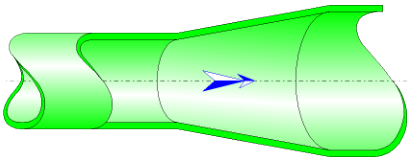
Gradual Expansion
Circular Cross-Section
(IDELCHIK)



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:

Top angle of cone (°):

$$\alpha = 2 \cdot \tan^{-1}\left(\frac{D_1 - D_0}{2 \cdot l}\right)$$

Minor cross-sectional area (m²):

$$F_0 = \pi \cdot \frac{D_0^2}{4}$$

Major cross-sectional area (m²):

$$F_1 = \pi \cdot \frac{D_1^2}{4}$$

Cross-sections ratio:

$$n_0 = \frac{F_0}{F_1}$$

Mean velocity in minor diameter (m/s):

$$w_0 = \frac{Q}{F_0}$$

Mean velocity in major diameter (m/s):

$$w_1 = \frac{Q}{F_1}$$

Mass flow rate (kg/s):

$$G = Q \cdot \rho$$

Fluid volume in the truncated cone (m³):

$$V = l \cdot \frac{\pi}{3} \cdot \left(\left(\frac{D_0}{2} \right)^2 + \left(\frac{D_1}{2} \right)^2 + \left(\frac{D_0}{2} \right) \cdot \left(\frac{D_1}{2} \right) \right)$$

Fluid mass in the truncated cone (kg):

$$M = V \cdot \rho$$

Reynolds number in minor diameter:

$$Re_0 = \frac{w_0 \cdot D_0}{\nu}$$

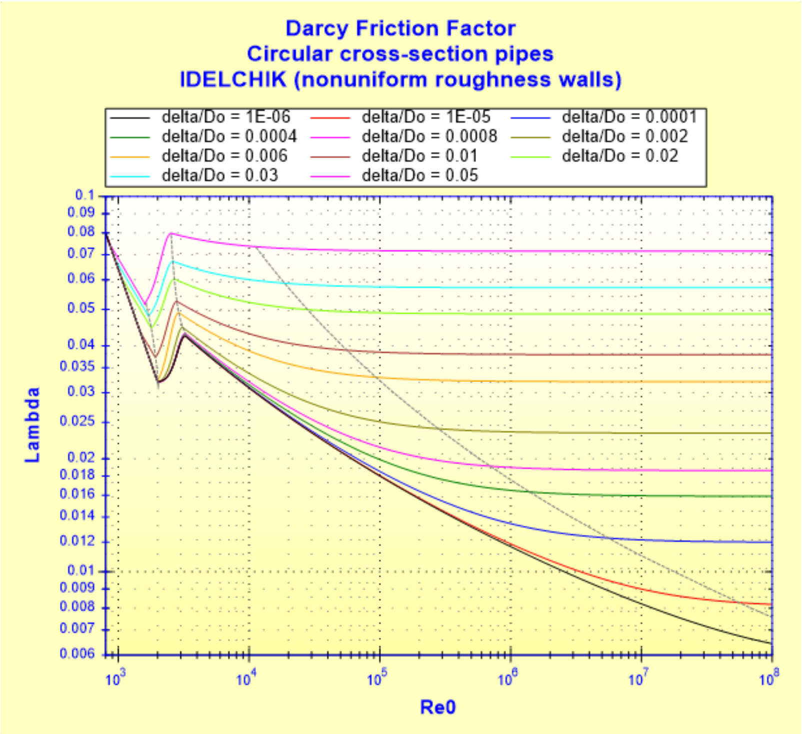
Reynolds number in major diameter:

$$Re_1 = \frac{w_1 \cdot D_1}{\nu}$$

Darcy friction factor:

$$\lambda = f\left(Re_0, \frac{\Delta}{D_0} \right)$$

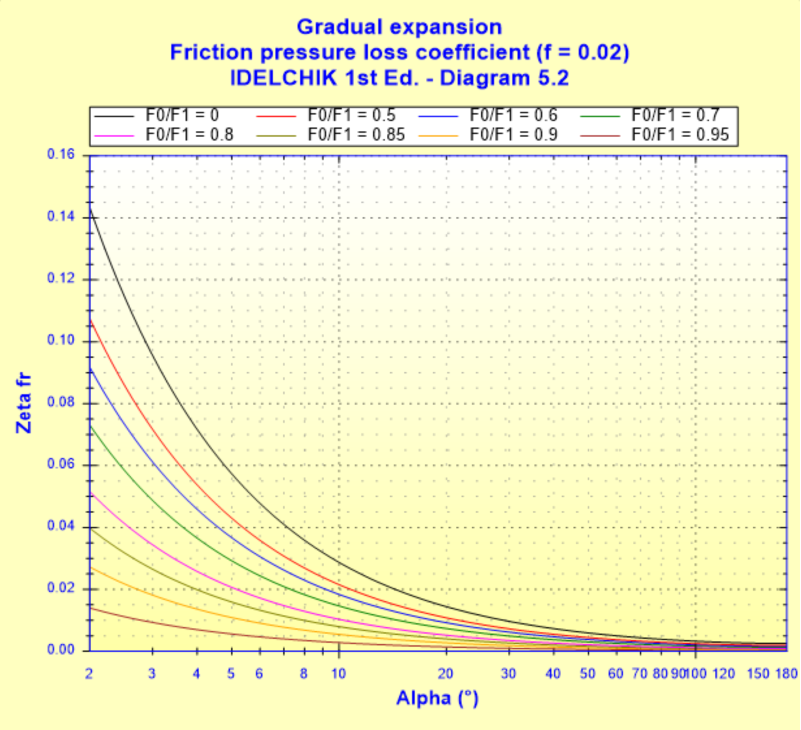
See Straight Pipe - Circular Cross-Section and Nonuniform Roughness Walls (IDELCHIK)



Friction resistance coefficient:

$$\zeta_{fr} = \frac{\lambda}{8 \cdot \sin(\alpha / 2)} \cdot \left[1 - \left(\frac{F_0}{F_1}\right)^2\right]$$

([1] diagram 5.2)

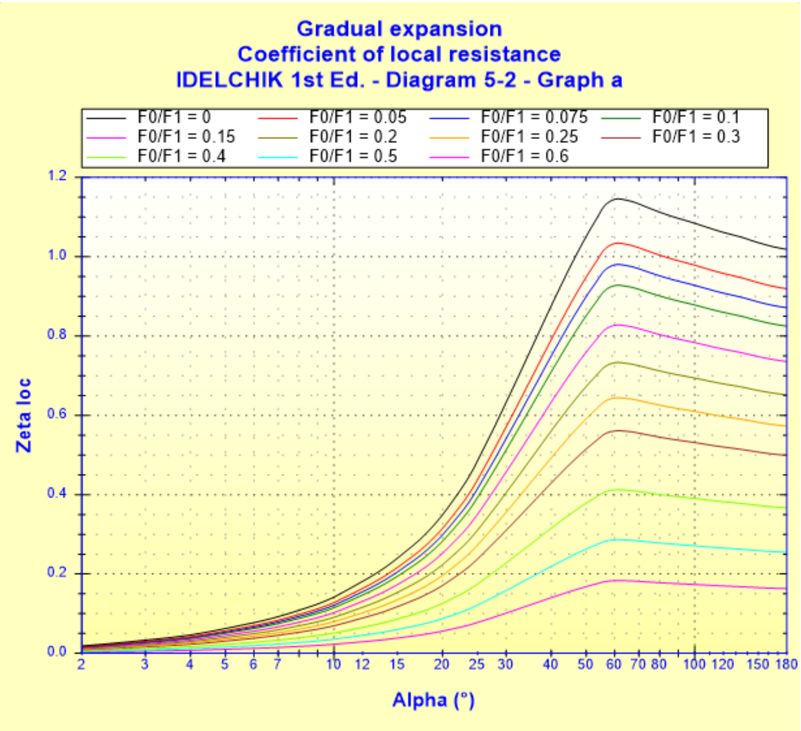


([1] diagram 5.2 with λ = 0.02)

Local resistance coefficient:

$$\zeta_{loc} = f(\alpha, \frac{F_0}{F_1})$$

([1] diagram 5.2 graph a)



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

$$\zeta = \zeta_{loc} + \zeta_{fr}$$

Total pressure loss (Pa):

$$\Delta P = \zeta \cdot \frac{\rho \cdot w_0^2}{2}$$

Total head loss of fluid (m):

$$\Delta H = \zeta \cdot \frac{w_0^2}{2 \cdot g}$$

Hydraulic power loss (W):

