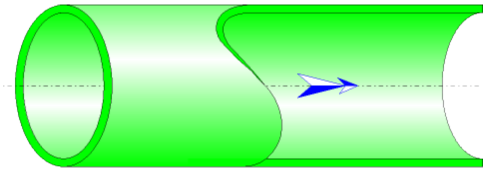
Straight Pipe
Circular Cross-Section and Smooth Walls
(IDELCHIK)



Model description:

This model of component calculates the major head loss (pressure drop) of a horizontal straight pipe of circular and constant cross-section.
In addition, the flow is assumed fully developed and stabilized.

The head loss is due to the friction of the fluid on the inner walls of the piping and is calculated with the Darcy formula. The inner wall of the piping is supposed to completely smooth (without roughness).

Darcy friction factor is determined:

- for laminar flow regime by the law of Hagen-Poiseuille,
- for turbulent flow regime by the explicit Filonenko and Althsul equation,
- for critical flow regime by interpolation between friction factors of laminar and turbulent flow.

Model formulation:

Hydraulic diameter (m):

$$\mathrm{D_h} = D_0$$

Cross-section area (m²):

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

Mean velocity (m/s):

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

Mass flow rate (kg/s):

$$G = Q \cdot \rho$$

Fluid volume in the pipe (m^3):

$$V = F_0 \cdot l$$

Fluid mass in the pipe (kg):

$$M = V \cdot \rho$$

Reynolds number:

$$\mathrm{Re} = \frac{w_0 \cdot D_h}{\nu}$$

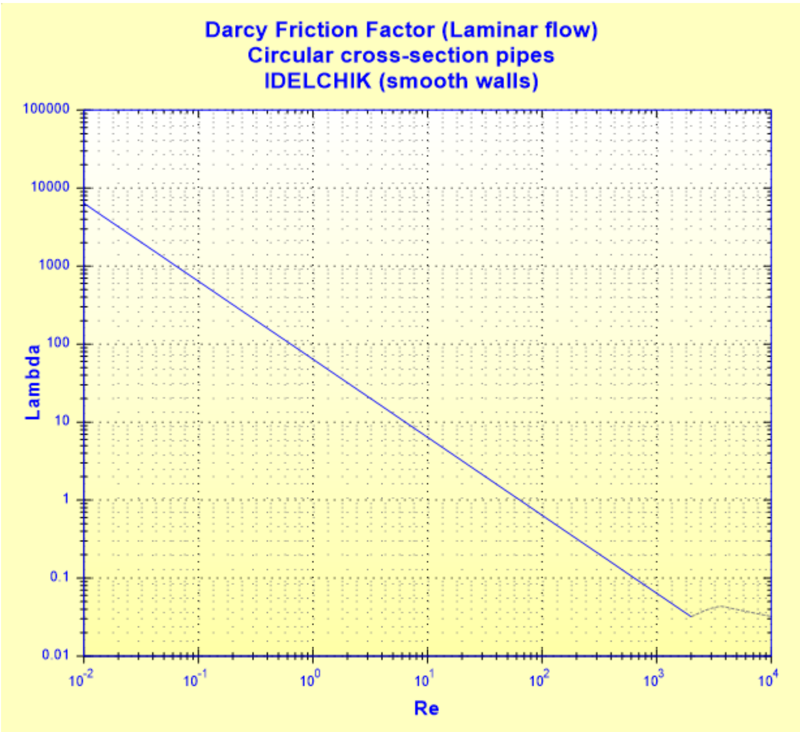
Darcy friction factor:

- laminar flow regime ($\mathrm{Re} \leq 2000$):

  Hagen-Poiseuille law

$$\lambda = \frac{64}{\mathrm{Re}}$$

([1] diagram 2.1)

