Effective closing time factor

Reduced free flow area in the throttle control system:

$$f_r = \frac{Q}{Q_{max}}$$

f_r	reduced free flow area in the throttle control system	[]
Q	flow coefficient	[]
Q_{max}	max. flow coefficient	[]

Relative Flow:

$$Q_p = \frac{f_r}{\sqrt{p + f_r^2(1-p)}}$$

Q_p	relative Flow	[]
f_r	reduced free flow area in the throttle control system	[]
p	pressure parameter	[]

Pressure parameter:

$$p = \frac{\Delta h}{h_0}$$

p	pressure parameter	[]
Δh	theoretical pressure in the closure at full opening	[m]
h_0	rated net head	[m]

Theoretical pressure in the closure at full opening:

$$\Delta h = \frac{v_0^2}{2g} * (\xi + 1)$$

Δh	theoretical pressure in the closure at full opening	[m]
v_0	valve speed	[m/s]
g	gravitational acceleration	[m/s^2]
ζ	local loss factor for open valve	[]

Valve speed:

$$v_0 = \frac{Q_0}{\frac{\pi * D_0^2}{4}}$$

v_0	valve speed	[m/s]
Q_0	flow	[m^3/s]
D_0	valve diameter	[mm]

Effective closing time factor:

$$c_{ef} = min\left[\lim_{n \to 90} \frac{0{,}1}{\left[Q_{pn} - Q_{pn+10}\right]}\right] > 0{,}125$$

c_{ef}	effective closing time factor	[]
Q_{pn}	relative flow in position n	[]

Flow characteristics:
The flow characteristic is the dependence of the actual flow rate on the position of the control actuator of the control system.
The flow characteristics of Fig.1-7 are the dependence of the actual flow rate on the position of the valve of the control system.

Note: The flow characteristics (depending on the valve manufacturer) that are dependent on the position of the valve must be recalculated for dependence on the position of the actuator. Because before the actuator may be a member (crank mechanism, ...) that is not linear.

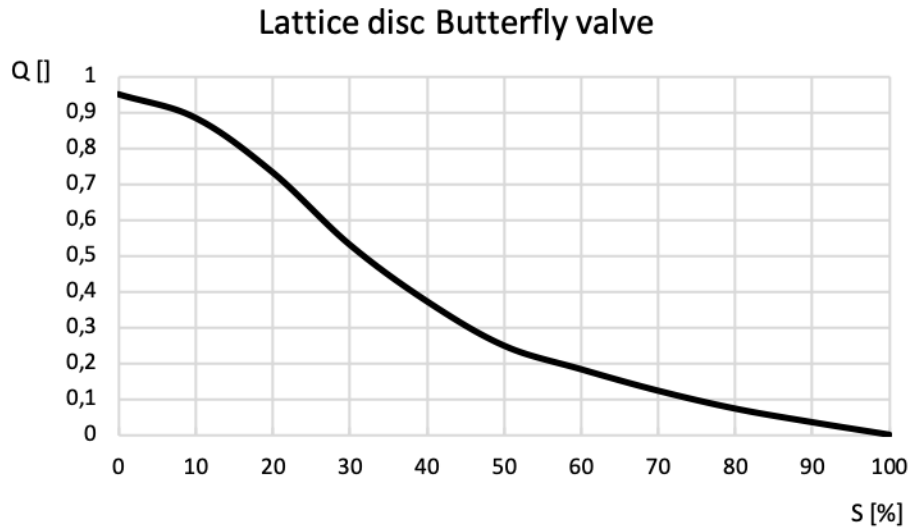

Fig.1 Flow characteristic Lattice disc Butterfly valve

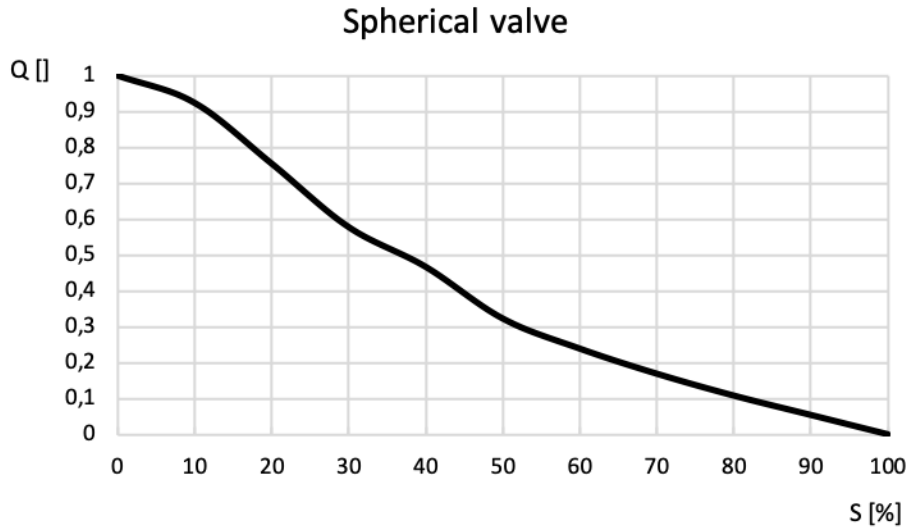

Fig.2 Flow characteristic Spherical valve

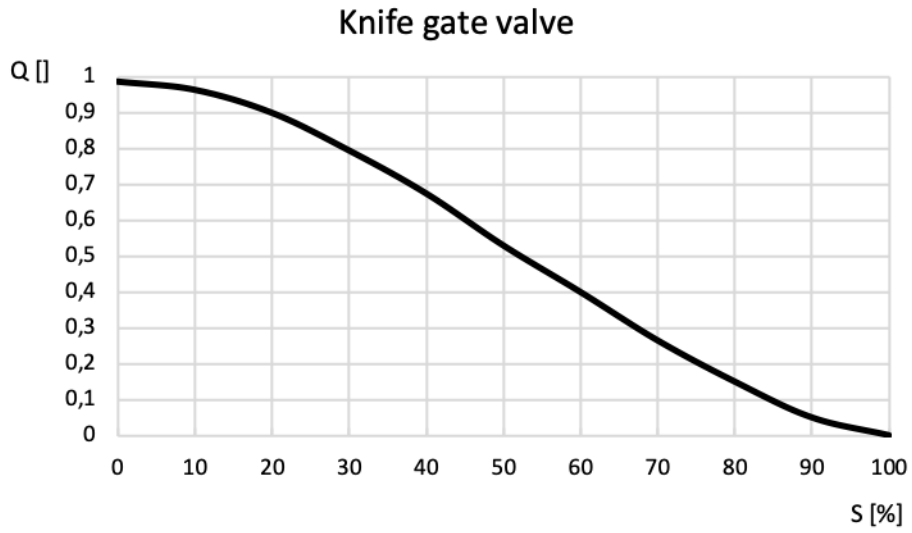

Fig.3 Flow characteristic Knife gate valve

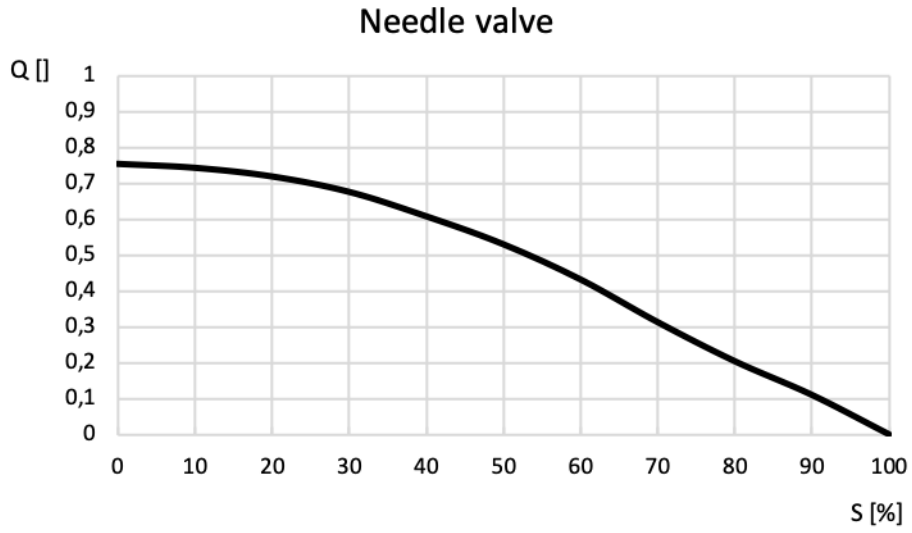

Fig.4 Flow characteristic Needle valve

Fig.5 Flow characteristic Holow-Jet

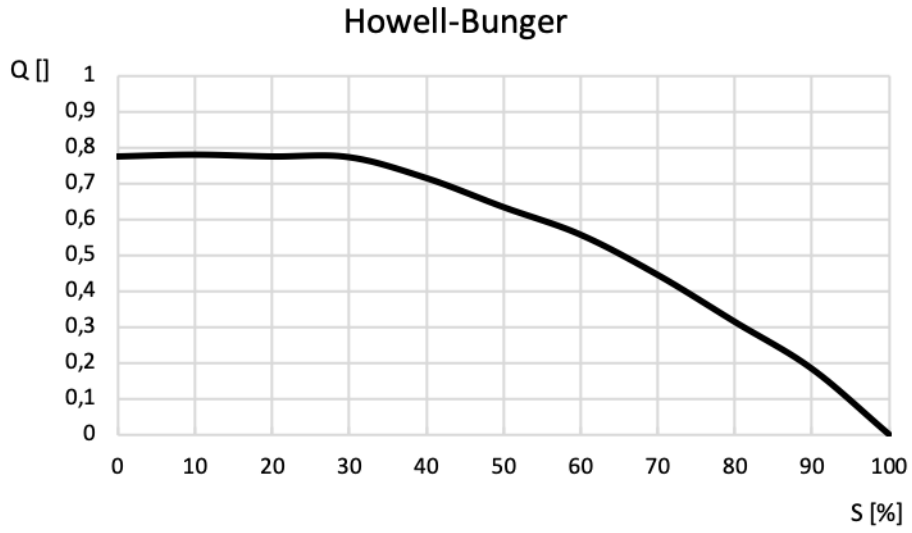

Fig.6 Flow characteristic Howell-Bunger

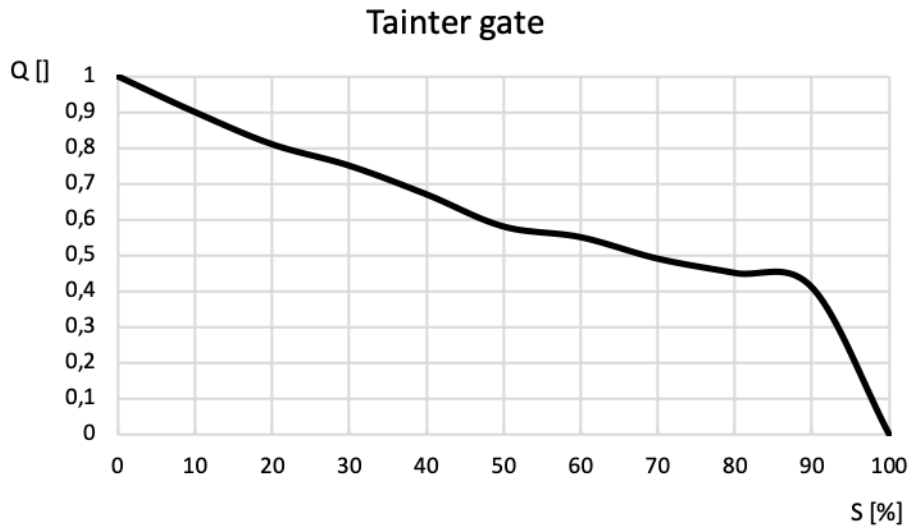

Fig.7 Flow characteristic Tainter gate

Example:
We have to determine the difference between the effective shut-off time for the flow characteristic of the valve and the flow characteristic of the control actuator (hydraulic cylinder) according to Fig.8 shut-off butterfly valve DN300 with the following parameters: h_0 = 33m; Q_0 = 0,314 m^3/s; ξ = 0,106

	0	10	20	30	40	50	60	70	80	90	100
Q1	0,951	0,885	0,733	0,531	0,373	0,249	0,183	0,123	0,073	0,035	0,000
Q2	0,951	0,888	0,755	0,583	0,433	0,306	0,218	0,155	0,102	0,047	0,000

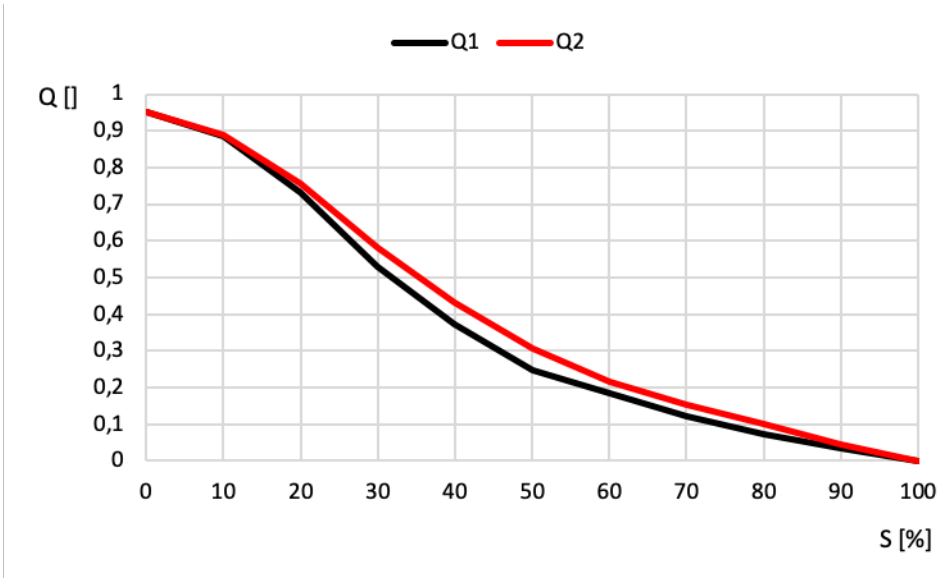

Fig.8 Flow characteristic

Q1 flow characteristic of the valve
Q2 flow characteristic of the control actuator

Valve speed:

$$v_0 = \frac{Q_0}{\frac{\pi * D_0^2}{4}} = \frac{0{,}314}{\frac{\pi * 0{,}3^2}{4}} = 4{,}44[m/s]$$

Theoretical pressure in the closure at full opening:

$$\Delta h = \frac{v_0^2}{2g} * (\xi + 1) = \frac{4{,}44^2}{2 * 9{,}81} * (0{,}106 + 1) = 1{,}11[m]$$

Pressure parameter:

$$p = \frac{\Delta h}{h_0} = \frac{1{,}11}{33} = 0{,}034[\,]$$

	0	10	20	30	40	50	60	70	80	90	100
Qp1	1,000	0,997	0,989	0,964	0,918	0,827	0,729	0,577	0,385	0,196	0,000
Qp2	1,000	0,998	0,990	0,973	0,941	0,879	0,787	0,667	0,505	0,259	0,000

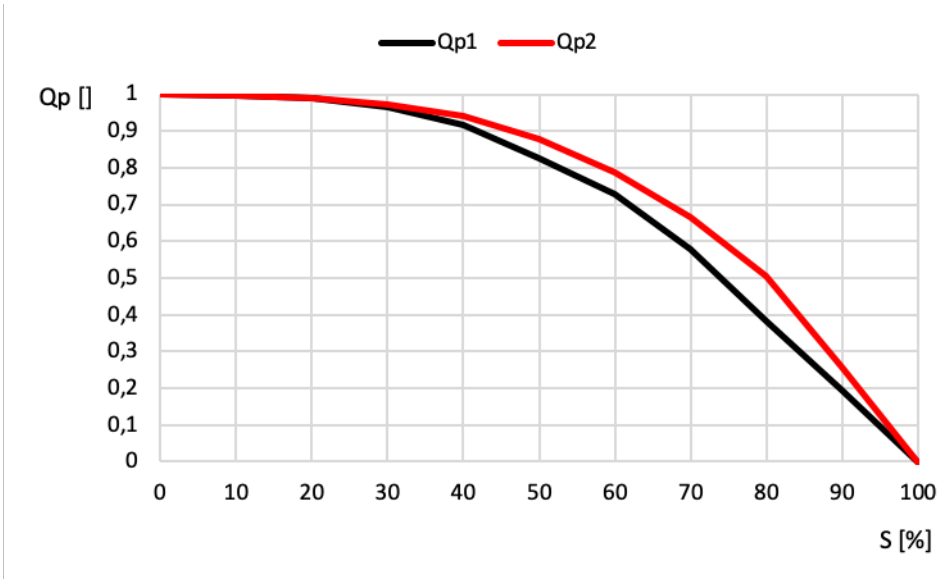

Fig.8 Relative flow characteristic p=0,034

Qp1 relative flow characteristic of the valve
Qp2 relative flow characteristic of the control actuator

$$c_{ef1} = 0{,}511[]$$
$$c_{ef2} = 0{,}386[]$$

c_{ef1} effective closing time factor (valve) []
c_{ef2} effective closing time factor (control actuator) []

$$x = 100 - \frac{c_{ef2}}{c_{ef1}} * 100 = 100 - \frac{0{,}386}{0{,}511} * 100 = 24{,}5\%$$

Literature:

F. Strohmer: Investigating the characteristics of shutoff valves by model tests. Water Power & Dam Construction 1977

By G. L. Beichley, M. ASCE and A. J. Peterka, F. ASCE: Hydraulic design of Hollow-Jet valve stilling basins. Journal of the hydraulics division 1961

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