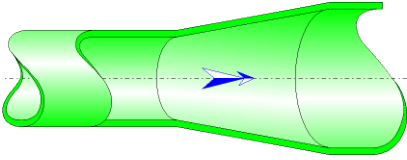




Gradual Expansion Circular Cross-Section (CRANE)



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 inlet and outlet piping is not taken into account in this component.

Model formulation:

Ratio of small to large diameter:

$$\beta = \frac{D_1}{D_2}$$

Half top angle of cone (°):

$$\theta = \tan^{-1}\left(\frac{D_2 - D_1}{2 \cdot L}\right)$$

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):

$$G = q \cdot \rho$$

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):

$$M = V \cdot \rho$$

Reynolds number in minor diameter:

$$Re_1 = \frac{v_1 \cdot D_1}{\nu}$$

Reynolds number in major diameter:

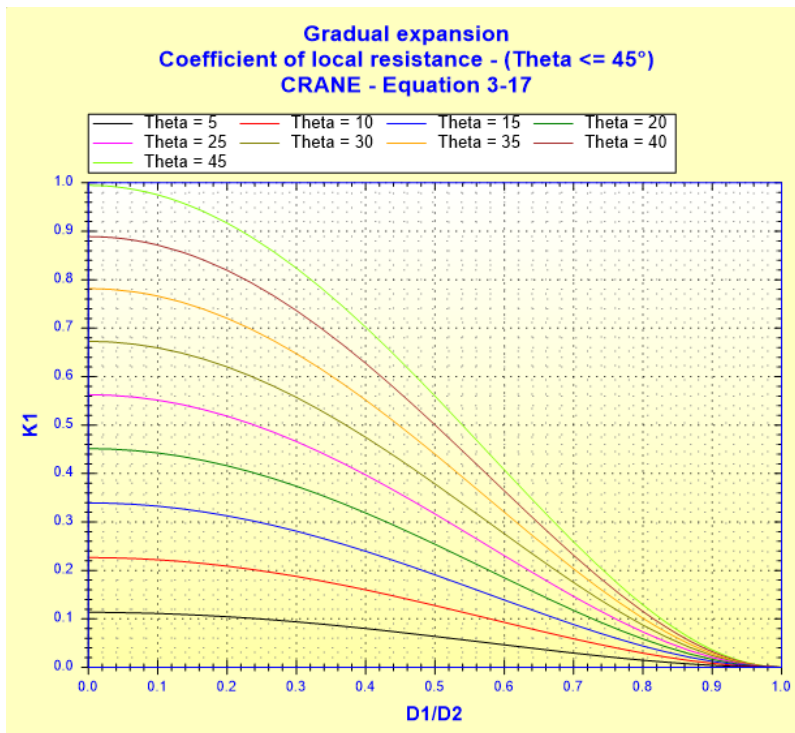
$$Re_2 = \frac{v_2 \cdot D_2}{\nu}$$

Local resistance coefficient:

■ $\theta \leq 45^\circ$:

$$K_1 = 2.6 \sin\left(\frac{\theta}{2}\right) (1 - \beta^2)^2$$

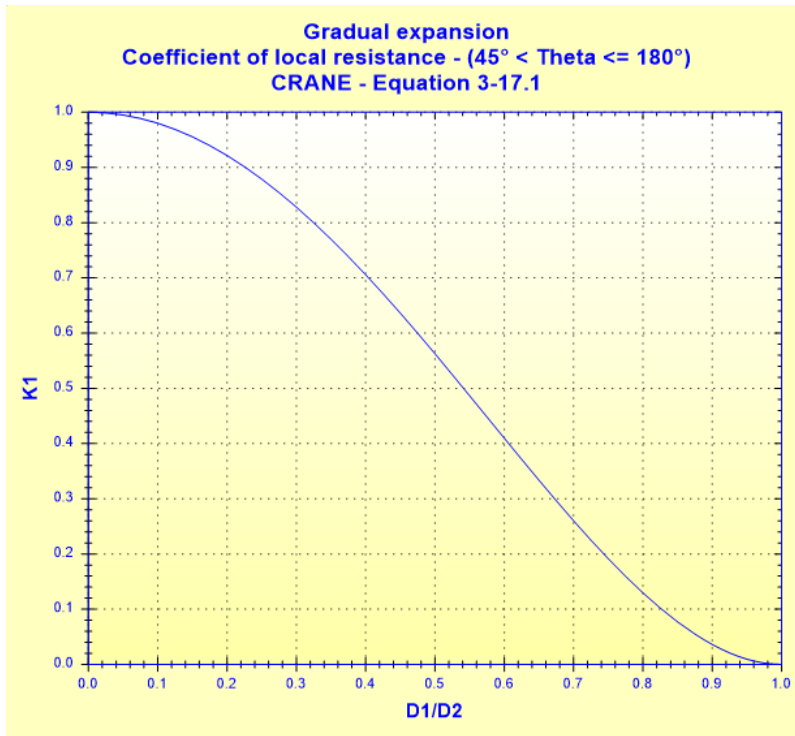
(Equation 3-17)



■ $45^\circ < \theta \leq 180^\circ$:

$$K_1 = (1 - \beta^2)^2$$

(Equation 3-17.1)



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

$$K = K_1$$

Total pressure loss (Pa):

$$\Delta P = K \cdot \frac{\rho \cdot v_1^2}{2}$$

Total head loss of fluid (m):

$$\Delta H = K \cdot \frac{v_1^2}{2 \cdot g}$$

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 ()
θ	Half top angle of cone ($^\circ$)
L	Contraction length (m)
A_1	Minor cross-sectional area (m^2)
A_2	Major cross-sectional area (m^2)
v_1	Mean velocity in minor diameter (m/s)
v_2	Mean velocity in major diameter (m/s)

q	Volume flow rate (m^3/s)
G	Mass flow rate (kg/s)
V	Fluid volume in the truncated cone (m^3)
M	Fluid mass in the truncated cone (kg)
Re_1	Reynolds number in minor diameter ()
Re_2	Reynolds number in major diameter ()
K_1	Local resistance coefficient ()
K	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	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 ($Re_1 \geq 10^4$)

Example of application:

The screenshot shows the HydrCalc 2018b interface for a 'Gradual expansion - CRANE (1999)' calculation. The fluid is Water @ 1 atm [HC] with a temperature of 20 °C and pressure of 1.013 bar. The flow is turbulent with a velocity of 3.427 m/s in the minor diameter (0.0431 m) and 1.288 m/s in the major diameter (0.0703 m). The length of the truncated cone is 0.01 m. The pressure loss is 0.0228341 bar, and the head loss is 0.2333 m of fluid.

Fluid characteristics:

- Fluid: Water @ 1 atm [HC]
- Temperature: 20 °C
- Pressure: 1.013 bar
- Density: 998.2061 kg/m^3
- Dynamic Viscosity: 0.00100159 $\text{N}\cdot\text{s}/\text{m}^2$
- Kinematic Viscosity: 1.00340E-06 m^2/s

Geometrical characteristics:

- Minor diameter: 0.0431 m
- Major diameter: 0.0703 m
- Length: 0.01 m
- Top angle of cone: 53.7 °

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	Re_1	147207.5	
Major diameter Reynolds number	Re_2	90251	
Top angle of cone	α	107.3464	°
Coefficient of local resistance (Equation 3-17.1)	K_1	0.3895316	
Pressure loss coefficient (based on velocity in minor diameter)	K	0.3895316	
Hydraulic power loss	Wh	11.41705	W

References:

