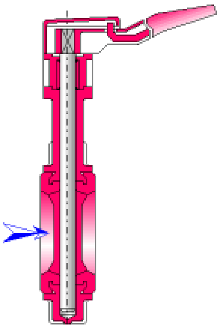
Butterfly valve
(Manufacturer defined)



Model description:

This model of component calculates the minor head loss (pressure drop) generated by the flow in a butterfly valve installed in a straight pipe.

The valve characteristics are defined by valves manufacturer. The pressure drop of the valves is characterized by a flow coefficient “Kv”, “Cv” or “Av” at full opening, and a law of flow coefficient evolution according the valve opening.

Model formulation:

Cross-sectional area (m²):

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

Mean velocity (m/s):

$$U = \frac{Q}{A}$$

Mass flow rate (kg/s):

$$G = Q \cdot \rho$$

Reynolds number:

$$\mathrm{Re} = \frac{U \cdot D}{\nu}$$

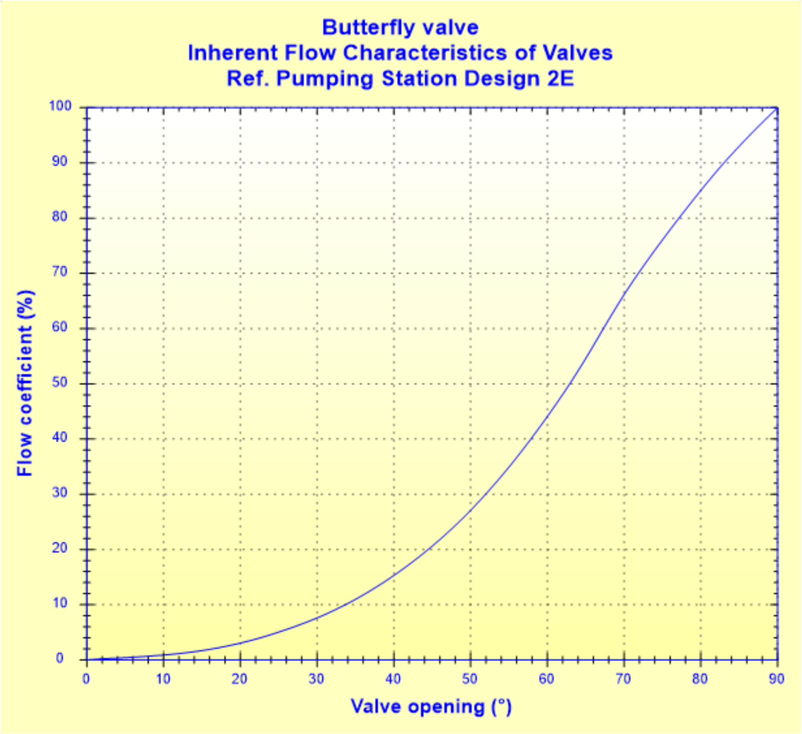
Evolution of the flow coefficients according to the opening of the valve:

$$Kv = Kvs \cdot F_{low}C_{oef}\left(V_{alve}O_{pening}\right)/100$$

$$\boxed{Cv = Cvs \cdot F_{low}C_{oef}\left(V_{alve}O_{pening}\right)/100}$$

$$\boxed{Av = Avs \cdot F_{low}C_{oef}\left(V_{alve}O_{pening}\right)/100}$$

Example of flow coefficient vs valve opening:



$F_{low}C_{oef}(V_{alve}O_{pening})$ ([1] Figure 5-2)

Local resistance coefficient (Pa):

- Re $\geq 10^4$ (turbulent flow)

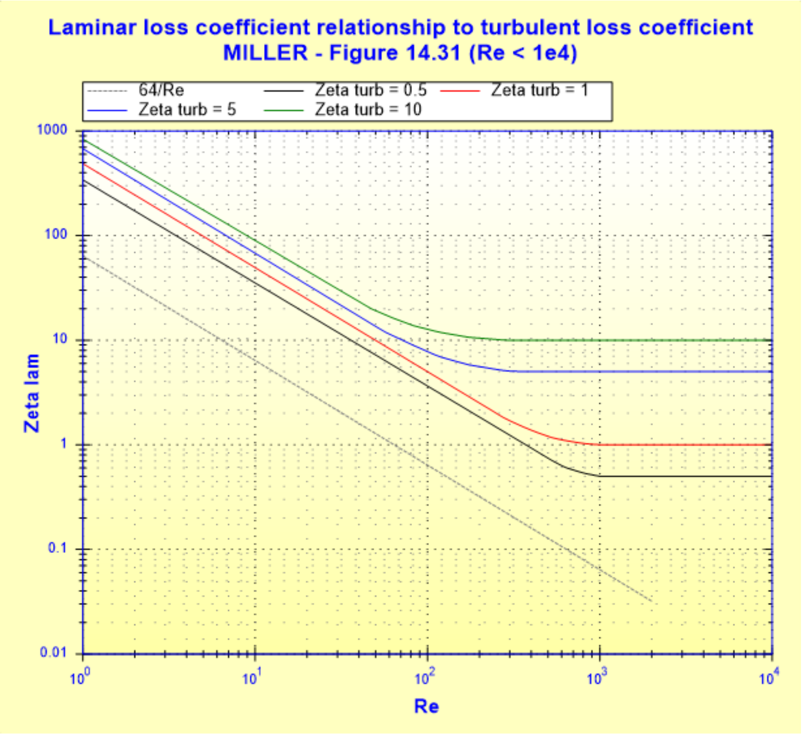
$$\boxed{K_{turb} = \frac{2 \cdot A^2}{\left(Kv/36023\right)^2}}$$

$$\boxed{K_{turb} = \frac{2 \cdot A^2}{\left(Cv/41650\right)^2}}$$

$$\boxed{K_{turb} = \frac{2 \cdot A^2}{Av^2}}$$

- Re $< 10^4$ (laminar flow)

$\boxed{K_{lam} = f(K_{turb}, \mathrm{Re})}$ ([2] figure 14.31)



Reynolds Number Correction (Re < 10^4):

$$C_{\mathrm{Re}} = \frac{K_{lam}}{K_{turb}}$$

Corrected flow coefficient in laminar flow (Re < 10^4):

$$Kv_c = \frac{Kv}{\sqrt{C_{Re}}}$$

$$Cv_c = \frac{Cv}{\sqrt{C_{Re}}}$$

$$Av_c = \frac{Av}{\sqrt{C_{Re}}}$$

Total pressure loss coefficient (based on mean velocity):

- turbulent flow (Re ≥ 10^4):

$$K = K_{turb}$$

- laminar flow (Re < 10^4):

$$K = K_{lam}$$

Total pressure loss (Pa):

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

Total head loss of fluid (m):

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

Hydraulic power loss (W):

$$\boxed{Wh = \Delta P \cdot Q}$$

Symbols, Definitions, SI Units:

D	Internal diameter (m)
A	Cross-sectional area (m²)
Q	Volume flow rate (m³/s)
G	Mass flow rate (kg/s)
U	Mean velocity (m/s)
Re	Reynolds number ()
α	Opening angle (°)
Kvs	Fully open flow coefficient (m³/h)
Cvs	Fully open flow coefficient (USG/min)
Avs	Fully open flow coefficient (m²)
Kv	Partial opening flow coefficient (m³/h)
Cv	Partial opening flow coefficient (USG/min)
Av	Partial opening flow coefficient (m²)
K_{turb}	Local resistance coefficient for $Re \geq 10^4$ ()
K_{lam}	Local resistance coefficient for $Re < 10^4$ ()
C_{Re}	Reynolds number correction for $Re < 10^4$ ()
Kv_c	Corrected flow coefficient in laminar flow (m³/h)
Cv_c	Corrected flow coefficient in laminar flow (USG/min)
Av_c	Corrected flow coefficient in laminar flow (m²)
K	Total pressure loss coefficient (based on mean velocity) ()
ΔP	Total pressure loss (Pa)
ΔH	Total head loss of fluid (m)
Wh	Hydraulic power loss (W)
ρ	Fluid density (kg/m³)
ν	Fluid kinematic viscosity (m²/s)
g	Gravitational acceleration (m/s²)

Validity range:

- any flow regime: laminar and turbulent

  note: for laminar flow regime ($Re < 10^4$), the pressure loss coefficient "K_{lam}" is estimated

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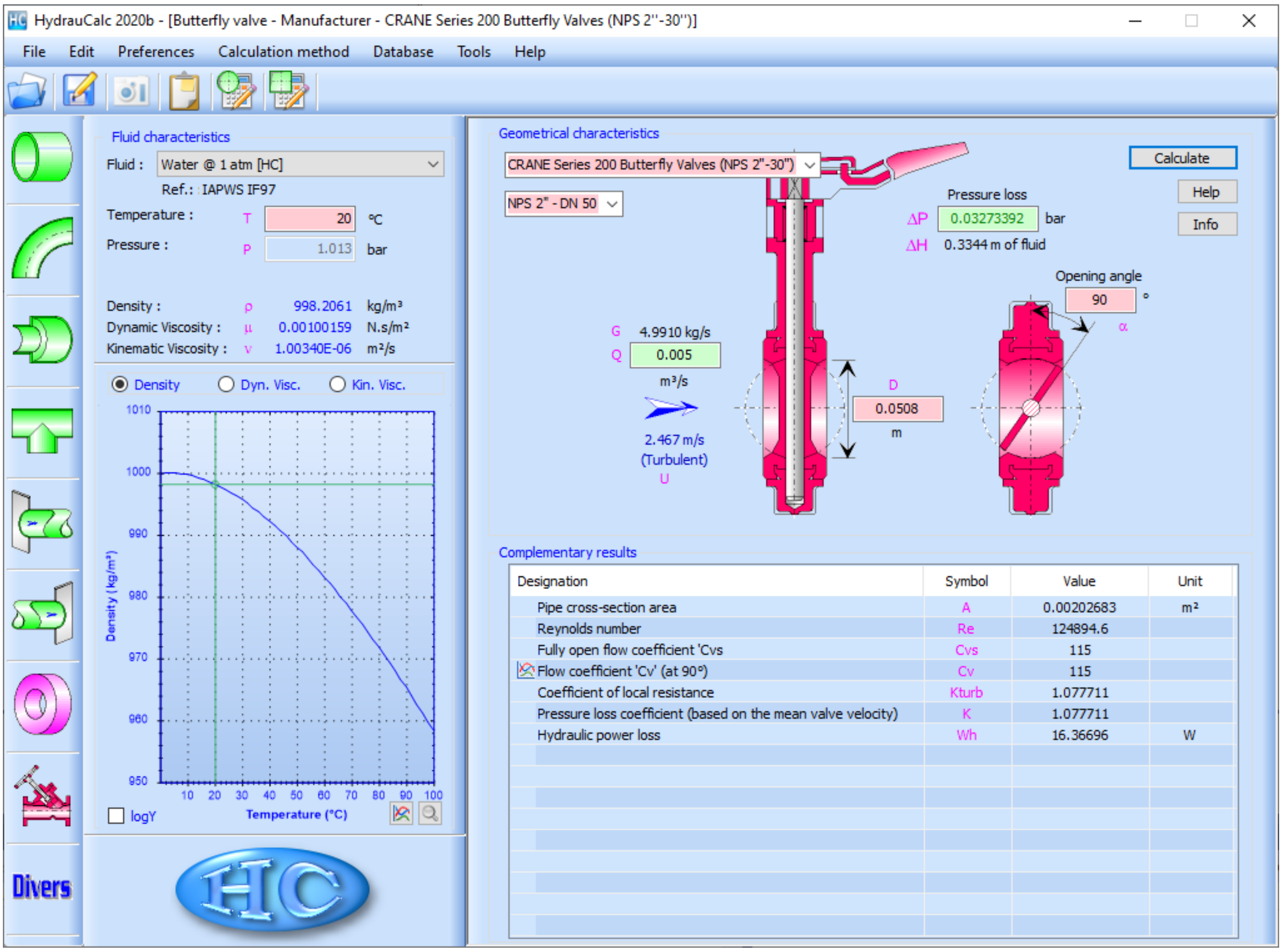
Example of application:



Designation	Symbol	Value	Unit
Pipe cross-section area	A	0.00202683	m²
Reynolds number	Re	124894.6	
Fully open flow coefficient 'Cvs	Cvs	115	
Flow coefficient 'Cv' (at 90°)	Cv	115	
Coefficient of local resistance	Kturb	1.077711	
Pressure loss coefficient (based on the mean valve velocity)	K	1.077711	
Hydraulic power loss	Wh	16.36696	W

References:

[1] Pumping Station Design, Second Edition, Garr M. Jones

[2] Internal Flow System, Second Edition, D.S. Miller