{d_2}{d_1}}$$

Top cone angle (°):

$$\boxed{\alpha = 2 \cdot \tan^{-1}\left(\frac{d_1 - d_2}{2 \cdot l}\right)}$$

Major cross-sectional area (m²):

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

Minor cross-sectional area (m²):

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

Mean velocity in major diameter (m/s):

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

Mean velocity in minor diameter (m/s):

$$V_2 = \frac{Q}{A_2}$$

Mass flow rate (kg/s):

$$G = Q \cdot \rho_m$$

Fluid volume in the truncated cone (m^3):

$$V = l \cdot \frac{\pi}{3} \cdot \left(\left(\frac{d_1}{2} \right)^2 + \left(\frac{d_2}{2} \right)^2 + \left(\frac{d_1}{2} \right) \cdot \left(\frac{d_2}{2} \right) \right)$$

Fluid mass in the truncated cone (kg):

$$M = V \cdot \rho_m$$

Reynolds number in major diameter:

$$N_{Re_1} = \frac{V_1 \cdot d_1}{\nu}$$

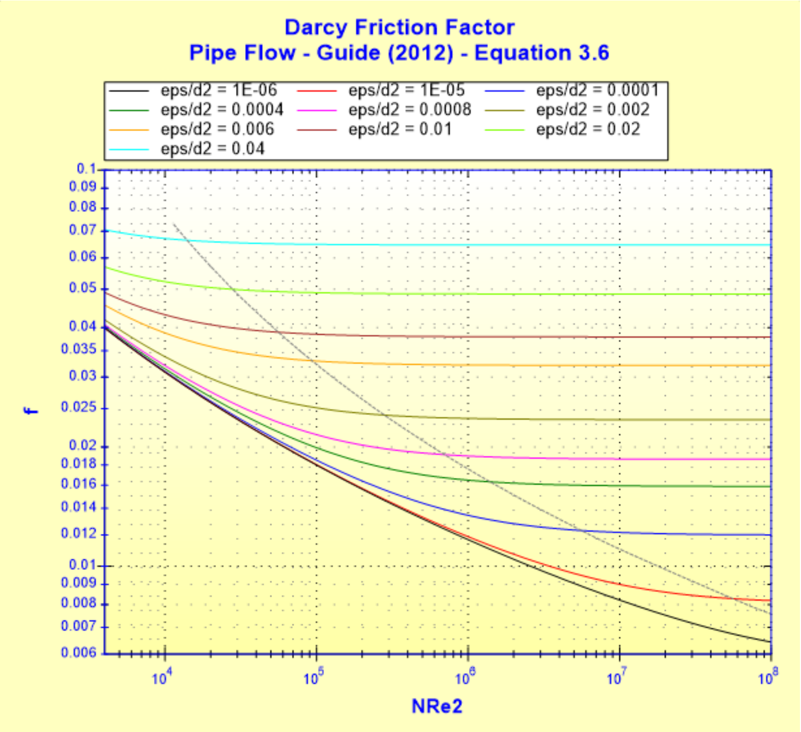
Reynolds number in minor diameter:

$$N_{Re_2} = \frac{V_2 \cdot d_2}{\nu}$$

Darcy friction factor:

$$f = \frac{1}{\left[2 \cdot \log \left(\frac{\varepsilon}{3.7 \cdot d_2} + \frac{2.51}{NRe_2 \cdot \sqrt{f}} \right) \right]^2}$$

