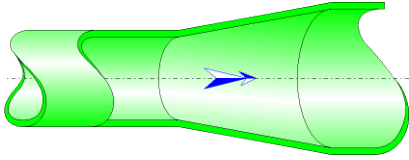




Gradual Expansion Circular Cross-Section (Pipe Flow - Guide)



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 gradual expansion is taken into account for cone angles less than 60 °, beyond this angle the head loss by friction becomes negligible.

The head loss by friction in the inlet and outlet piping is not taken into account in this component.

Model formulation:

Ratio of small to large diameter:

$$\beta = \frac{d_1}{d_2}$$

Top angle of cone (°):

$$\alpha = 2 \cdot \tan^{-1} \left(\frac{d_2 - d_1}{2 \cdot l} \right)$$

Minor cross-sectional area (m²):

$$A_1 = \pi \cdot \frac{d_1^2}{4}$$

Major cross-sectional area (m²):

$$A_2 = \pi \cdot \frac{d_2^2}{4}$$

Mean velocity in minor diameter (m/s):

$$V_1 = \frac{Q}{A_1}$$

Mean velocity in major diameter (m/s):

$$V_2 = \frac{Q}{A_2}$$

Mass flow rate (kg/s):

$$G = Q \cdot \rho_m$$

Fluid volume in the truncated cone (m³):

$$V = l \cdot \frac{\pi}{3} \cdot \left(\left(\frac{d_1}{2} \right)^2 + \left(\frac{d_2}{2} \right)^2 + \left(\frac{d_1}{2} \right) \cdot \left(\frac{d_2}{2} \right) \right)$$

Fluid mass in the truncated cone (kg):

$$M = V \cdot \rho_m$$

Reynolds number in minor diameter:

$$N_{Re_1} = \frac{V_1 \cdot d_1}{\nu}$$

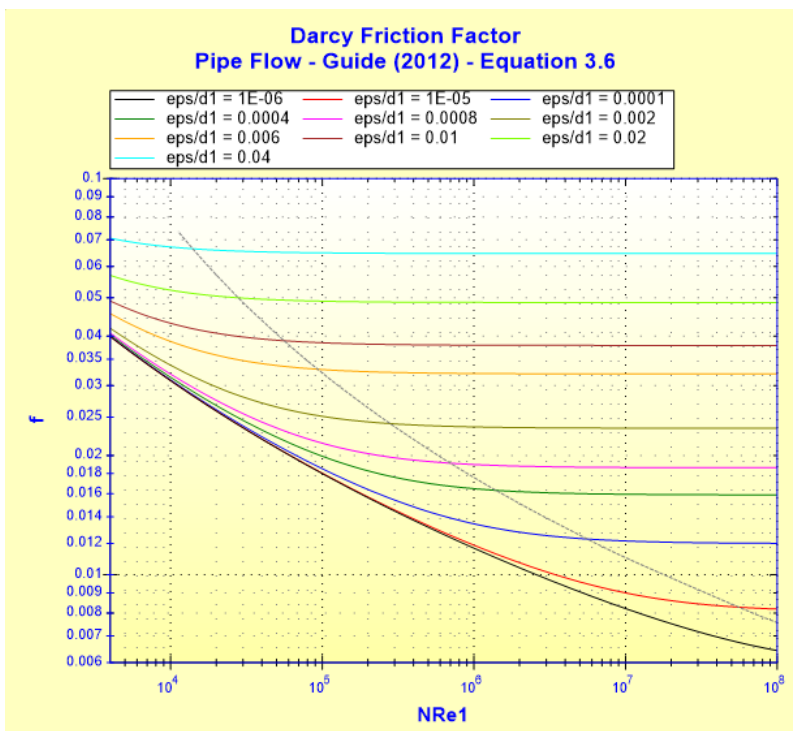
Reynolds number in major diameter:

$$N_{Re_2} = \frac{V_2 \cdot d_2}{\nu}$$

Darcy friction factor:

$$f = \frac{1}{\left[2 \cdot \log \left(\frac{\varepsilon}{3.7 \cdot d_1} + \frac{2.51}{N_{Re_1} \cdot \sqrt{f}} \right) \right]^2}$$

