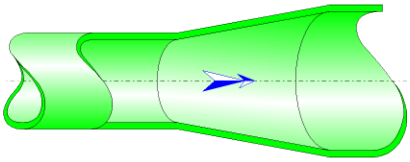
Gradual Expansion
Circular Cross-Section
(CRANE)



Model description:

This model of component calculates the head loss (pressure drop) generated by the flow in a gradual expansion.

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:

$$\boxed{\beta = \frac{D_1}{D_2}}$$

Half top angle of cone (°):

$$\boxed{\theta = \tan^{-1}\left(\frac{D_2 - D_1}{2 \cdot L}\right)}$$

Minor cross-sectional area (m²):

$$\boxed{A_1 = \pi \cdot \frac{D_1^{\,2}}{4}}$$

Major cross-sectional area (m²):

$$\boxed{A_2 = \pi \cdot \frac{D_2^{\,2}}{4}}$$

Mean velocity in minor diameter (m/s):

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

Mean velocity in major diameter (m/s):

$$v_2 = \frac{q}{A_2}$$

Mass flow rate (kg/s):

$$G = q \cdot \rho$$

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):

$$M = V \cdot \rho$$

Reynolds number in minor diameter:

$$Re_1 = \frac{v_1 \cdot D_1}{\nu}$$

Reynolds number in major diameter:

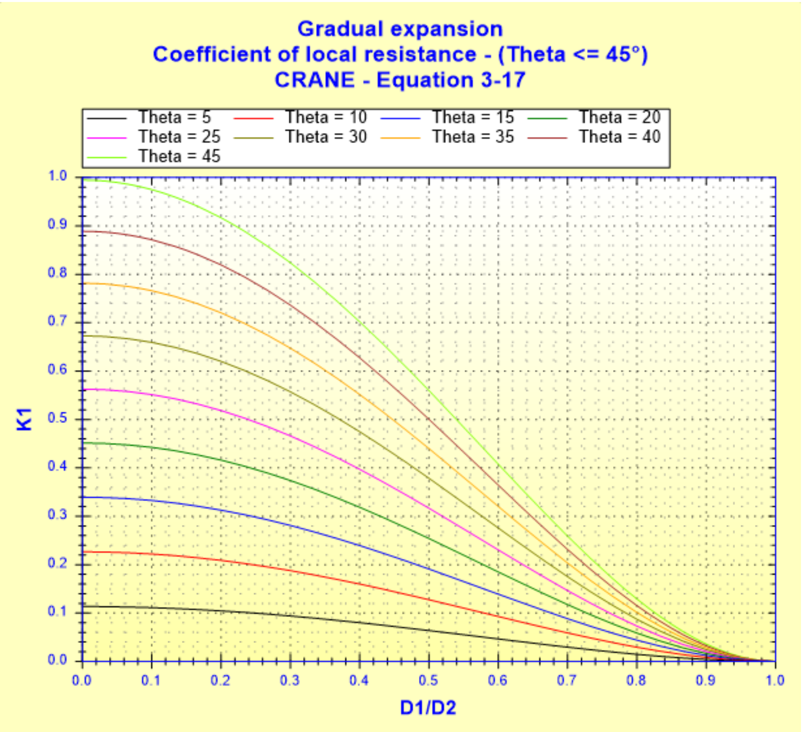
$$Re_2 = \frac{v_2 \cdot D_2}{\nu}$$

Local resistance coefficient:

- $\theta \leq 45°$:

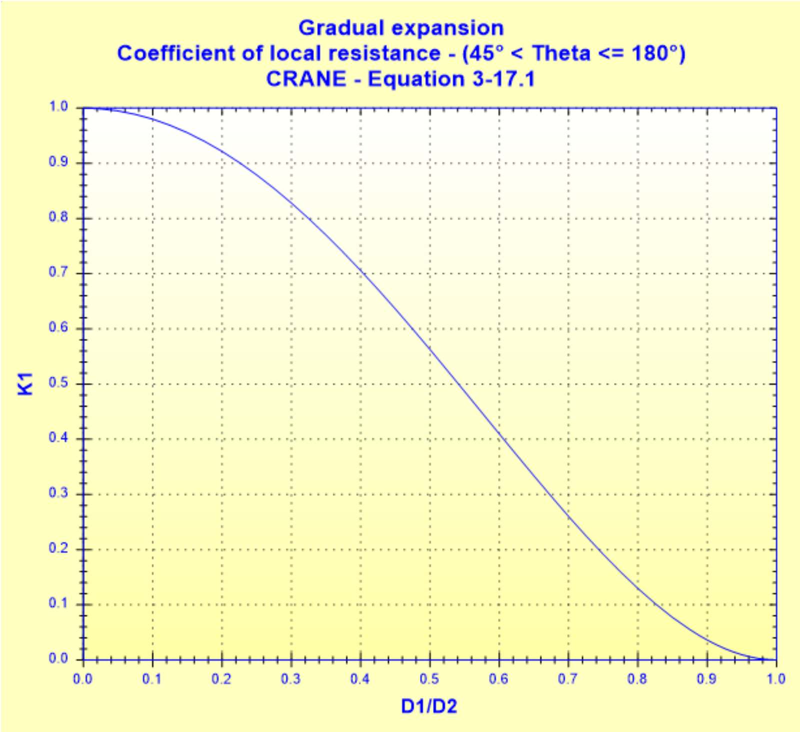
$$K_1 = 2.6 \sin\left(\frac{\theta}{2}\right)\left(1 - \beta^2\right)^2$$