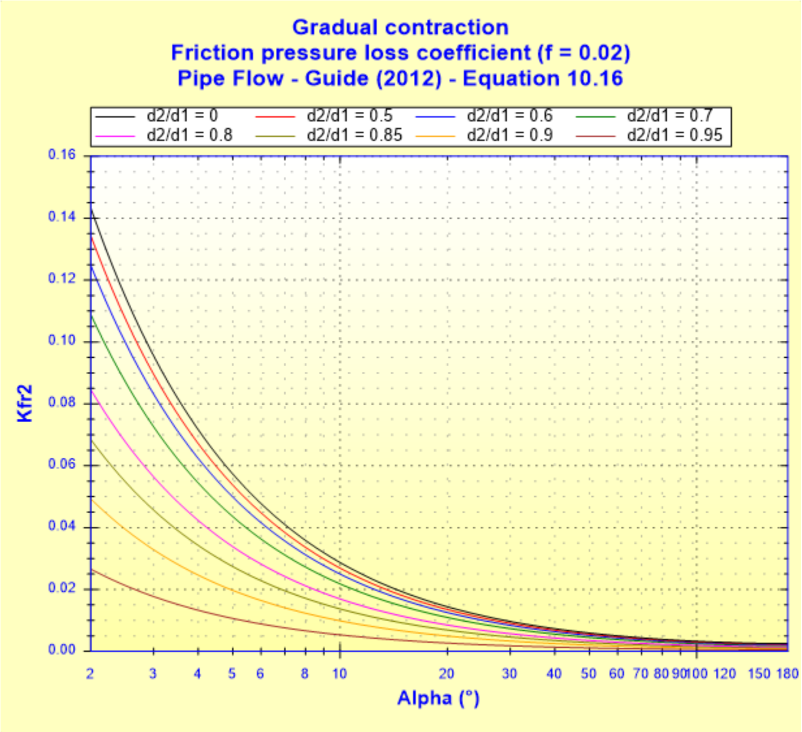
Colebrook-White equation ([1] equation 3.6)



Friction pressure loss coefficient:

$$K_{fr\,2} = \frac{f \cdot \left(1 - \beta^4\right)}{8 \cdot \sin\left(\frac{\alpha}{2}\right)}$$

([1] equation 10.16)

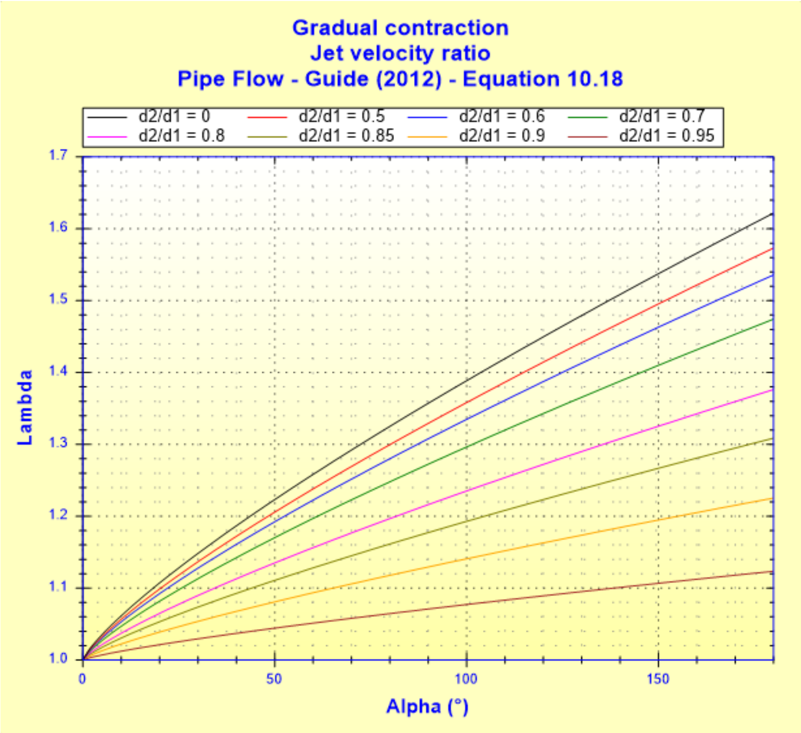


([1] equation 10.16 with f = 0.02)

Jet velocity ratio:

$$\lambda = 1 + 0.622 \cdot \left(\frac{\alpha}{180}\right)^{\frac{4}{5}} \cdot \left(1 - 0.215\beta^2 - 0.785\beta^5\right)$$

