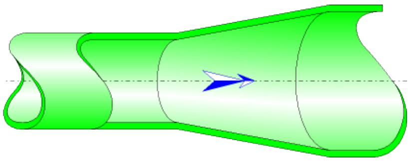
Gradual Expansion
Circular Cross-Section
(MILLER)



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:

Half top angle of cone (°):

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

Minor cross-sectional area (m²):

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

Major cross-sectional area (m²):

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

Mean velocity in minor diameter (m/s):

$$U_1 = \frac{Q}{A_1}$$

Mean velocity in major diameter (m/s):

$$U_2 = \frac{Q}{A_2}$$

Mass flow rate (kg/s):

$$G = Q \cdot \rho$$

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

$$V = N \cdot \frac{\pi}{3} \cdot \left(\left(\frac{D_1}{2}\right)^2 + \left(\frac{D_2}{2}\right)^2 + \left(\frac{D_1}{2}\right) \cdot \left(\frac{D_2}{2}\right) \right)$$

Fluid mass in the truncated cone (kg):

$$M = V \cdot \rho$$

Reynolds number in minor diameter:

$$Re_1 = \frac{U_1 \cdot D_1}{\nu}$$

Reynolds number in major diameter:

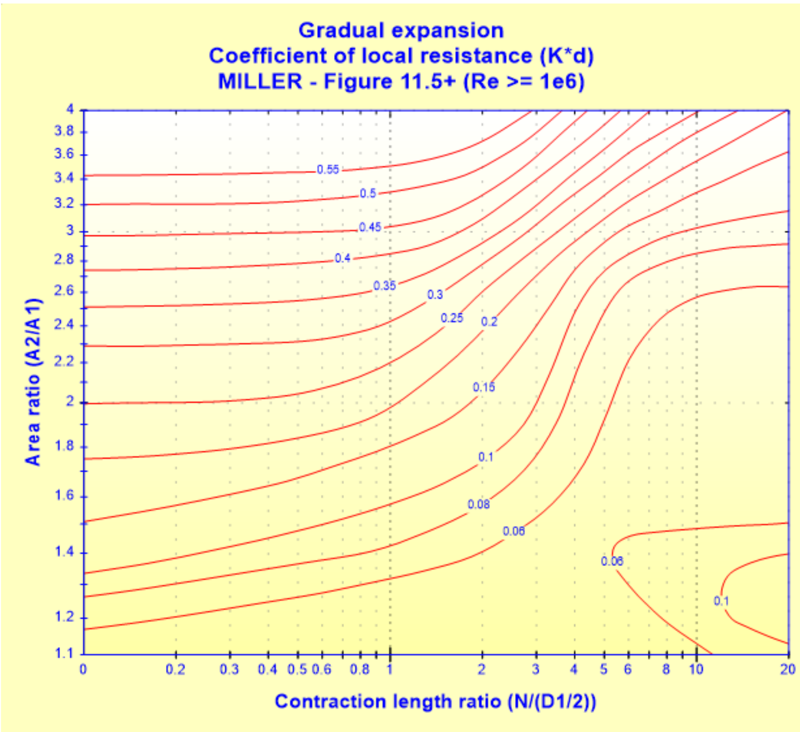
$$Re_2 = \frac{U_2 \cdot D_2}{\nu}$$

Local resistance coefficient:

- $Re_1 \geq 10^4$

$$K_{*d} = f\left(\frac{N}{D_1/2}, \frac{A_2}{A_1}\right)$$

([1] figure 11.5+)



