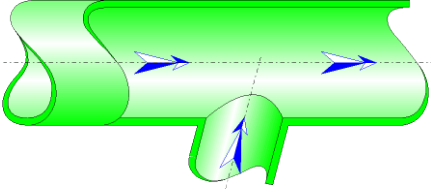




## Combining sharp-edged junction Circular Cross-Section (CRANE)



### Model description:

This model of component calculates the minor head loss (pressure drop) generated by the flow in a combining sharp-edged junction.

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

### Model formulation:

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Ratio between the diameter of the lateral branch and that of the common branch:

$$\beta_b = \frac{d_b}{d_c}$$

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Cross-sectional area of the lateral branch (m<sup>2</sup>):

$$A_b = \pi \cdot \frac{d_b^2}{4}$$

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Cross-sectional area of the common branch and the straight branch (m<sup>2</sup>):

$$A_c = \pi \cdot \frac{d_c^2}{4}$$

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Volume flow rate in the common branch (m<sup>3</sup>/s):

$$Q_c = Q_b + Q_r$$

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Mean velocity in the lateral branch (m/s):

$$v_b = \frac{Q_b}{A_b}$$

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Mean velocity in the straight branch (m/s):

$$v_r = \frac{Q_r}{A_c}$$

Mean velocity in the common branch (m/s):

$$v_c = \frac{Q_c}{A_c}$$

Mass flow rate in the lateral branch (kg/s):

$$G_b = Q_b \cdot \rho$$

Mass flow rate in the straight branch (kg/s):

$$G_r = Q_r \cdot \rho$$

Mass flow rate in the common branch (kg/s):

$$G_c = Q_c \cdot \rho$$

Reynolds number in the lateral branch:

$$Re_b = \frac{v_b \cdot d_b}{\nu}$$

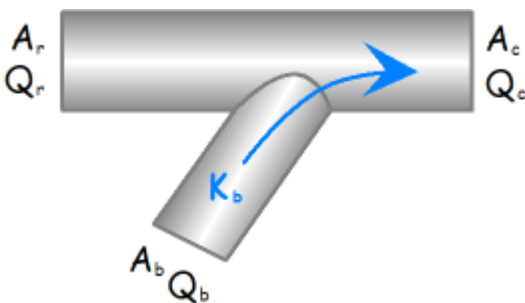
Reynolds number in the straight branch:

$$Re_r = \frac{v_r \cdot d_c}{\nu}$$

Reynolds number in the common branch:

$$Re_c = \frac{v_c \cdot d_c}{\nu}$$

Pressure loss coefficient of the lateral branch (based on mean velocity in the common branch):



$$K_b = C_b \cdot \left[ 1 + D_b \cdot \left( \frac{Q_b}{Q_c} \cdot \frac{1}{\beta_b^2} \right)^2 - E_b \cdot \left( 1 - \frac{Q_b}{Q_c} \right)^2 - F_b \cdot \frac{1}{\beta_b^2} \cdot \left( \frac{Q_b}{Q_c} \right)^2 \right]$$

([1] equation 2-35)

with:

Values of  $D_b$ ,  $E_b$ ,  $F_b$

Angle	$D_b$	$E_b$	$F_b$
30°	1	2	1.74
45°	1	2	1.41
60°	1	2	1
90°	1	2	0

([1] table 2-1)