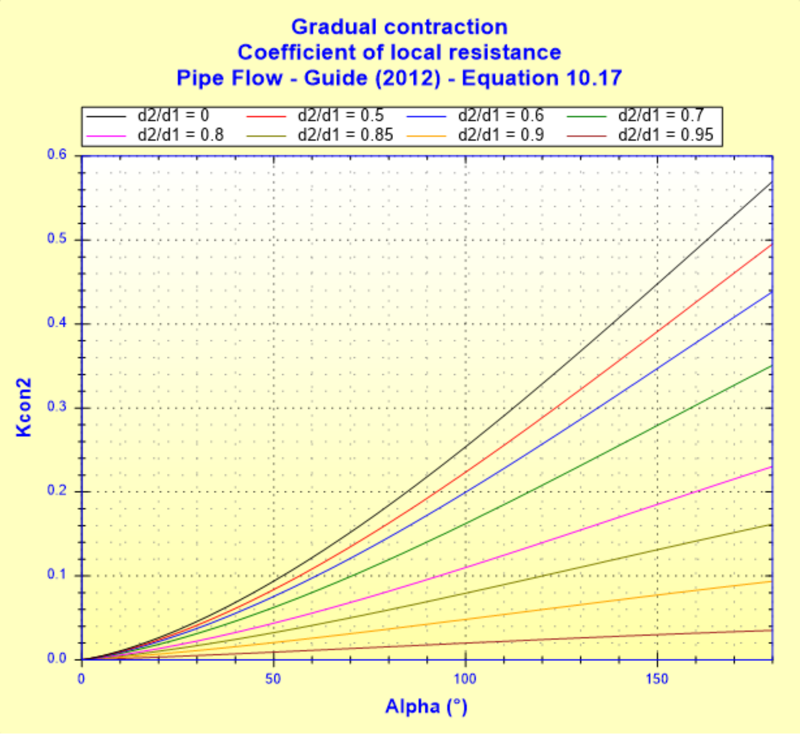
([1] equation 10.18)



Local resistance coefficient:

$$K_{con2} = 0.0696 \cdot \sin\left(\frac{\alpha}{2}\right) \cdot \left(1-\beta^5\right) \cdot \lambda^2 + (\lambda - 1)^2$$

([1] equation 10.17)



Total pressure loss coefficient (based on mean velocity in minor diameter):

$$K_2 = K_{fr2} + K_{con2}$$

([1] equation 10.11)

Total pressure loss (Pa):

$$\Delta P = K_2 \cdot \frac{\rho_m \cdot v_2^2}{2}$$

Total head loss of fluid (m):

$$\Delta H = K_2 \cdot \frac{v_2^2}{2 \cdot g}$$

Hydraulic power loss (W):

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

Symbols, Definitions, SI Units:

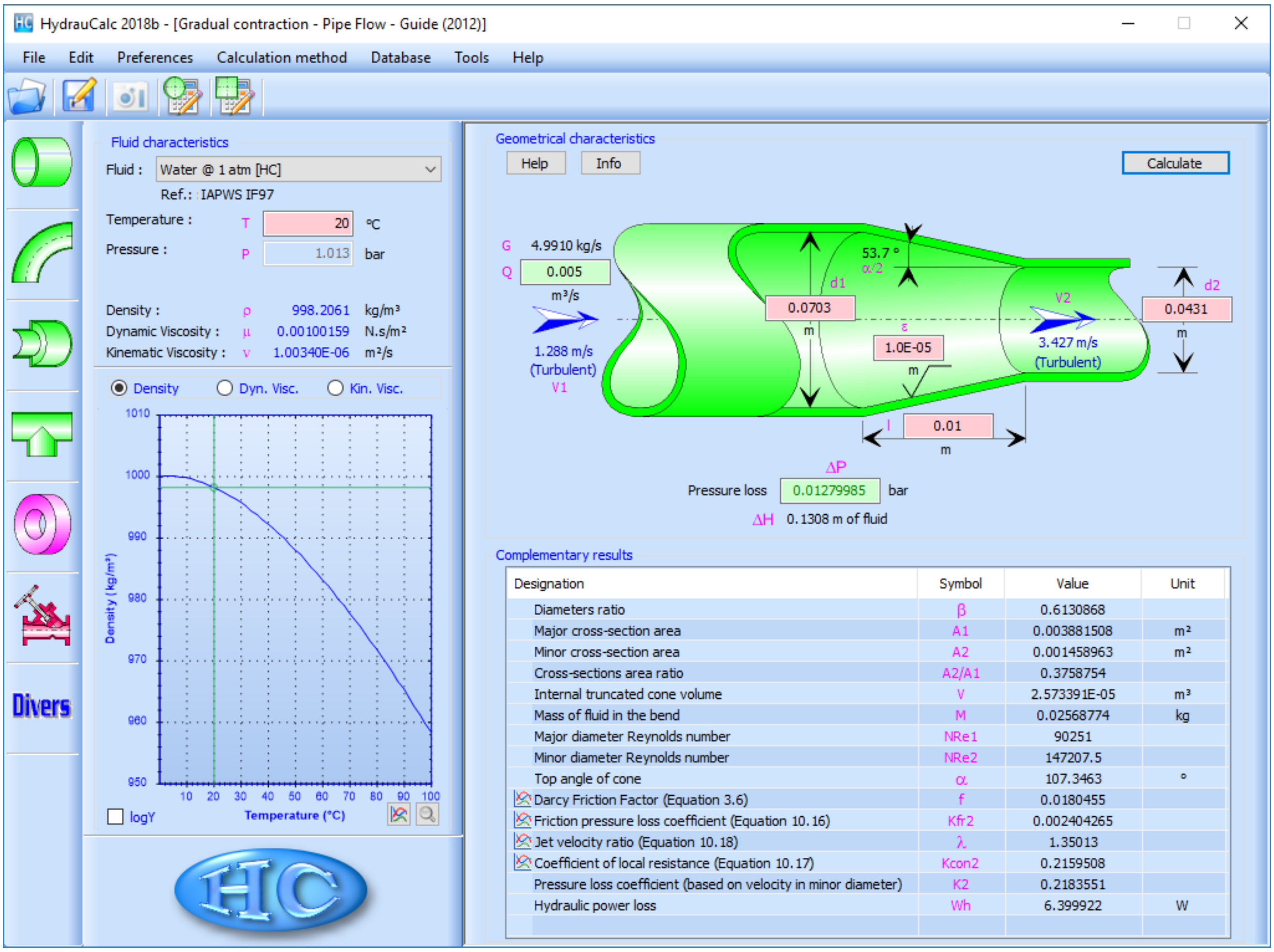
d_1	Major diameter (m)
d_2	Minor diameter (m)
β	Ratio of small to large diameter ()
l	Contraction length (m)
α	Top cone angle (°)
A_1	Major cross-sectional area (m^2)
A_2	Minor cross-sectional area (m^2)
V_1	Mean velocity in major diameter (m/s)
V_2	Mean velocity in minor diameter (m/s)

Q	Volume flow rate (m^3/s)
G	Mass flow rate (kg/s)
V	Fluid volume in the truncated cone (m^3)
M	Fluid mass in the truncated cone (kg)
NRe_1	Reynolds number in major diameter ()
NRe_2	Reynolds number in minor diameter ()
f	Darcy friction factor ()
ε	Absolute roughness of the cone walls (m)
Kfr_2	Friction pressure loss coefficient ()
λ	Jet velocity ratio ()
$Kcon_2$	Local resistance coefficient ()
K_2	Total pressure loss coefficient (based on mean velocity in minor diameter) ()
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 minor diameter ($NRe_2 \geq 10^4$)

Example of application:



References:

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