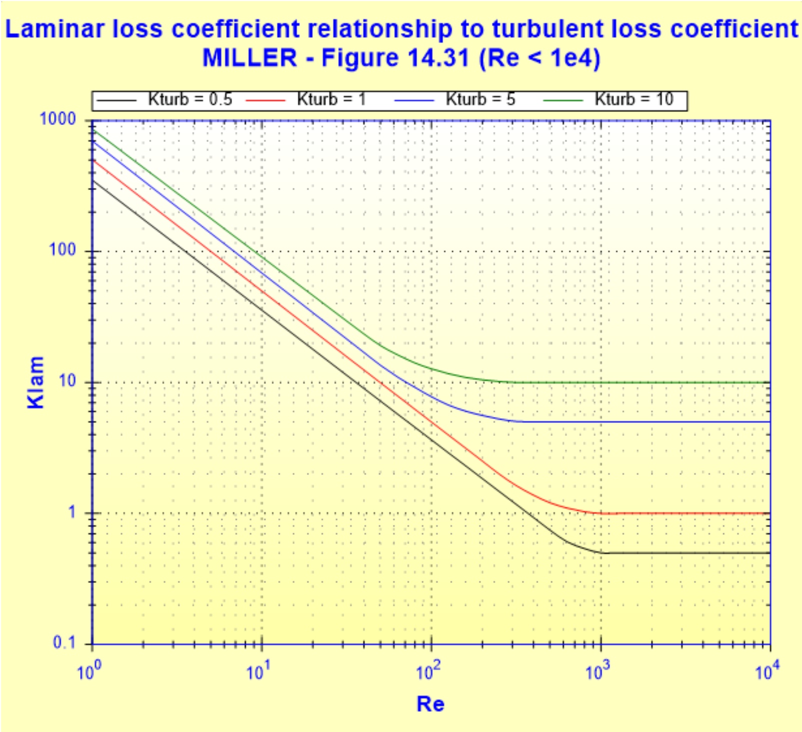
- $Re_1 < 10^4$

$$K_{lam} = f(K_{turb}, Re_1)$$

([1] figure 14.31)

where:

K_{turb} is the local resistance coefficient in turbulent regime (K_{*d} for $Re_1 = 10^4$ - figure 11.5+)



Reynolds Number Correction ($Re_1 < 10^4$):

$$C_{Re} = \frac{K_{lam}}{K_{turb}}$$

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

- turbulent flow ($Re_1 \geq 10^4$):

$$K = K_{*d}$$

- laminar flow ($Re_1 < 10^4$):

$$K = K_{lam}$$

Total pressure loss (Pa):

$$\Delta P = K \cdot \frac{\rho \cdot U_1^2}{2}$$

Total head loss of fluid (m):

$$\Delta H = K \cdot \frac{U_1^2}{2 \cdot g}$$

Hydraulic power loss (W):

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

Symbols, Definitions, SI Units:

D_1 Minor diameter (m)

D_2 Major diameter (m)
N Truncated cone length (m)
θ Half top angle of cone (°)
A_1 Minor cross-sectional area (m²)
A_2 Major cross-sectional area (m²)
Q Volume flow rate (m³/s)
U_1 Mean velocity in minor diameter (m/s)
U_2 Mean velocity in major diameter (m/s)
G Mass flow rate (kg/s)
V Fluid volume in the truncated cone (m³)
M Fluid mass in the truncated cone (kg)
Re_1 Reynolds number in minor diameter ()
Re_2 Reynolds number in major diameter ()
K^*_d Local resistance coefficient for $Re_1 \geq 10^4$ ()
K_{turb} Local resistance coefficient for $Re_1 = 10^4$ ()
K_{lam} Local resistance coefficient for $Re_1 < 10^4$ ()
C_{Re} Reynolds number correction ()
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/m³)
ν Fluid kinematic viscosity (m²/s)
g Gravitational acceleration (m/s²)

Validity range:

- any flow regime: laminar and turbulent
- area ratio (A2/A1) between 1.1 and 4
- contraction length ratio (N/(D1/2)) less than 20

note: for Reynolds number "Re_1" lower than 10^4, and coefficients "K_{turb}" lower than 0.5 or greater than 10, the laminar pressure loss coefficient "K_{lam}" is extrapolated

