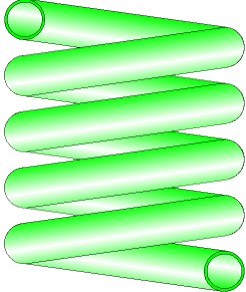




## Helical Tube (Coil) Circular Cross-Section (CRANE)



### Model description:

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

### Model formulation:

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Cross-section area (m<sup>2</sup>):

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

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Mean velocity (m/s):

$$v = \frac{q}{A}$$

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Length measured along the axis (m):

$$L = 2 \cdot \pi \cdot r \cdot N_t$$

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Mass flow rate (kg/s):

$$w = q \cdot \rho$$

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Fluid volume (m<sup>3</sup>):

$$V = A \cdot L$$

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Fluid mass (kg):

$$M = Vol \cdot \rho_m$$

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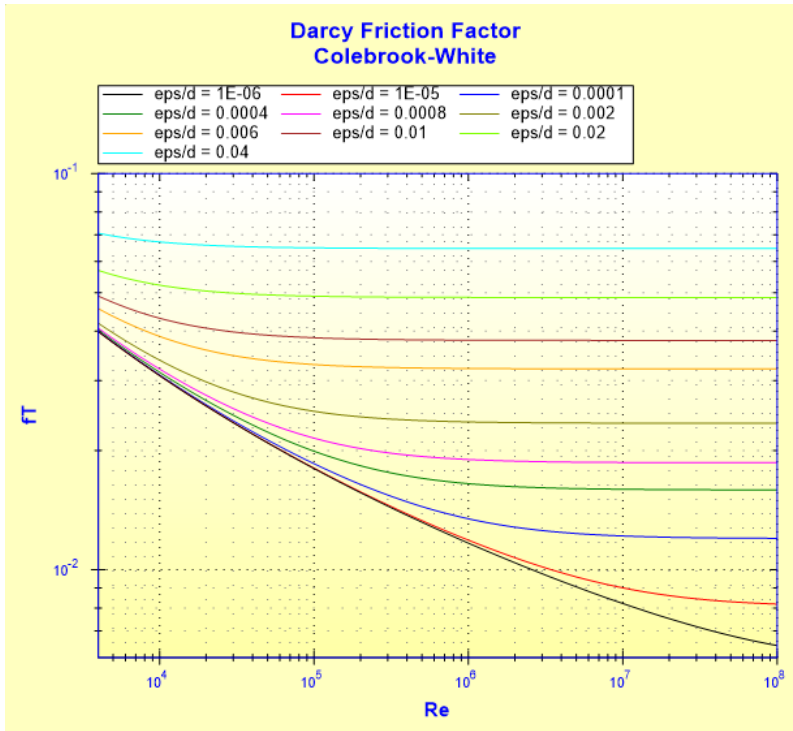
Reynolds number:

$$\text{Re} = \frac{v \cdot d}{\nu}$$

Darcy friction factor:

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

Colebrook-White equation

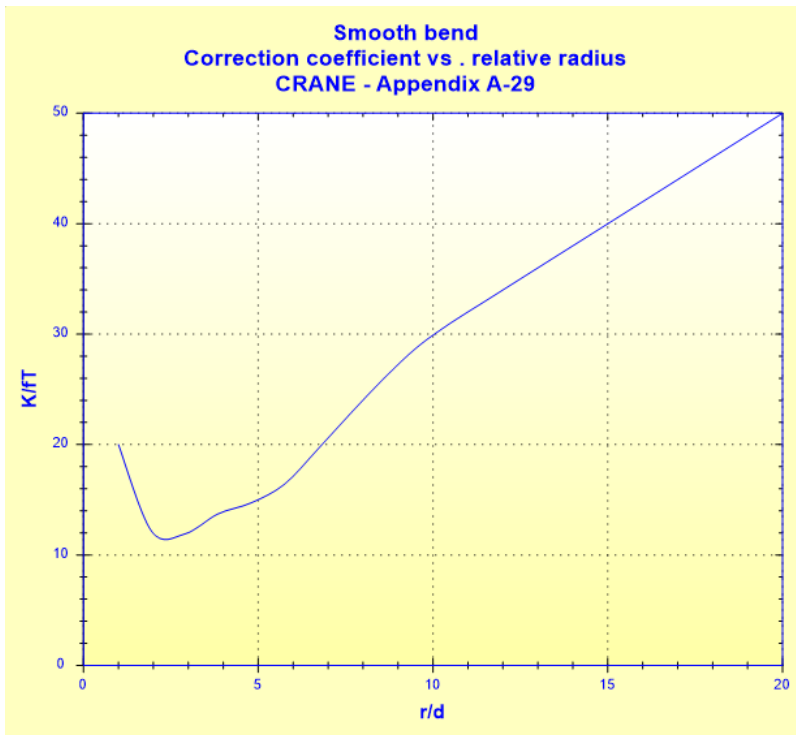


Resistance coefficient for one 90° smooth bend:

$$K = f \left( \frac{r}{d}, f_T \right)$$

([1] Appendix A-29)

$r/d$	$K$	$K/f_T$
1	$20 f_T$	20
1.5	$14 f_T$	14
2	$12 f_T$	12
3	$12 f_T$	12
4	$14 f_T$	14
6	$17 f_T$	17
8	$24 f_T$	24
10	$30 f_T$	30
12	$34 f_T$	34
14	$38 f_T$	38
16	$42 f_T$	42
20	$50 f_T$	50



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

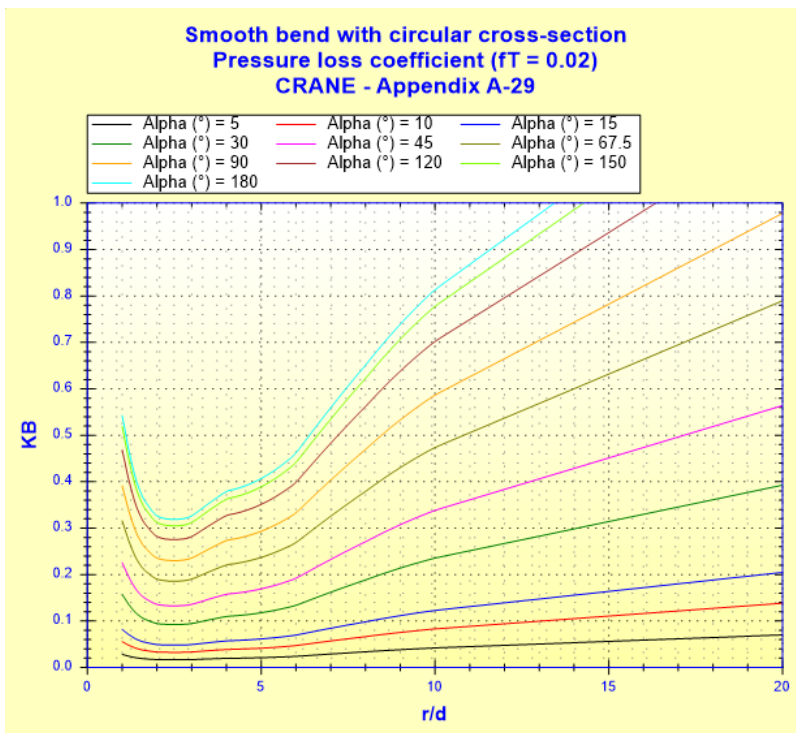
$$K_B = (n-1) \left( 0.25 \cdot \pi \cdot f_T \cdot \frac{r}{d} + 0.5 \cdot K_1 \right) + K_1 \quad ([1] \text{ Equation 2-20})$$

with:

$$n = 4 \cdot N_t$$

and:

$$K_1 = K \cdot F_t$$



(with  $f_T = 0.02$ )

