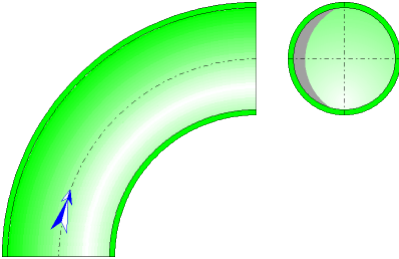




## Smooth Bend Circular Cross-Section (CRANE)



### 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:

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

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

---

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):

$$w = q \cdot \rho$$

---

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

$$V = A \cdot L$$

---

Fluid mass (kg):

$$M = Vol \cdot \rho_m$$

---

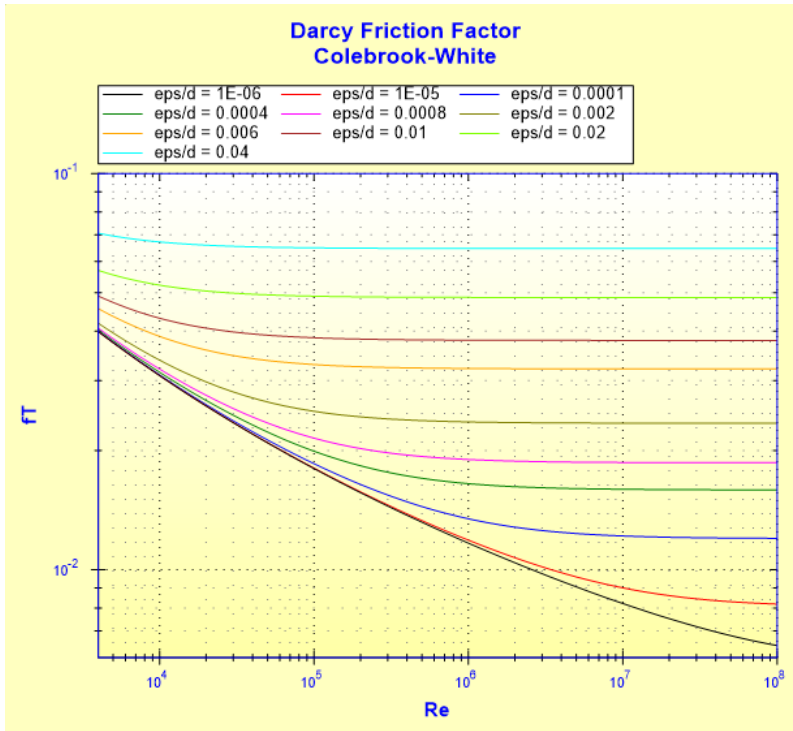
Reynolds number:

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

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

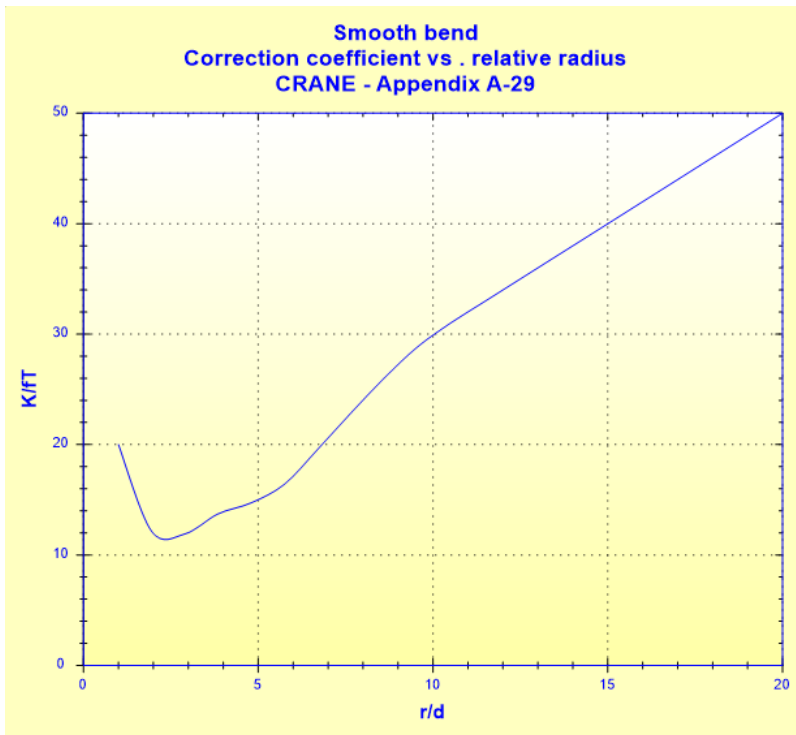


Resistance coefficient for one 90° smooth bend:

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

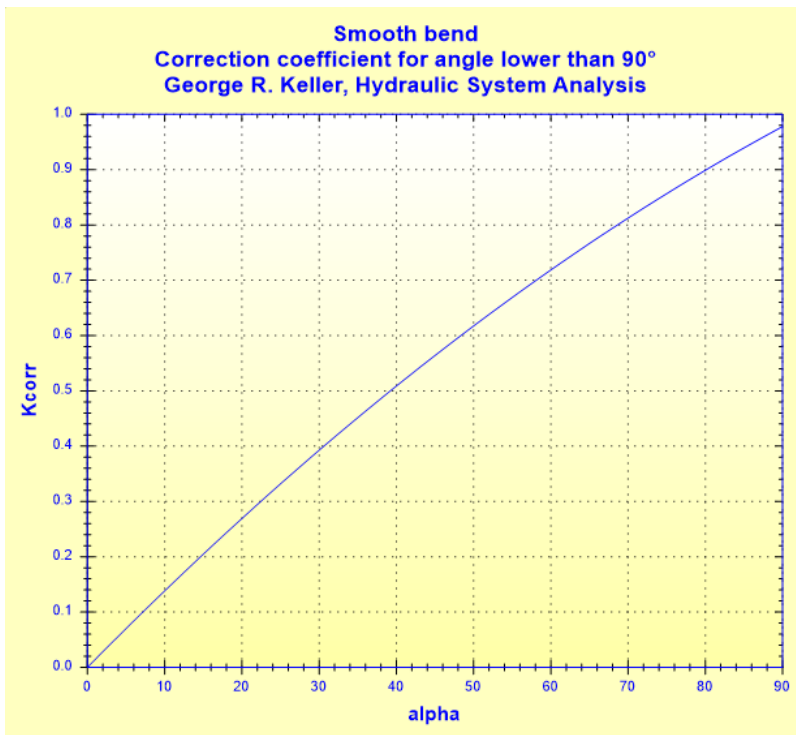
([1] Appendix A-29)

$r/d$	$K$	$K/f_T$
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



Correction coefficient for angle lower than 90°:

$$K_{corr} = \alpha \cdot (0.0142 - 3.703 \cdot 10^{-5} \cdot \alpha) \quad ([2])$$



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

- $\alpha \geq 90^\circ$

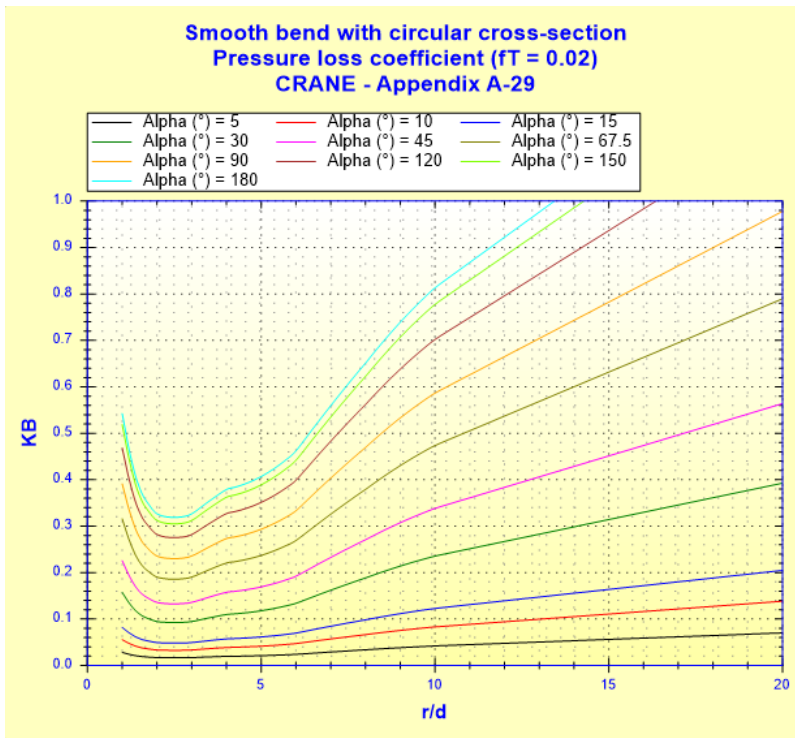
$$K_B = \left( \frac{\alpha}{90} - 1 \right) \left( 0.25 \cdot \pi \cdot f_T \cdot \frac{r}{d} + 0.5 \cdot K \right) + K$$

([1] Appendix A-29)

