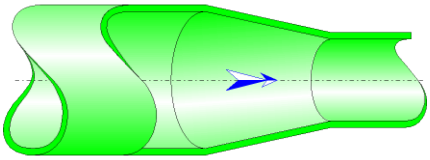
Gradual Contraction
Circular Cross-Section
(MILLER)



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 inlet and outlet piping is not taken into account in this component.

Model formulation:

Half top angle of cone (°):

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

Major cross-sectional area (m²):

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

Minor cross-sectional area (m²):

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

Mean velocity in major diameter (m/s):

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

Mean velocity in minor 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 major diameter:

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

Reynolds number in minor diameter:

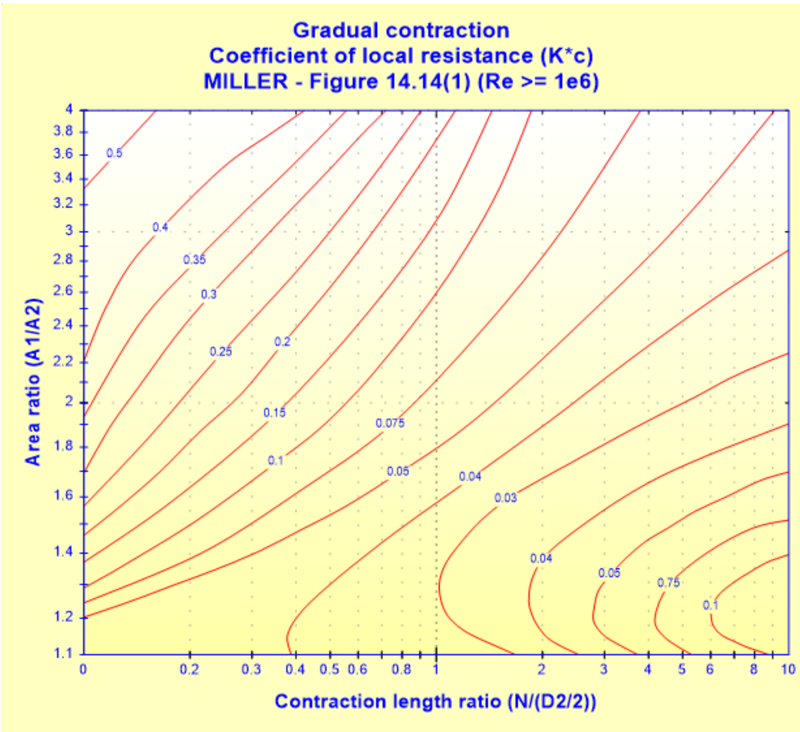
$$Re_2 = \frac{U_2 \cdot D_2}{\nu}$$

Local resistance coefficient:

- $Re_2 \geq 10^4$

$$K^*_c = f\left(\frac{N}{D_2/2}, \frac{A_1}{A_2}\right)$$

([1] figure 14.14+)



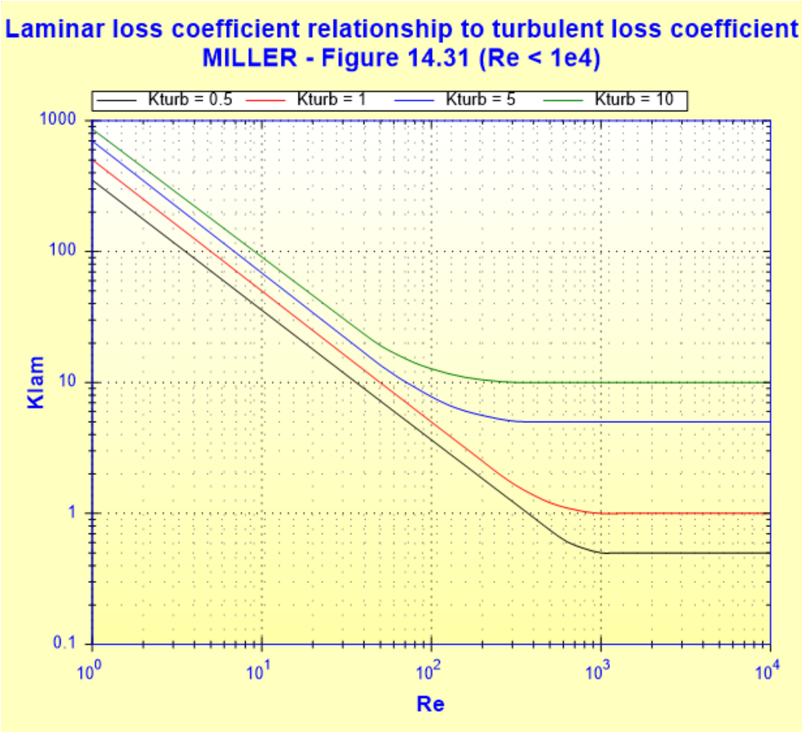
- $Re_2 < 10^4$

$$K_{lam} = f(K_{turb}, Re_2)$$

([1] figure 14.31)

where:

K_{turb} is the local resistance coefficient in turbulent regime (K_s for $Re_2 = 10^4$ - figure 14.14+)



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 ($Re_2 \geq 10^4$):

$$K = K^*_c$$

- laminar flow ($Re_2 < 10^4$):

$$K = K_{lam}$$

Total pressure loss (Pa):

$$\Delta P = K \cdot \frac{\rho \cdot U_2^{\ 2}}{2}$$

Total head loss of fluid (m):

$$\Delta H = K \cdot \frac{U_2^{\ 2}}{2 \cdot g}$$

Hydraulic power loss (W):

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

Symbols, Definitions, SI Units:

D_1	Major diameter (m)
D_2	Minor diameter (m)
N	Contraction length (m)
θ	Half top angle of cone (°)
A_1	Major cross-sectional area (m^2)
A_2	Minor cross-sectional area (m^2)
U_1	Mean velocity in major diameter (m/s)
U_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)
Re_1	Reynolds number in major diameter ()
Re_2	Reynolds number in minor diameter ()
K^*_c	Local resistance coefficient for $Re_2 \geq 10^4$ ()
K_{turb}	Local resistance coefficient for $Re_2 = 10^4$ ()
K_{lam}	Local resistance coefficient for $Re_2 < 10^4$ ()
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/m^3)
ν	Fluid kinematic viscosity (m^2/s)
g	Gravitational acceleration (m/s^2)

Validity range:

- any flow regime: laminar and turbulent
- area ratio (A1/A2) between 1.1 and 4
- contraction length ratio (N/(D2/2)) less than 10

  note: for Reynolds number "Re_2" lower than 10^4, and coefficients "K_{turb}" lower than 0.5 or greater than 10, the laminar pressure loss coefficient is extrapolated

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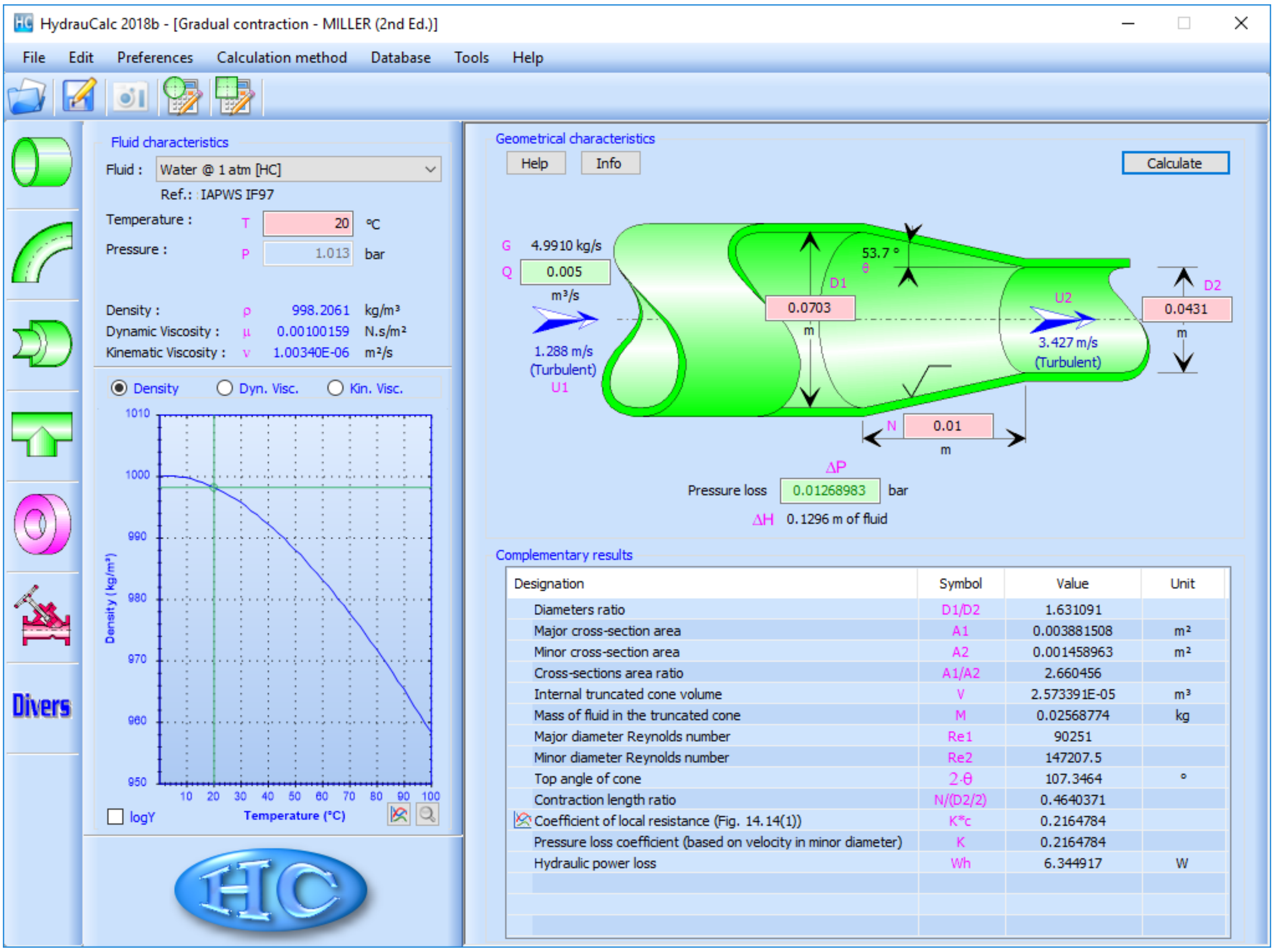
Example of application:



Designation	Symbol	Value	Unit
Diameters ratio	D1/D2	1.631091	
Major cross-section area	A1	0.003881508	m²
Minor cross-section area	A2	0.001458963	m²
Cross-sections area ratio	A1/A2	2.660456	
Internal truncated cone volume	V	2.573391E-05	m³
Mass of fluid in the truncated cone	M	0.02568774	kg
Major diameter Reynolds number	Re1	90251	
Minor diameter Reynolds number	Re2	147207.5	
Top angle of cone	2·θ	107.3464	°
Contraction length ratio	N/(D2/2)	0.4640371	
Coefficient of local resistance (Fig. 14.14(1))	K*c	0.2164784	
Pressure loss coefficient (based on velocity in minor diameter)	K	0.2164784	
Hydraulic power loss	Wh	6.344917	W

References:

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