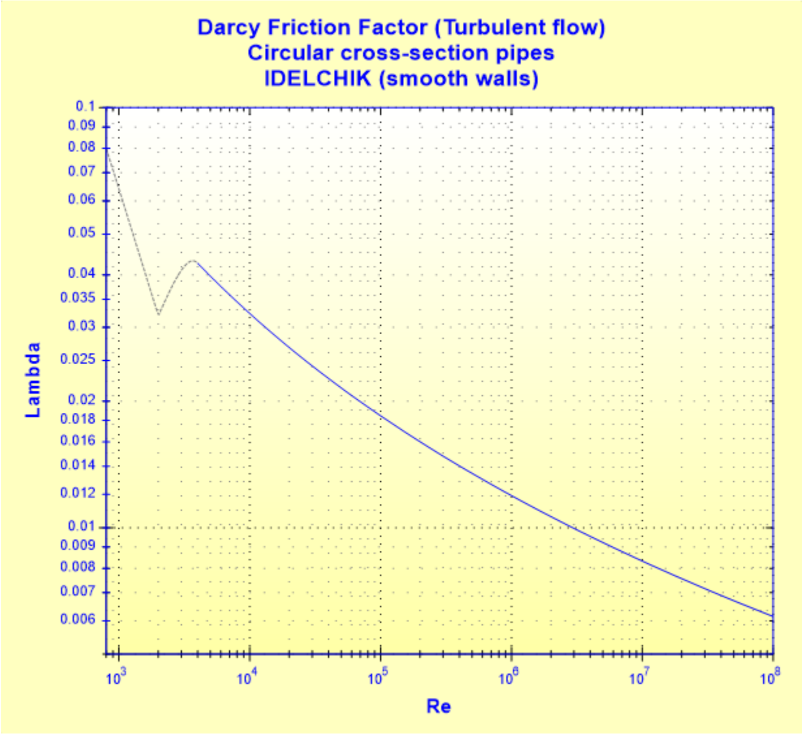


- turbulent flow regime ($\mathrm{Re} \geq 4000$):

  Filonenko and Althsul Equation

$$\lambda = \frac{1}{\left[1.8 \cdot \log(\mathrm{Re}) - 1.64\right]^2}$$

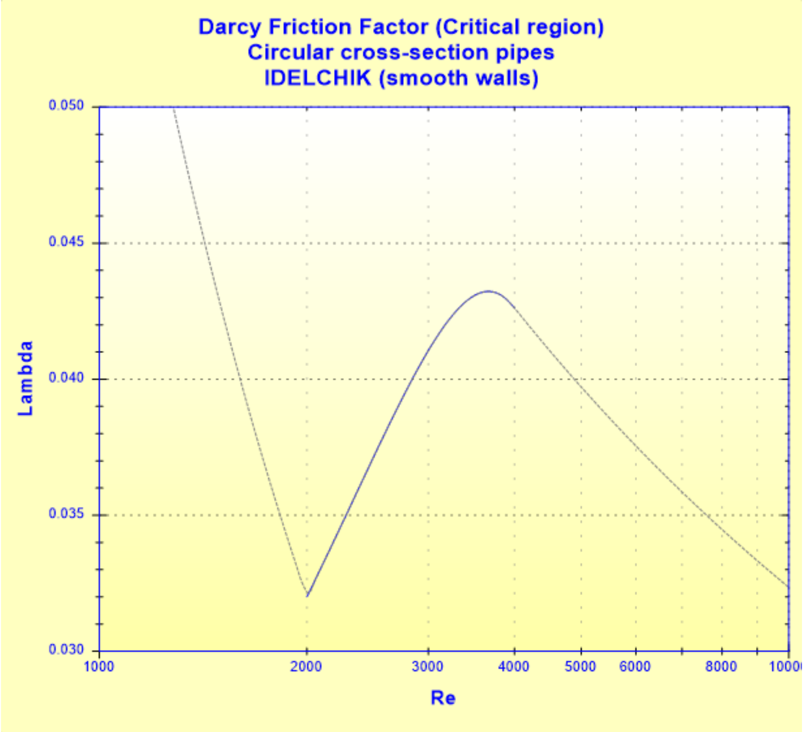
([1] diagram 2.1)



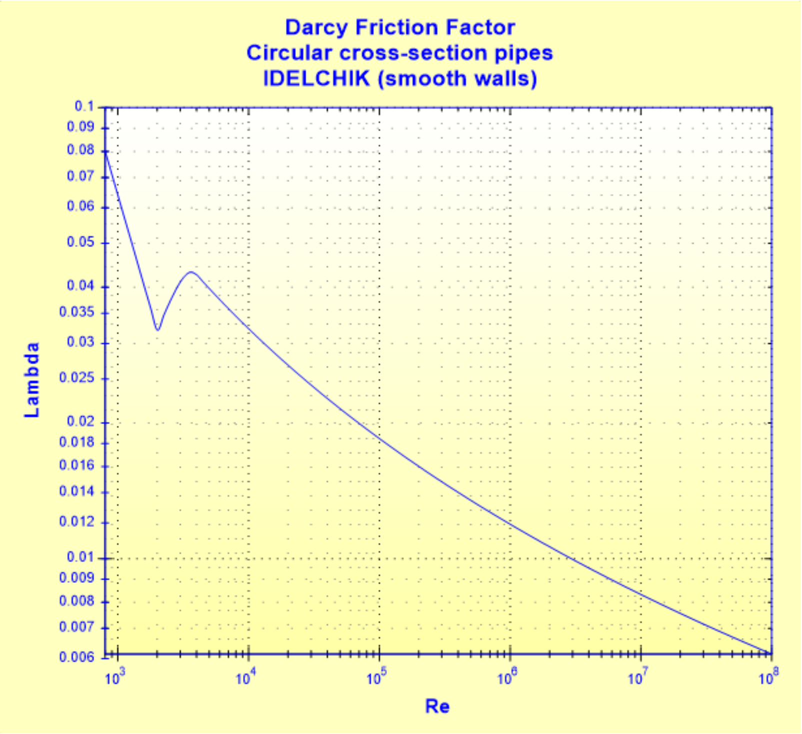
■ critical flow regime (2000 < Re < 4000):

interpolation between laminar and turbulent flows

$\boxed{\lambda = f(\text{Re})}$ ([1] diagram 2.1)



■ all flow regimes:



Pressure loss coefficient (based on the mean pipe velocity):

$$\zeta = \lambda \cdot \frac{l}{D_h}$$

([1] equation 2-2)

Total pressure loss (Pa):

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

([1] equation 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:

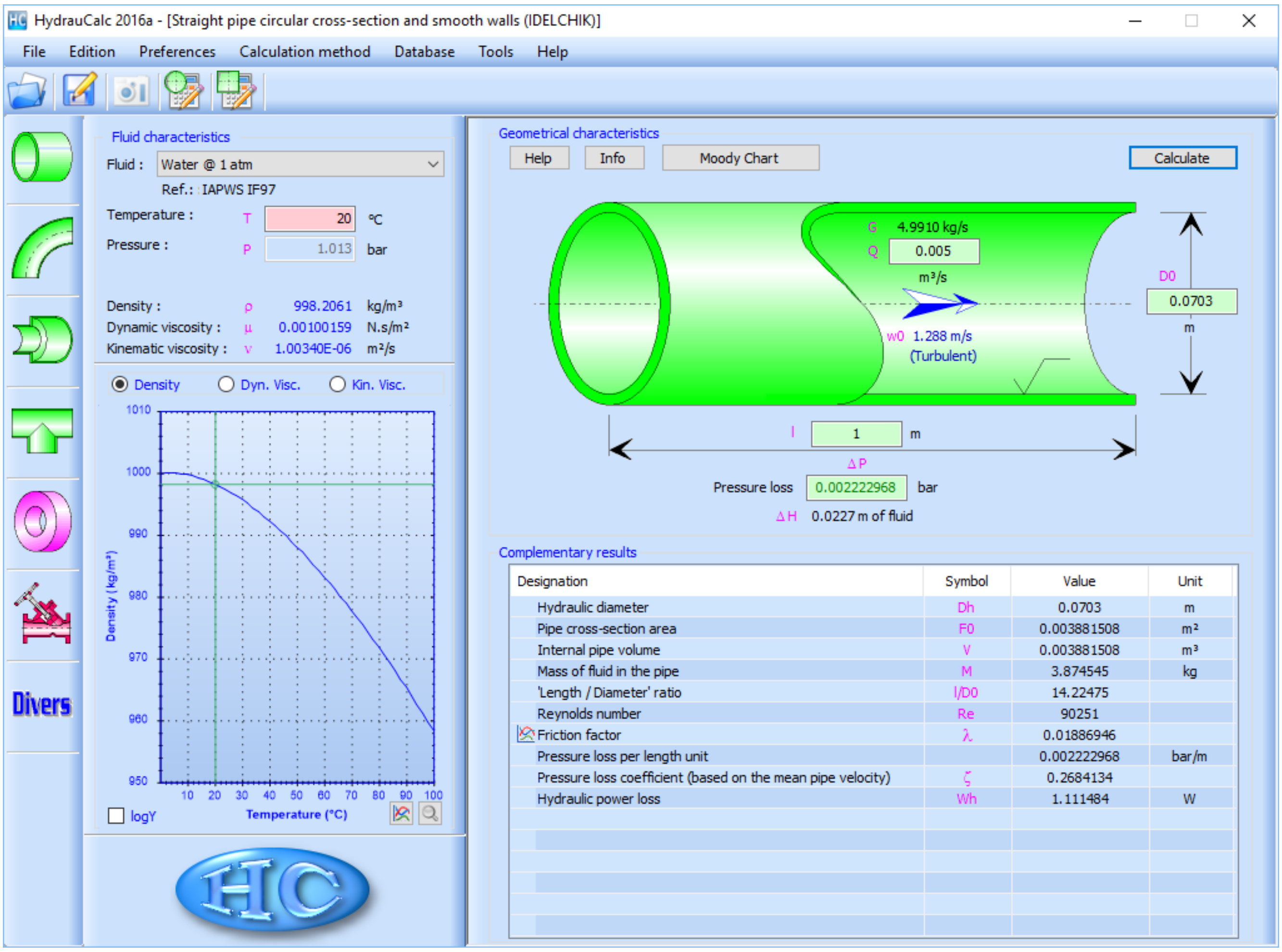
D_h	Hydraulic diameter (m)
D_0	Internal diameter (m)
F_0	Cross-sectional area (m^2)
Q	Volume flow rate (m^3/s)
G	Mass flow rate (kg/s)
w_0	Mean velocity (m/s)
l	Pipe length (m)
V	Fluid volume in the pipe (m^3)
M	Fluid mass in the pipe (kg)
Re	Reynolds number ()
λ	Darcy friction factor ()

ζ	Pressure loss coefficient (based on the mean pipe velocity) ()
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, critical and turbulent ($Re \le 10^8$)
- stabilized flow

Example of application:



References:

[1] Handbook of Hydraulic Resistance, 3rd Edition, I.E. Idelchik (2008)