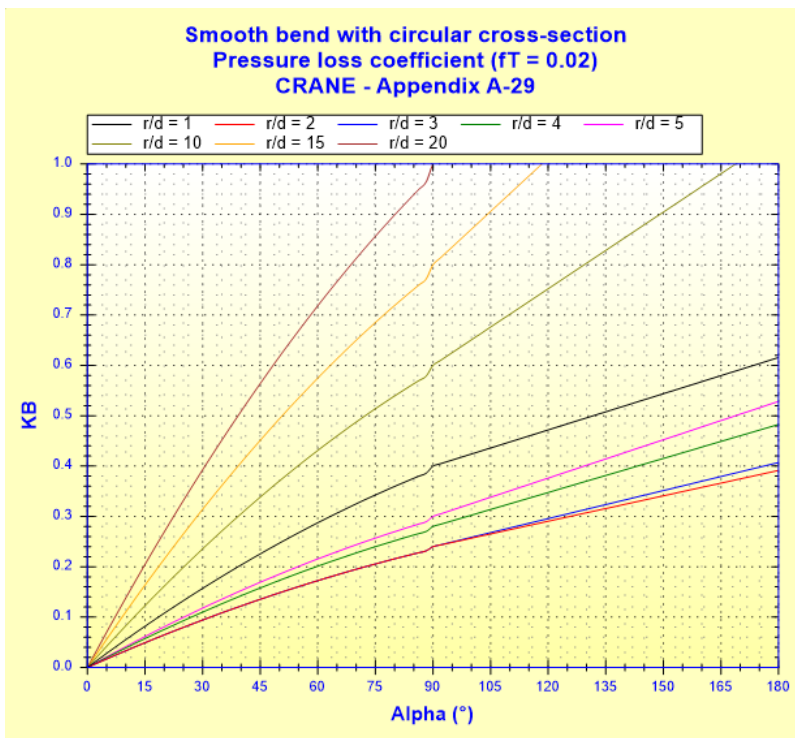
- $\alpha < 90^\circ$

$$K_B = K \cdot K_{corr}$$

(([1] Appendix A-29 & [2])



(with  $f_T = 0.02$ )



(with  $f_T = 0.02$ )

Total pressure loss (Pa):

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

Total head loss of fluid (m):

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

Hydraulic power loss (W):

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

Straight length of equivalent pressure loss (m):

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

---

**Symbols, Definitions, SI Units:**

d	Pipe internal diameter (m)
A	Cross-section area (m <sup>2</sup> )
q	Volume flow rate (m <sup>3</sup> /s)
v	Mean velocity (m/s)
L	Length measured along the axis (m)
r	Radius of curvature (m)
$\alpha$	Curvature angle (°)
w	Mass flow rate (kg/s)
V	Fluid volume (m <sup>3</sup> )
M	Fluid mass (kg)
Re	Reynolds number ( )
$f_T$	Darcy friction factor
$\varepsilon$	Absolute roughness of walls (m)
K	Resistance coefficient for one 90° smooth bend ( )
$K_{corr}$	Correction coefficient for angle lower than 90° ( )
$K_B$	Total pressure loss coefficient (based on mean velocity in bend) ( )
$\Delta P$	Total pressure loss (Pa)
$\Delta H$	Total head loss of fluid (m)
Wh	Hydraulic power loss (W)
$L_{eq}$	Straight length of equivalent pressure loss (m)
$\rho$	Fluid density (kg/m <sup>3</sup> )
$\nu$	Fluid kinematic viscosity (m <sup>2</sup> /s)
g	Gravitational acceleration (m/s <sup>2</sup> )

---

**Validity range:**

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

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**Example of application:**

HydrauCalc 2018b - [Smooth bend with circular cross-section - CRANE (1999)]

File Edit Preferences Calculation method Database Tools Help

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

Density  Dyn. Visc.  Kn. Visc.

Geometrical characteristics

Pressure loss  
 $\Delta P$  0.001856354 bar  
 $\Delta H$  0.0190 m of fluid

Complementary results

Designation	Symbol	Value	Unit
Cross-sectional area	A	0.003881508	m <sup>2</sup>
Relative radius of curvature	r/d	2.489331	
Developed straight length from the axis	L	0.2748893	m
Internal bend volume	V	0.001066985	m <sup>3</sup>
Internal bend volume	M	1.065071	kg
Reynolds number	Re	90251	
Relative roughness	c/d	0.0001422475	
<input checked="" type="checkbox"/> Darcy Friction Factor	f <sub>T</sub>	0.01907611	
<input checked="" type="checkbox"/> Resistance coefficient for one 90° smooth bend	K	11.75011	fT
<input checked="" type="checkbox"/> Coefficient of local resistance (Appendix A-29)	KB	0.2241464	
Pressure loss coefficient (based on the mean bend velocity)	KB	0.2241464	
Hydraulic power loss	Wh	0.9281772	W
Straight length of equivalent pressure loss	Leq	0.8260329	m

## References:

- [1] CRANE - Flow of Fluids Through Valves, Fitting and Pipe - Technical Paper No. 410 - Edition 1999
- [2] George R. Keller, Hydraulic System Analysis, Published by the Editors of Hydraulics & Pneumatics Magazine, 1970