(Equation 3-17)



- $45° < \theta \leq 180°$:

$$K_1 = \left(1-\beta^2\right)^2$$ (Equation 3-17.1)



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

$$K = K_1$$

Total pressure loss (Pa):

$$\Delta P = K \cdot \frac{\rho \cdot v_1^2}{2}$$

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_1	Minor diameter (m)
D_2	Major diameter (m)
β	Ratio of small to large diameter ()
θ	Half top angle of cone (°)
L	Contraction length (m)
A_1	Minor cross-sectional area (m^2)
A_2	Major cross-sectional area (m^2)
v_1	Mean velocity in minor diameter (m/s)
v_2	Mean velocity in major diameter (m/s)

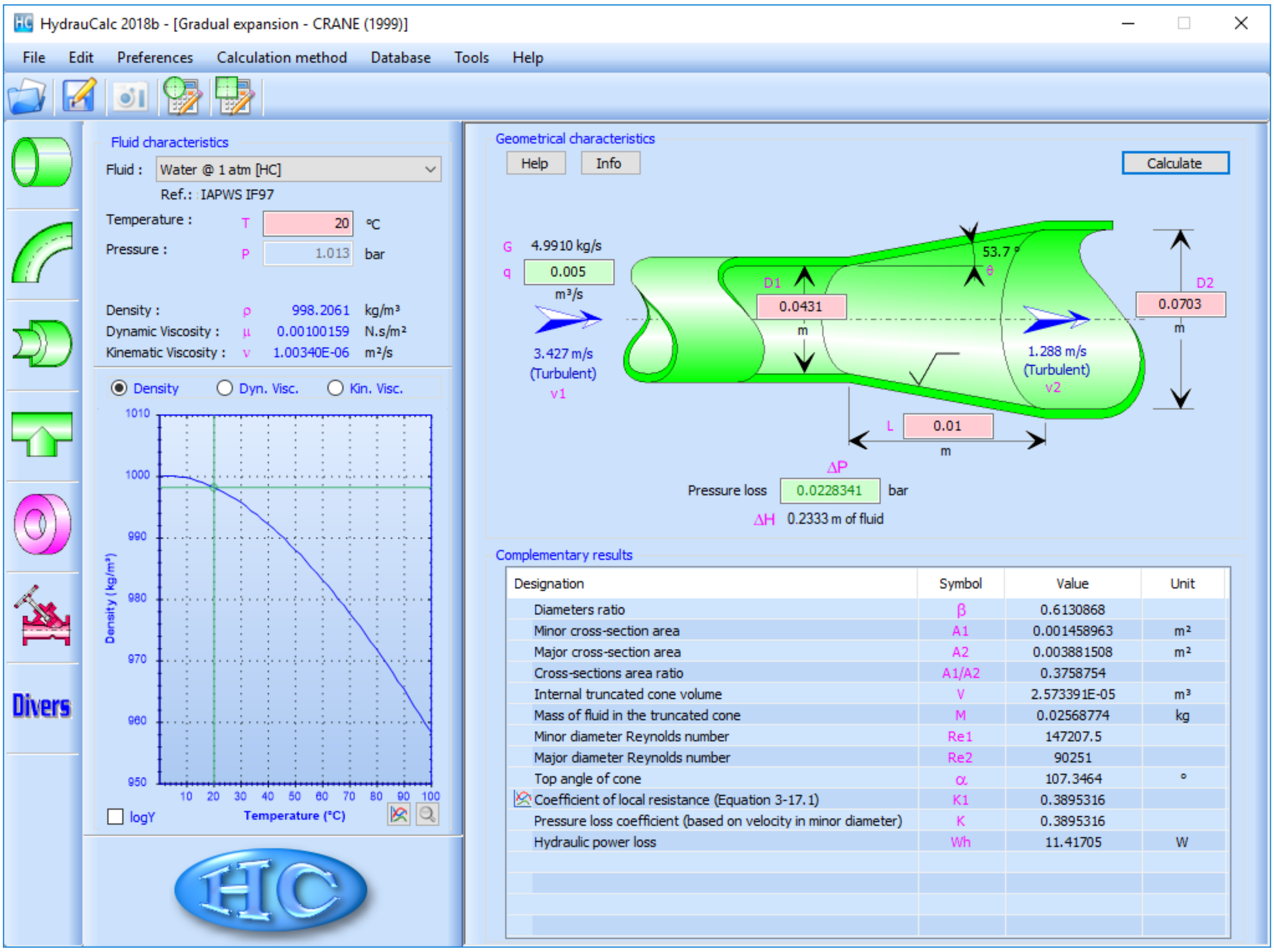
q	Volume flow rate (m^3/s)
G	Mass flow rate (kg/s)
V	Fluid volume in the truncated cone (m^3)
M	Fluid mass in the truncated cone (kg)
Re_1	Reynolds number in minor diameter ()
Re_2	Reynolds number in major diameter ()
K_1	Local resistance coefficient ()
K	Total pressure loss coefficient (based on mean velocity in minor diameter) ()
ΔP	Total pressure loss (Pa)
ΔH	Total head loss of fluid (m)
Wh	Hydraulic power loss (W)

ρ	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 ($Re_1 \geq 10^4$)

Example of application:



References:

[1] CRANE - Flow of Fluids Through Valves, Fitting and Pipe - Technical Paper No. 410 – Edition 1999