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

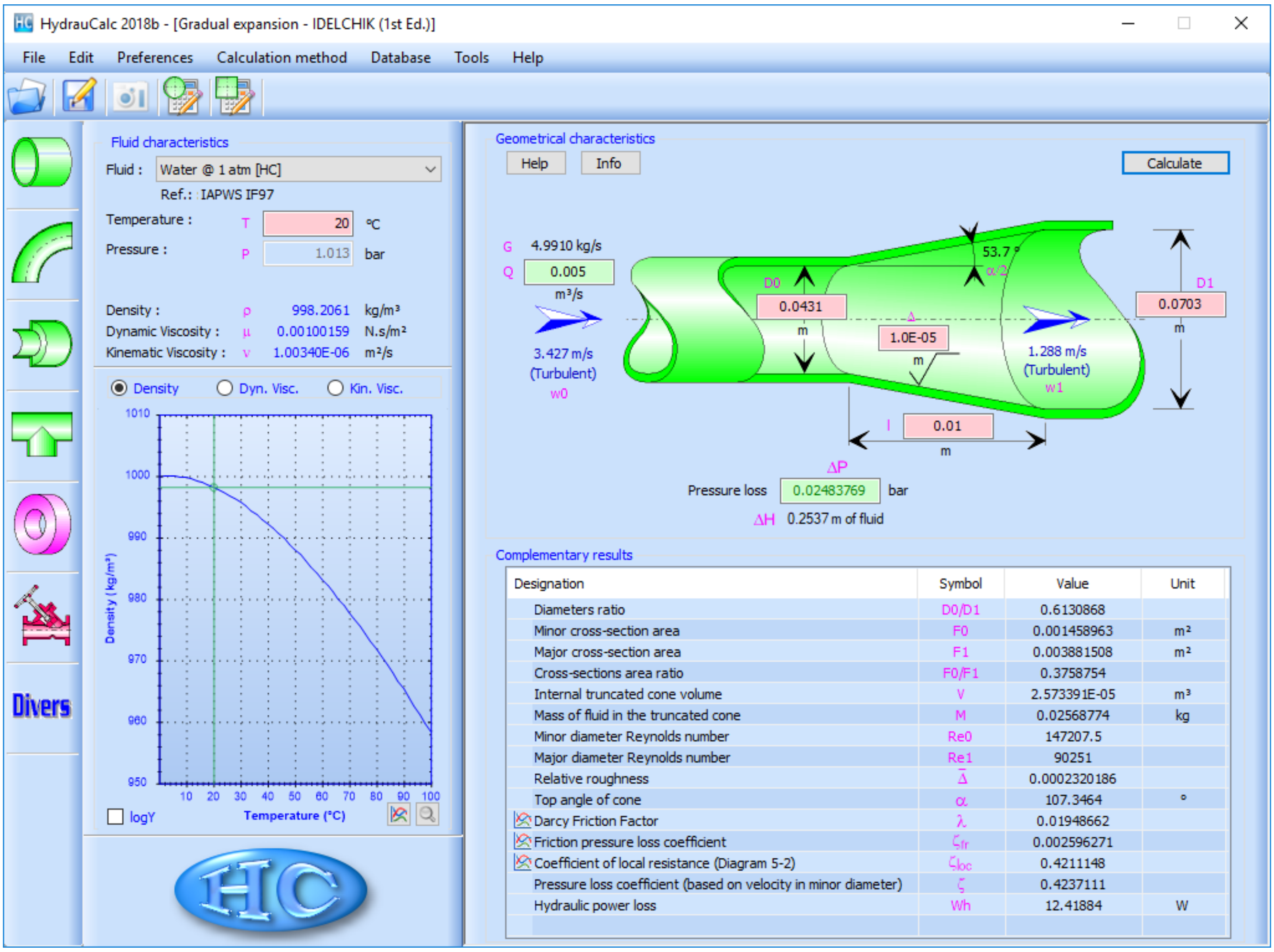
Symbols, Definitions, SI Units:

D_0	Minor diameter (m)
D_1	Major diameter (m)
α	Top angle of cone (°)
l	Truncated cone length (m)
F_0	Minor cross-sectional area (m²)
F_1	Major cross-sectional area (m²)
n_0	Cross-sections area ratio ()
w_0	Mean velocity in minor diameter (m/s)
w_1	Mean velocity in major diameter (m/s)
Q	Volume flow rate (m³/s)
G	Mass flow rate (kg/s)
V	Fluid volume in the truncated cone (m³)
M	Fluid mass in the truncated cone (kg)
Re_0	Reynolds number in minor diameter ()
Re_1	Reynolds number in major diameter ()
Δ	Absolute roughness of walls (m)
$\overline{\Delta}$	Relative roughness of walls ()
λ	Darcy friction factor ()
ζ_{loc}	Local resistance coefficient ()
ζ_{fr}	Friction resistance coefficient ()
ζ	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:

- turbulent flow regime in minor diameter ($Re_0 \geq 10^5$)

Example of application:



Designation	Symbol	Value	Unit
Diameters ratio	D0/D1	0.6130868	
Minor cross-section area	F0	0.001458963	m²
Major cross-section area	F1	0.003881508	m²
Cross-sections area ratio	F0/F1	0.3758754	
Internal truncated cone volume	V	2.573391E-05	m³
Mass of fluid in the truncated cone	M	0.02568774	kg
Minor diameter Reynolds number	Re0	147207.5	
Major diameter Reynolds number	Re1	90251	
Relative roughness	Δ̄	0.0002320186	
Top angle of cone	α	107.3464	°
Darcy Friction Factor	λ	0.01948662	
Friction pressure loss coefficient	ζfr	0.002596271	
Coefficient of local resistance (Diagram 5-2)	ζloc	0.4211148	
Pressure loss coefficient (based on velocity in minor diameter)	ζ	0.4237111	
Hydraulic power loss	Wh	12.41884	W

References:

[1] Handbook of Hydraulic Resistance, 1st Edition, I.E. Idelchik