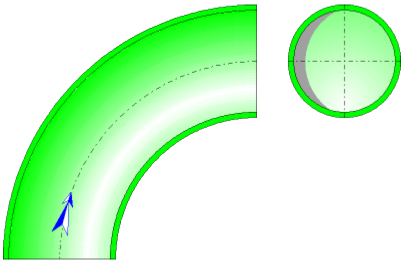
Smooth Bend
Circular Cross-Section
(Pipe Flow - Guide)



Model description:

This model of component calculates the head loss (pressure drop) of a bend smoothly curved whose cross-section is circular and constant. In addition, the flow is assumed fully developed and stabilized upstream of the bend.

Model formulation:

Cross-section area (m^2):

$$A = \pi \cdot \frac{d^2}{4}$$

Mean velocity (m/s):

$$V = \frac{Q}{A}$$

Length measured along the axis (m):

$$L = 2 \cdot \pi \cdot r \cdot \frac{\alpha}{360}$$

Mass flow rate (kg/s):

$$G = Q \cdot \rho_m$$

Fluid volume (m^3):

$$Vol = A \cdot L$$

Fluid mass (kg):

$$Mas = Vol \cdot \rho_m$$

Reynolds number:

$$N_{Re} = \frac{V \cdot d}{\nu}$$

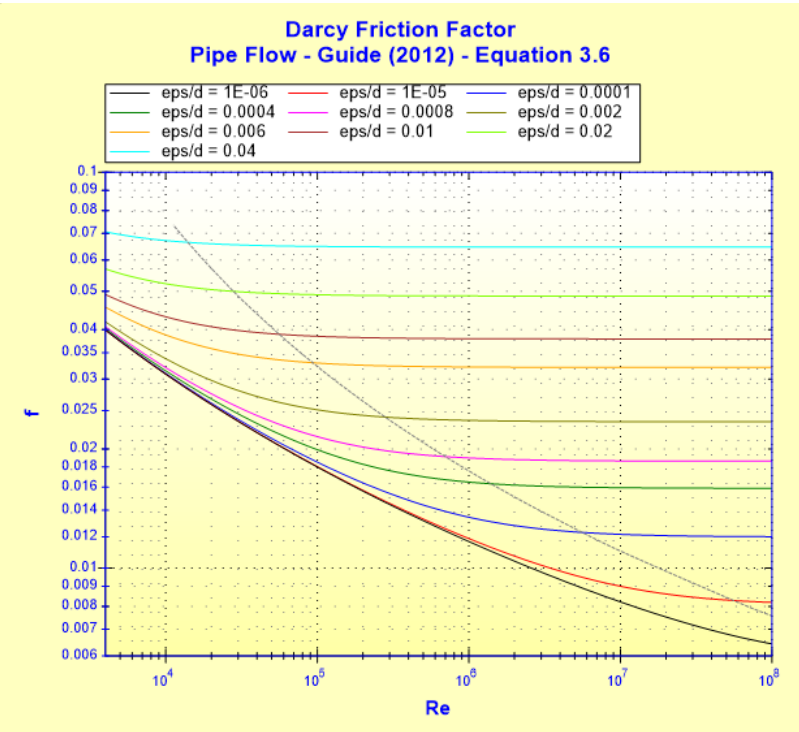
Relative roughness:

$$R_r = \frac{\varepsilon}{d}$$

Darcy friction factor:

$$f = \frac{1}{\left[2 \cdot \log\left(\frac{\varepsilon}{3.7 \cdot d} + \frac{2.51}{N_{Re} \cdot \sqrt{f}}\right)\right]^2}$$

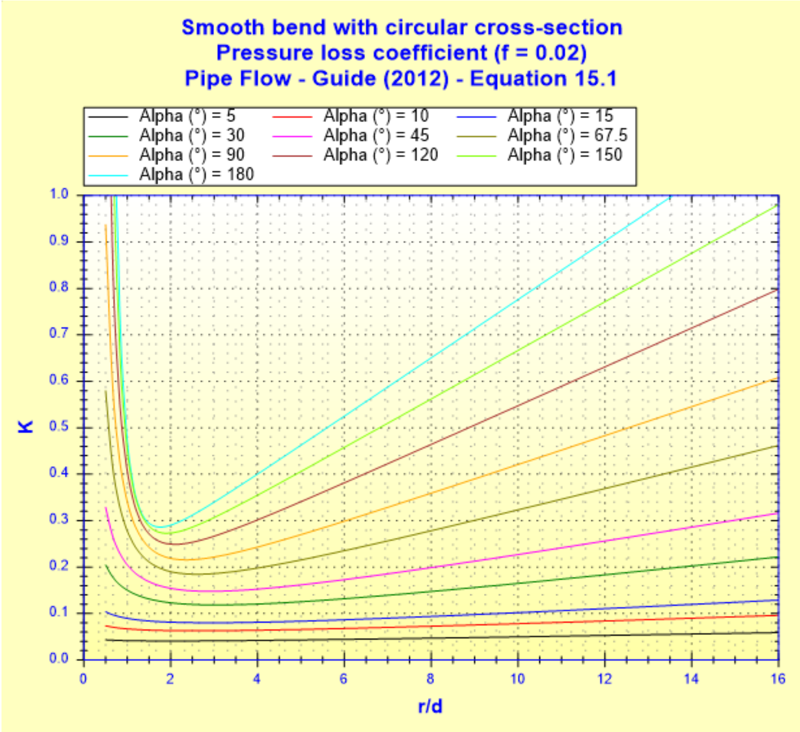
Colebrook-White equation ([1] equation 3.6)