Total pressure loss (Pa):

$$\Delta P = K_B \cdot \frac{\rho \cdot v^2}{2}$$

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Total head loss of fluid (m):

$$\Delta H = K_B \cdot \frac{v^2}{2 \cdot g}$$

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Hydraulic power loss (W):

$$Wh = \Delta P \cdot q$$

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Straight length of equivalent pressure loss (m):

$$L_{eq} = K_B \cdot \frac{d}{f_T}$$

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**Symbols, Definitions, SI Units:**

d	Internal diameter of the helical tube (m)
A	Cross-section area (m <sup>2</sup> )
q	Volume flow rate (m <sup>3</sup> /s)
v	Mean velocity (m/s)
N <sub>t</sub>	Number of turns constituting the helical tube ( )
r	Radius of curvature (m)
L	Length measured along the axis (m)
w	Mass flow rate (kg/s)
V	Fluid volume (m <sup>3</sup> )
M	Fluid mass (kg)
Re	Reynolds number ( )
ε	Absolute roughness of walls (m)
f <sub>T</sub>	Darcy friction factor
n	Number of 90° bends constituting the helical tube ( )
K <sub>1</sub>	Resistance coefficient for one 90° smooth bend ( )
K <sub>B</sub>	Total pressure loss coefficient (based on mean velocity in helical tube) ( )
ΔP	Total pressure loss (Pa)
ΔH	Total head loss of fluid (m)
Wh	Hydraulic power loss (W)
L <sub>eq</sub>	Straight length of equivalent pressure loss (m)
ρ	Fluid density (kg/m <sup>3</sup> )
ν	Fluid kinematic viscosity (m <sup>2</sup> /s)
g	Gravitational acceleration (m/s <sup>2</sup> )

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**Validity range:**

- turbulent flow regime (Re ≥ 10<sup>4</sup>)
- stabilized flow upstream of the helical tube

- relative radius of curvature ( $r/d$ ) range between 1 and 20  
for relative radii ' $r/d$ ' between 0.5 and 1 or those greater than 20, the coefficient ' $K$ ' is linearly extrapolated.

### Example of application:

The screenshot displays the HydraulCalc 2021a software interface for a helical tube calculation. The window title is "HydrauCalc 2021a - [Helical tube with circular cross-section - CRANE (1999)]".

**Fluid characteristics:**

- Fluid: Water @ 1 atm [HC]
- Ref.: IAPWS IF97
- Temperature:  $T = 20$  °C
- Pressure:  $P = 1.013$  bar
- Density:  $\rho = 998.2061$  kg/m<sup>3</sup>
- Dynamic Viscosity:  $\mu = 0.00100159$  N.s/m<sup>2</sup>
- Kinematic Viscosity:  $\nu = 1.00340E-06$  m<sup>2</sup>/s

**Geometrical characteristics:**

- Velocity:  $v = 1.132$  m/s (Turbulent)
- Mass flow rate:  $w = 4.9910$  kg/s
- Volume flow rate:  $q = 0.005$  m<sup>3</sup>/s
- Radius:  $r = 0.6$  m
- Number of turns:  $Nt = 10$
- Pressure loss:  $\Delta P = 0.09077288$  bar
- Head loss:  $\Delta H = 0.9273$  m of fluid
- Tube diameter:  $d = 0.075$  m

**Complementary results:**

Designation	Symbol	Value	Unit
Passage cross-section area	$A$	0.004417865	m <sup>2</sup>
Relative radius of curvature	$r/d$	8	
Developed straight length from the axis	$L$	37.69911	m
Internal helical tube volume	$V$	0.1665496	m <sup>3</sup>
Mass of fluid in the helical tube	$M$	166.2508	kg
Reynolds number	$Re$	84595.27	
Relative roughness	$e/d$	0.0001333333	
Darcy Friction Factor	$f_t$	0.01926448	
Resistance coefficient for one 90° smooth bend	$K$	24 ft	
Coefficient K1	$K1$	0.4623475	
Number of progressive 90° bends	$n$	40	
Coefficient of local resistance (Equation 2-20)	$KB$	14.19877	
Pressure loss coefficient (based on the mean helical tube vel...)	$KB$	14.19877	
Hydraulic power loss	$Wh$	45.38644	W
Straight length of equivalent pressure loss	$Leq$	55.27832	m

### References:

[1] CRANE - Flow of Fluids Through Valves, Fitting and Pipe - Technical Paper No. 410 - Edition 1999