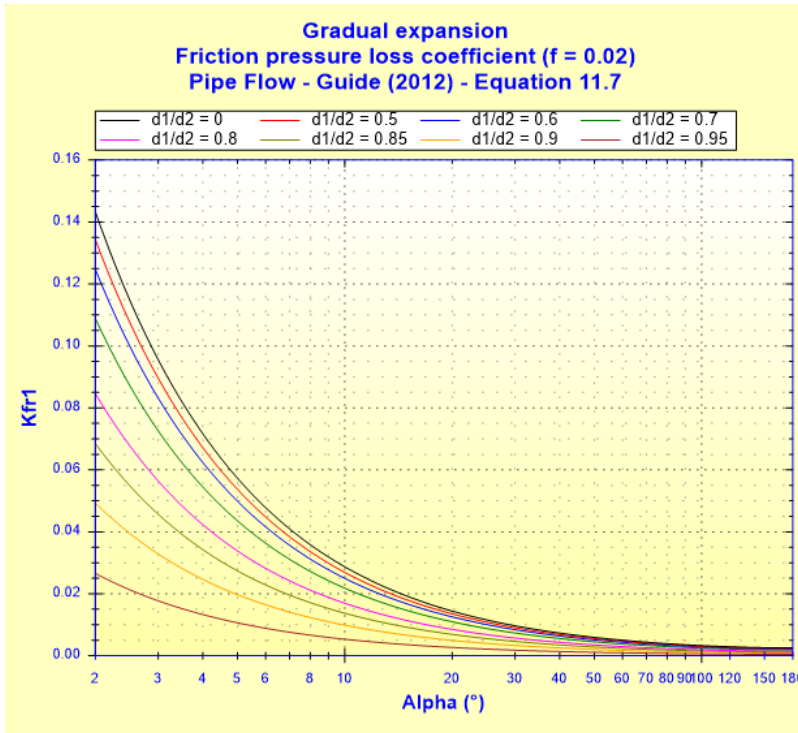
Colebrook-White equation ([1] equation 3.6)



Friction pressure loss coefficient:

$$K_{fr1} = \frac{f \cdot (1 - \beta^4)}{8 \cdot \sin\left(\frac{\alpha}{2}\right)}$$

([1] equation 11.7)



([1] equation 11.7 with f =

0.02)

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

■ $0^\circ \leq \alpha \leq 20^\circ$:

$$K_1 = 8.30 \cdot \left[\tan\left(\frac{\alpha}{2}\right) \right]^{1.75} \cdot (1 - \beta^2)^2 + \frac{f \cdot (1 - \beta^4)}{8 \cdot \sin\left(\frac{\alpha}{2}\right)}$$

([1] equation 11.8)

■ $20^\circ \leq \alpha < 60^\circ$:

● $0 \leq \beta < 0.5$

$$K_1 = \left\{ 1.366 \cdot \sin\left[2 \cdot (\alpha - 15)^{1/2}\right] - 0.170 - 3.28 \cdot \left((0.0625 - \beta^4) \cdot \sqrt{\frac{\alpha - 20}{40}} \right) \right\} \cdot (1 - \beta^2)^2 + \frac{f \cdot (1 - \beta^4)}{8 \cdot \sin\left(\frac{\alpha}{2}\right)}$$

([1] equation 11.9a)

● $0.5 \leq \beta \leq 1$

$$K_1 = \left\{ 1.366 \cdot \sin\left[2 \cdot (\alpha - 15)^{1/2}\right] - 0.170 \right\} \cdot (1 - \beta^2)^2 + \frac{f \cdot (1 - \beta^4)}{8 \cdot \sin\left(\frac{\alpha}{2}\right)}$$

([1] equation

11.9b)

■ $60^\circ \leq \alpha \leq 180^\circ$:

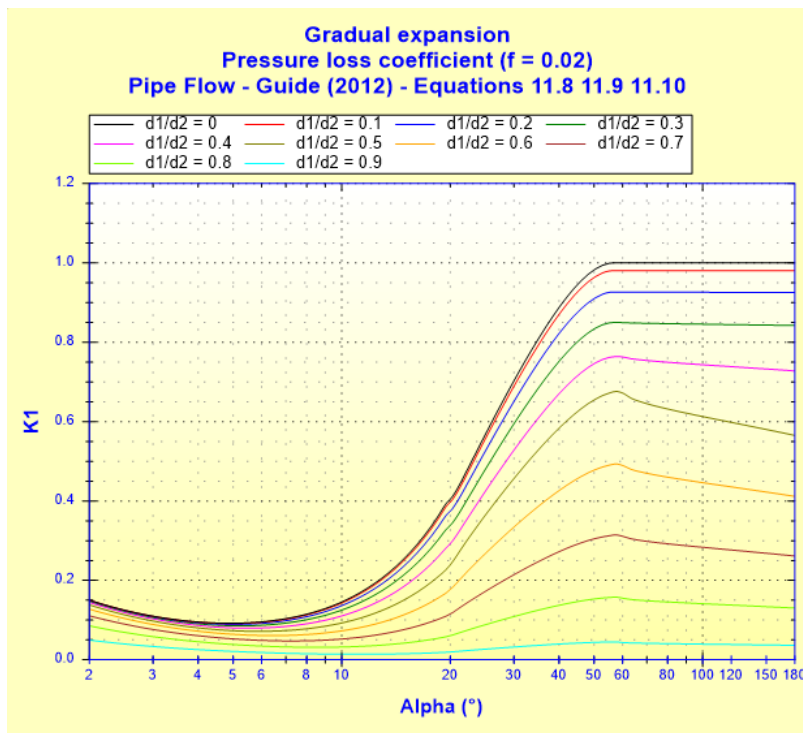
- $0 \leq \beta < 0.5$

$$K_1 = \left[1.205 - 3.28 \cdot (0.0625 - \beta^4) - 12.8 \cdot \beta^6 \cdot \sqrt{\frac{\alpha - 60}{120}} \right] \cdot (1 - \beta^2)^2 \quad ([1])$$

equation 11.10a)

- $0.5 \leq \beta \leq 1$

$$K_1 = \left[1.205 - 0.20 \cdot \sqrt{\frac{\alpha - 60}{120}} \right] \cdot (1 - \beta^2)^2 \quad ([1] \text{ equation 11.10b})$$



Local resistance coefficient:

■ $0^\circ \leq \alpha < 60^\circ$:

$$K_{L1} = K_1 - K_{fr1}$$

■ $60^\circ \leq \alpha \leq 180^\circ$:

$$K_{L1} = K_1$$

Total pressure loss (Pa):

$$\Delta P = K_1 \cdot \frac{\rho_m \cdot V_1^2}{2}$$

Total head loss of fluid (m):

$$\Delta H = K_1 \cdot \frac{V_1^2}{2 \cdot g}$$

Hydraulic power loss (W):

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

Symbols, Definitions, SI Units:

d_1	Minor diameter (m)
d_2	Major diameter (m)
β	Ratio of small to large diameter ()
α	Top angle of cone (°)
l	Truncated cone length (m)
A_1	Minor cross-sectional area (m ²)
A_2	Major cross-sectional area (m ²)
Q	Volume flow rate (m ³ /s)
V_1	Mean velocity in minor diameter (m/s)
V_2	Mean velocity in major diameter (m/s)
G	Mass flow rate (kg/s)
V	Fluid volume in the truncated cone (m ³)
M	Fluid mass in the truncated cone (kg)
NRe_1	Reynolds number in minor diameter ()
NRe_2	Reynolds number in major diameter ()
f	Darcy friction factor ()
ε	Absolute roughness of the cone walls (m)
K_{fr1}	Friction pressure loss coefficient ()
K_{L1}	Local resistance coefficient ()
K_1	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_m	Fluid density (kg/m ³)
ν	Fluid kinematic viscosity (m ² /s)
g	Gravitational acceleration (m/s ²)

Validity range:

- turbulent flow regime in minor diameter ($NRe_1 \geq 10^4$)

Example of application:

HydrauCalc 2018b - [Gradual expansion - Pipe Flow - Guide (2012)]

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Fluid characteristics

Fluid: Water @ 1 atm [HC]
Ref.: IAPWS IF97

Temperature: T 20 °C
Pressure: P 1.013 bar

Density: ρ 998.2061 kg/m³
Dynamic Viscosity: μ 0.00100159 N.s/m²
Kinematic Viscosity: ν 1.00340E-06 m²/s

Density Dyn. Visc. Kn. Visc.

HC

Geometrical characteristics

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Pressure loss ΔP 0.02464652 bar
 ΔH 0.2518 m of fluid

Complementary results

Designation	Symbol	Value	Unit
Diameters ratio	β	0.6130868	
Minor cross-section area	A_1	0.001458963	m ²
Major cross-section area	A_2	0.003881508	m ²
Cross-sections area ratio	A_1/A_2	0.3758754	
Internal truncated cone volume	V	2.573391E-05	m ³
Mass of fluid in the truncated cone	M	0.02568774	kg
Minor diameter Reynolds number	NRe_1	147207.5	
Major diameter Reynolds number	NRe_2	90251	
Top angle of cone	α	107.3464	°
<input checked="" type="checkbox"/> Pressure loss coefficient (Equations 11.8 11.9 11.10)	K_1	0.4204499	
Pressure loss coefficient (based on velocity in minor diameter)	K	0.4204499	
Hydraulic power loss	Wh	12.32326	W

References:

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