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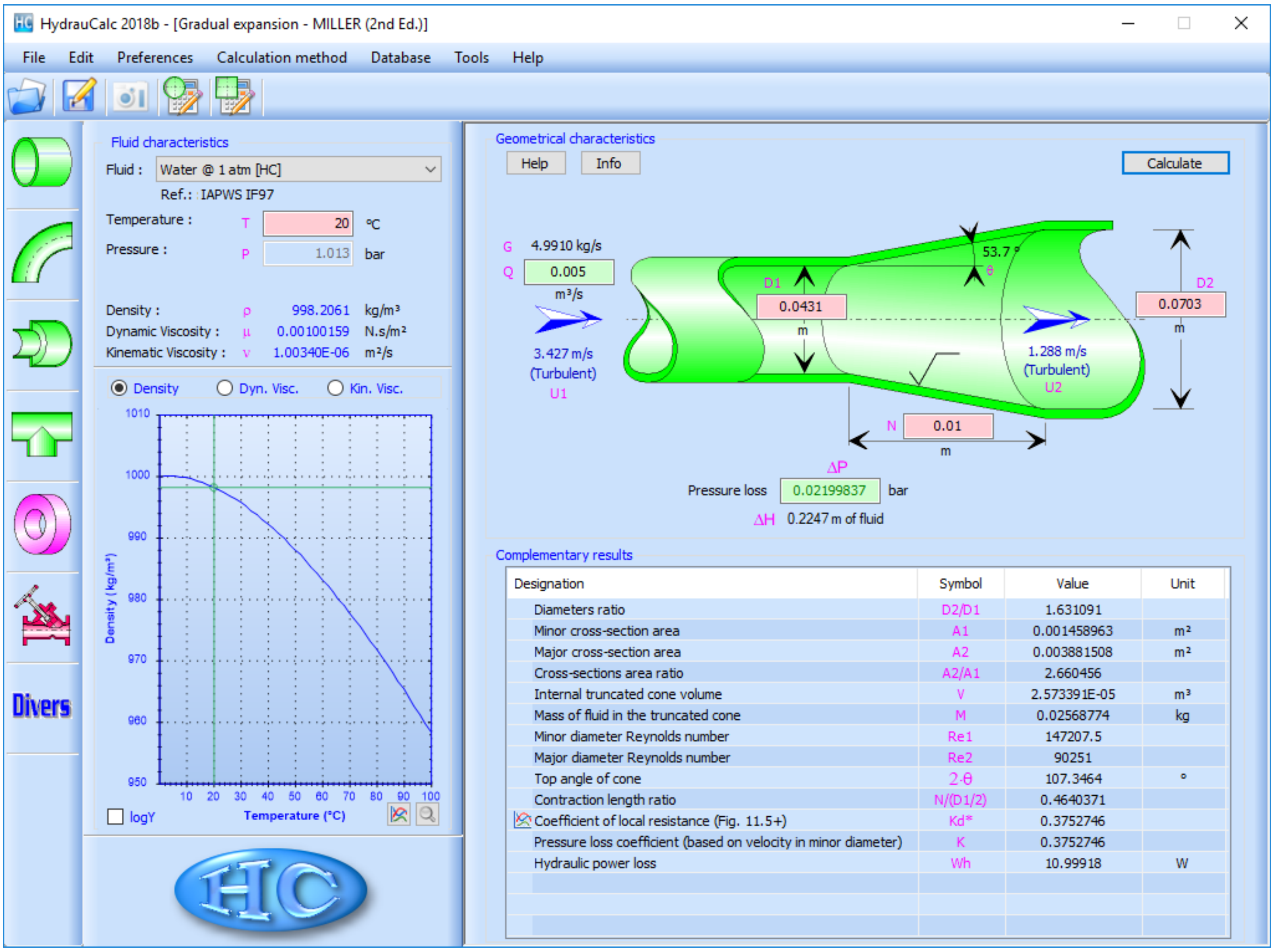
Example of application:



References:

[1] Internal Flow System, Second Edition, D.S. Miller