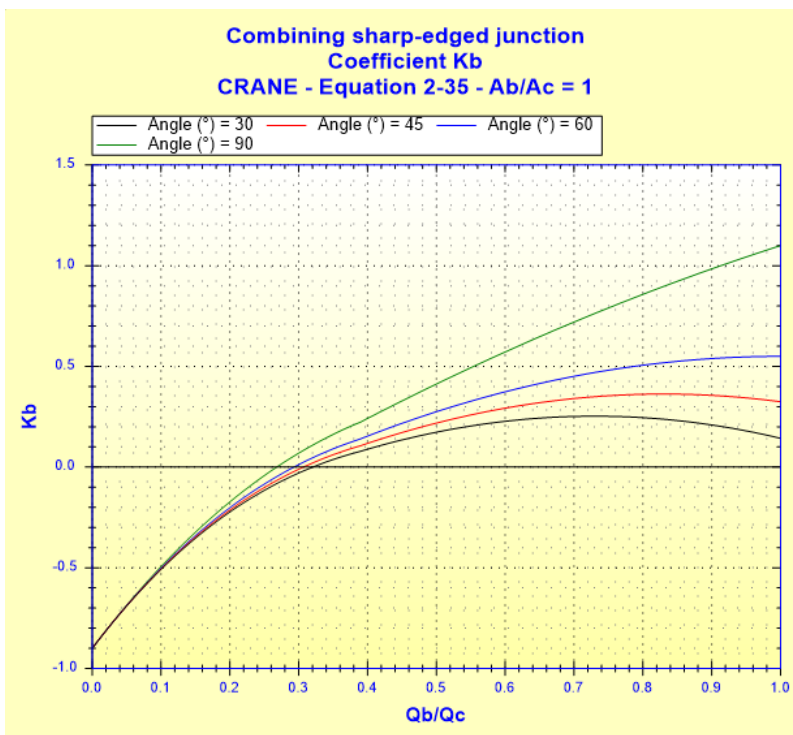
For any angles between 30° and 90°, the coefficients  $D_b$ ,  $E_b$ ,  $F_b$  are obtained by linear interpolation of the coefficients of the table 2-1.

Values of  $C_b$

$Q_b / Q_c$	$\leq 0.4$		$> 0.4$	
	$\leq 0.35$	$> 0.35$	$\leq 0.35$	$> 0.35$
$\beta^2_b$				
$C_b$	1	$0.9 \cdot \left(1 - \frac{Q_b}{Q_c}\right)$	1	0.55

([1] table

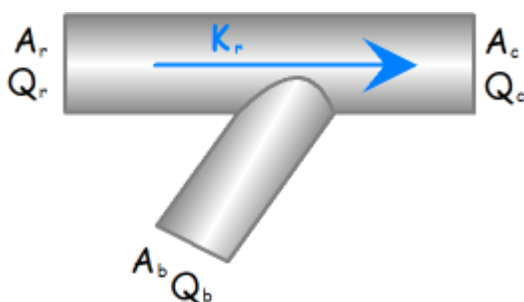
2-2)



([1] equation 2-35 with

$A_b/A_c = 1$ )

Pressure loss coefficient of the straight branch (based on mean velocity in the common branch):



■ Angle  $\leq 60^\circ$

$$K_r = C_r \cdot \left[ 1 + D_r \cdot \left( \frac{Q_b}{Q_c} \cdot \frac{1}{\beta_b^2} \right)^2 - E_r \cdot \left( 1 - \frac{Q_b}{Q_c} \right)^2 - F_r \cdot \frac{1}{\beta_b^2} \cdot \left( \frac{Q_b}{Q_c} \right)^2 \right]$$

[[1] equation 2-

35)

with:

Values of  $C_r$ ,  $D_r$ ,  $E_r$ ,  $F_r$

Angle	$C_r$	$D_r$	$E_r$	$F_r$
30°	1	0	1	1.74
45°	1	0	1	1.41
60°	1	0	1	1

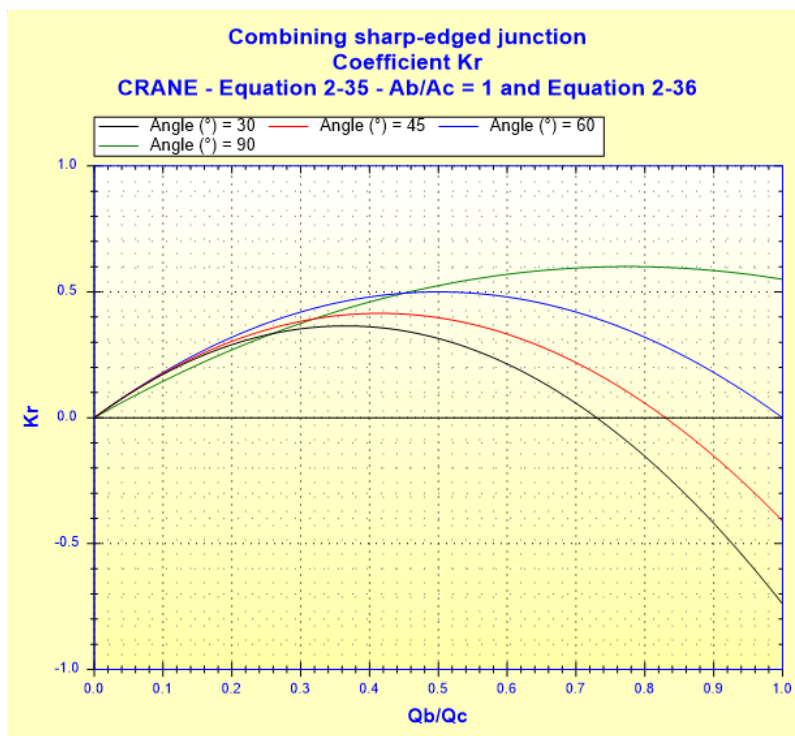
[[1] table 2-1)

For arbitrary angles between 30° and 60°, the coefficients  $C_r$ ,  $D_r$ ,  $E_r$ ,  $F_r$  are obtained by linear interpolation of the coefficients of table 2-1.

■ Angle = 90°

$$K_r = 1.55 \cdot \left( \frac{Q_b}{Q_c} \right) - \left( \frac{Q_b}{Q_c} \right)^2$$

[[1] equation 2-36)



[[1] equations 2-35 with

$Ab/Ac = 1$  and 2-36)

For any angles between 60° and 90°, the coefficient  $K_r$  is obtained by linear interpolation between the value of  $K_r$  calculated at 60° and that calculated at 90°.

Pressure loss in the lateral branch (Pa):

$$\Delta P_b = K_b \cdot \frac{\rho \cdot V_c^2}{2}$$

Pressure loss in the straight branch (Pa):

$$\Delta P_r = K_r \cdot \frac{\rho \cdot v_c^2}{2}$$

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Head loss of fluid in the lateral branch (m):

$$\Delta H_b = K_b \cdot \frac{v_c^2}{2 \cdot g}$$

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Head loss of fluid in the straight branch (m):

$$\Delta H_r = K_r \cdot \frac{v_c^2}{2 \cdot g}$$

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Hydraulic power loss in the lateral branch (W):

$$Wh_b = \Delta P_b \cdot Q_b$$

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Hydraulic power loss in the straight branch (W):

$$Wh_r = \Delta P_r \cdot Q_r$$

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### Symbols, Definitions, SI Units:

$d_b$	Diameter of the lateral branch (m)
$d_c$	Diameter of the common branch and the straight branch (m)
$\beta_b$	Ratio between the diameter of the lateral branch and that of the common branch ( )
$A_b$	Cross-sectional area of the lateral branch (m <sup>2</sup> )
$A_c$	Cross-sectional area of the common branch and the straight branch (m <sup>2</sup> )
$Q_b$	Volume flow rate in the lateral branch (m <sup>3</sup> /s)
$v_b$	Mean velocity in the lateral branch (m/s)
$Q_r$	Volume flow rate in the straight branch (m <sup>3</sup> /s)
$v_r$	Mean velocity in the straight branch (m/s)
$Q_c$	Volume flow rate in the common branch (m <sup>3</sup> /s)
$v_c$	Mean velocity in the common branch (m/s)
$G_b$	Mass flow rate in the lateral branch (kg/s)
$G_r$	Mass flow rate in the straight branch (kg/s)
$G_c$	Mass flow rate in the common branch (kg/s)
$Re_b$	Reynolds number in the lateral branch ( )
$Re_r$	Reynolds number in the straight branch ( )
$Re_c$	Reynolds number in the common branch ( )
$\alpha$	Angle of the lateral branch (m)
$K_b$	Pressure loss coefficient of the lateral branch (based on mean velocity in the common branch) ( )
$K_r$	Pressure loss coefficient of the straight branch (based on mean velocity in the common branch) ( )
$\Delta P_b$	Pressure loss in the lateral branch (Pa)
$\Delta P_r$	Pressure loss in the straight branch (Pa)
$\Delta H_b$	Head loss of fluid in the lateral branch (m)

$\Delta H_r$  Head loss of fluid in the straight branch (m)  
 $W_{hb}$  Hydraulic power loss in the lateral branch (W)  
 $W_{hr}$  Hydraulic power loss in the straight branch (W)

$\rho$  Fluid density ( $\text{kg/m}^3$ )  
 $\nu$  Fluid kinematic viscosity ( $\text{m}^2/\text{s}$ )  
 $g$  Gravitational acceleration ( $\text{m/s}^2$ )

note: the indices  $b$ ,  $r$  and  $c$  correspond respectively to the indices branch, run and combined of the reference document.

### Validity range:

- turbulent flow regime ( $Re_c \geq 10^4$ )
- angle of the lateral branch: between  $30^\circ$  and  $90^\circ$

### Example of application:

The screenshot displays the HydraulCalc 2019a software interface for a 'Combining sharp-edged junction - CRANE (2013)'. The interface is divided into several panels:

- Fluid characteristics:**
  - Fluid: Water @ 1 atm [HC]
  - Ref.: IAPWS IF97
  - Temperature:  $T = 20$  °C
  - Pressure:  $P = 1.013$  bar
  - Density:  $\rho = 998.2061$   $\text{kg/m}^3$
  - Dynamic Viscosity:  $\mu = 0.00100159$   $\text{N.s/m}^2$
  - Kinematic Viscosity:  $\nu = 1.00340E-06$   $\text{m}^2/\text{s}$
  - Graph: Density ( $\text{kg/m}^3$ ) vs Temperature ( $^\circ\text{C}$ )
- Geometrical characteristics:**
  - Help Info
  - Straight passage pressure loss:  $\Delta P_r = 0.002749586$  bar,  $\Delta H_r = 0.0281$  m of fluid
  - Calculate button
  - Gr: 4.9910  $\text{kg/s}$ , Qr: 0.005  $\text{m}^3/\text{s}$ , vr: 1.288  $\text{m/s}$  (Turbulent)
  - Side branch:  $\alpha = 90^\circ$ , db: 0.0431 m, Gb: 0.9982  $\text{kg/s}$ , Qb: 0.001  $\text{m}^3/\text{s}$ , vb: 0.685  $\text{m/s}$  (Turbulent)
  - Common channel:  $d_c = 0.0703$  m, Gc: 5.9892  $\text{kg/s}$ , Qc: 0.0060  $\text{m}^3/\text{s}$ , vc: 1.546  $\text{m/s}$  (Turbulent)
  - Side branch pressure loss:  $\Delta P_b = -0.001719809$  bar,  $\Delta H_b = -0.0176$  m of fluid
- Complementary results:**

Designation	Symbol	Value	Unit
Diameters ratio 'Side branch / Common channel'	$d_b/d_c$	0.6130868	
Side branch cross-section area	$A_b$	0.001458963	$\text{m}^2$
Straight passage cross-section area	$A_r$	0.003881508	$\text{m}^2$
Common channel cross-section area	$A_c$	0.003881508	$\text{m}^2$
Cross-sections area ratio 'Side branch / Common channel'	$A_b/A_c$	0.3758754	
Flow rate ratio 'Side branch / Common channel'	$Q_b/Q_c$	0.1666667	
Side branch Reynolds number	$Re_b$	29441.51	
Straight passage Reynolds number	$Re_r$	90251	
Common channel Reynolds number	$Re_c$	108301.2	
Side branch pressure loss coefficient (based on vc)	$K_b$	-0.1442077	
Straight passage pressure loss coefficient (based on vc)	$K_r$	0.2305556	
Side branch hydraulic power loss	$W_{hb}$	-0.1719809	W
Straight passage hydraulic power loss	$W_{hr}$	1.374793	W

### References:

[1] CRANE - Flow of Fluids Through Valves, Fitting and Pipe - Technical Paper No. 410 - Edition 2013