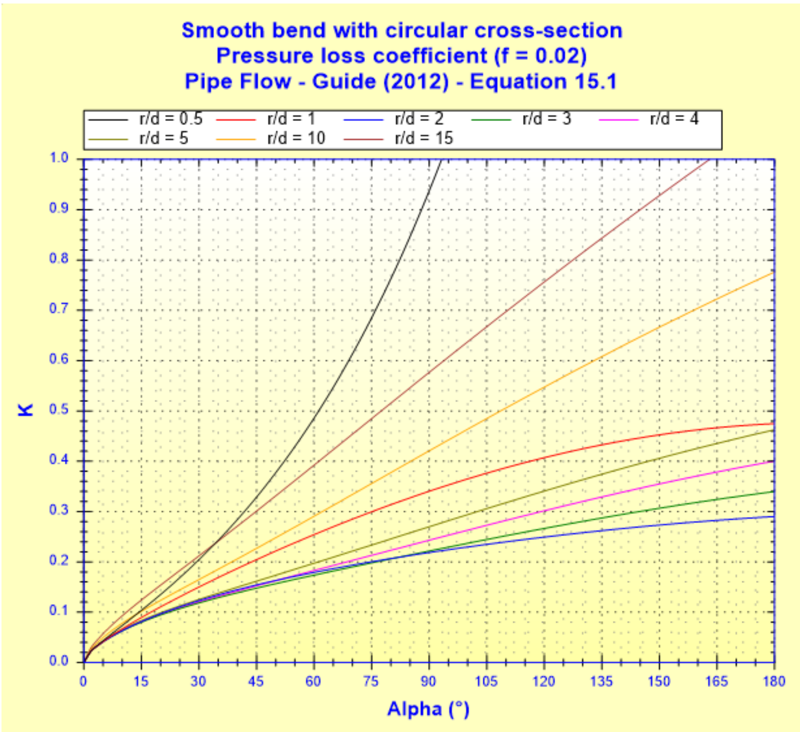
Total pressure loss coefficient (based on mean velocity in bend):

$$K = f \cdot \alpha \cdot \frac{r}{d} + (0.10 + 2.4 \cdot f) \cdot \sin(\alpha/2) + \frac{6.6 \cdot f \cdot \left(\sqrt{\sin(\alpha/2)} + \sin(\alpha/2)\right)}{\left(\frac{r}{d}\right)^{\frac{4 \cdot \alpha}{\pi}}}$$

([1] equation 15.1)



([1] equation 15.1 with f = 0.02)



([1] equation 15.1 with f = 0.02)

Total pressure loss (Pa):

$$\Delta P = K \cdot \frac{\rho_m \cdot V^2}{2}$$

Total head loss of fluid (m):

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

Hydraulic power loss (W):

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

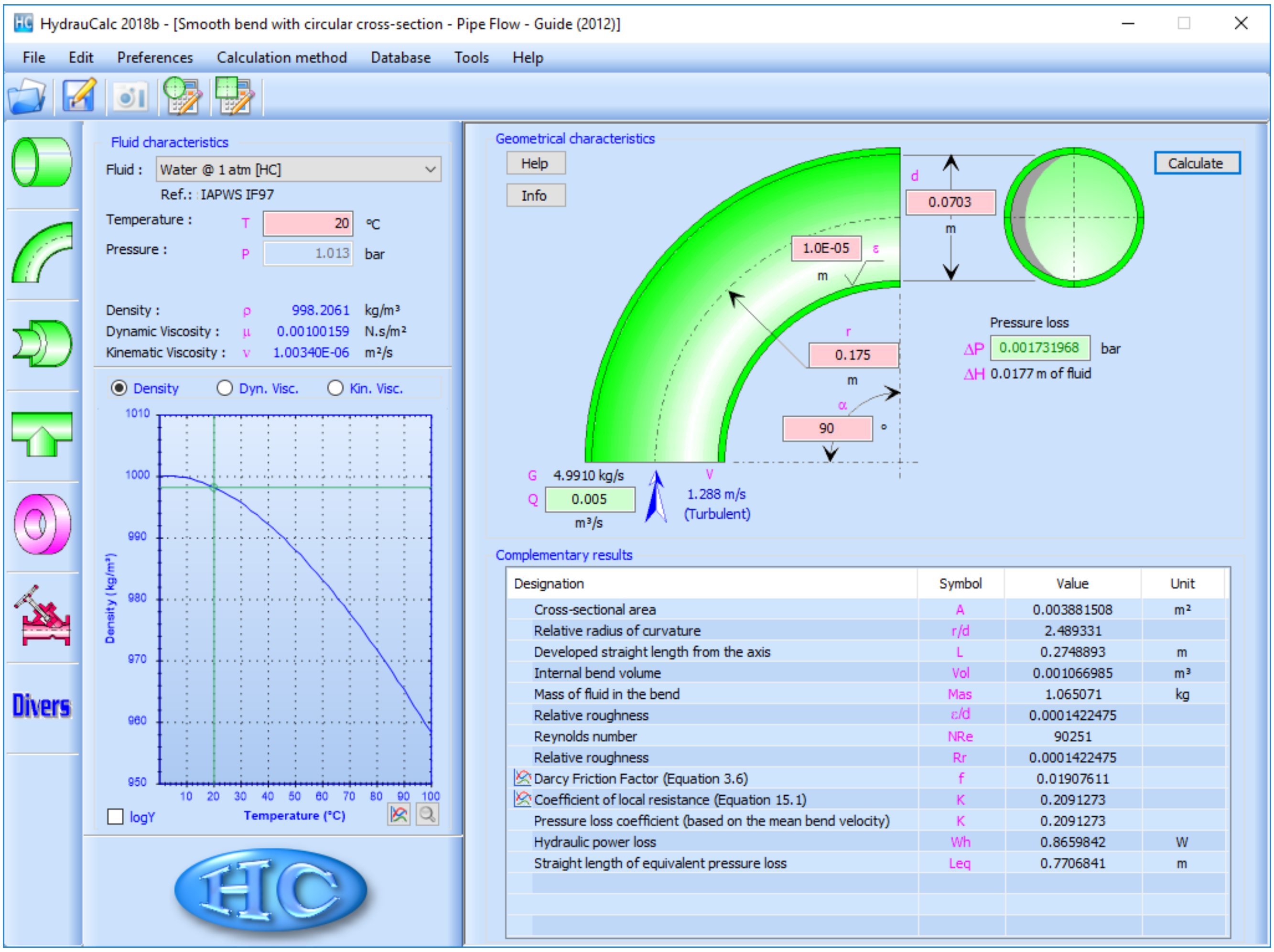
Symbols, Definitions, SI Units:

d	Pipe internal diameter (m)
A	Cross-section area (m^2)
Q	Volume flow rate (m^3/s)
V	Mean velocity (m/s)
L	Length measured along the axis (m)
r	Radius of curvature (m)
α	Curvature angle (°)
G	Mass flow rate (kg/s)
Vol	Fluid volume (m^3)
Mas	Fluid mass (kg)
N_{Re}	Reynolds number ()
R_r	Relative roughness ()
ε	Absolute roughness of walls (m)
f	Darcy friction factor
K	Total pressure loss coefficient (based on mean velocity in bend) ()
ΔP	Total pressure loss (Pa)
ΔH	Total head loss of fluid (m)
Wh	Hydraulic power loss (W)
ρ_m	Fluid density (kg/m^3)
ν	Fluid kinematic viscosity (m^2/s)
g	Gravitational acceleration (m/s^2)

Validity range:

- turbulent flow regime ($N_{Re} \geq 10^4$)
- stabilized flow upstream of the bend
- curvature angle between 0° and 180°

Example of application:



Designation	Symbol	Value	Unit
Cross-sectional area	A	0.003881508	m²
Relative radius of curvature	r/d	2.489331	
Developed straight length from the axis	L	0.2748893	m
Internal bend volume	Vol	0.001066985	m³
Mass of fluid in the bend	Mas	1.065071	kg
Relative roughness	ε/d	0.0001422475	
Reynolds number	NRe	90251	
Relative roughness	Rr	0.0001422475	
Darcy Friction Factor (Equation 3.6)	f	0.01907611	
Coefficient of local resistance (Equation 15.1)	K	0.2091273	
Pressure loss coefficient (based on the mean bend velocity)	K	0.2091273	
Hydraulic power loss	Wh	0.8659842	W
Straight length of equivalent pressure loss	Leq	0.7706841	m

References:

[1] Pipe Flow: A Practical and Comprehensive Guide. Donald C. Rennels and Hobart M. Hudson. (2012)