# Water hammer

**Values for calculation:**

| | | | |
|---|---|---|---|
| Flow | $Q_{max}$ | 30 | $\mathrm{m^3/s}$ |
| Valve diameter | $D$ | 2600 | $\mathrm{mm}$ |
| Internal pipe diameter | $D_p$ | 3000 | $\mathrm{mm}$ |
| Pipe length | $L$ | 25 | $\mathrm{m}$ |
| Rated net head (max 6500m) | $h_0$ | 20 | $\mathrm{m}$ |
| Gravitational acceleration | $g$ | 9.81 | $\mathrm{m/s^2}$ |
| The water temperature | $T$ | 10 | $\mathrm{C^\circ}$ |
| Density | $\rho$ | 999.8 | $\mathrm{kg/m^3}$ |
| Medium compressibility factor | $\beta$ | 4.924E-10 | $\mathrm{Pa^{-1}}$ |
| Pipe material | | Steel | |
| Young's modulus for pipe | $E$ | 200000000000 | $\mathrm{Pa}$ |
| Loss coefficient | $\xi$ | 0.15 | |
| Effective closing time factor | $c_{ef}$ | 0.595 | |
| Closing time | $t$ | 4 | $\mathrm{s}$ |
| Thickness of the pipe wall | $e$ | 20 | $\mathrm{mm}$ |

**Valve speed:**

$$v_0 = \frac{4 \cdot 10^6 \cdot Q_{max}}{\pi \cdot D^2} = \frac{4 \cdot 10^6 \cdot 30}{\pi \cdot 2600^2} = 5.7\mathrm{m/s}$$

**Theoretical pressure in the valve at full opening:**

$$\Delta h = \frac{v_0^2}{2g} \cdot (\xi + 1) = \frac{5.7^2}{2 \cdot 9.81} \cdot (0.15 + 1) = 1.9\text{m}$$

**Pressure parameter:**

$$p = \frac{\Delta h}{h_0} = \frac{1.9}{20} = 0.094$$

$$0 < p \leq 1 \rightarrow 0 < 0.094 \leq 1$$

**Does suit.**

**Effective closing time:**

$$t_{ef} = t \cdot c_{ef} = 4 \cdot 0.595 = 2.4\text{s}$$

**Volume elastic modulus:**

$$K = \frac{1}{\beta} = \frac{1}{4.924E - 10} = 2030869212\text{Pa}$$

**Sound Speed in liquid:**

$$c = \sqrt{\frac{K}{\rho}} = \sqrt{\frac{2030869212}{999.8}} = 1425.2\text{m/s}$$

**Speed pressure waves in the pipe:**

$$a = \frac{c}{\sqrt{1 + \frac{D_p}{e} \cdot \frac{K}{E}}} = \frac{1425.2}{\sqrt{1 + \frac{3000}{20} \cdot \frac{2030869212}{200000000000}}} = 897.2\text{m/s}$$

**Pipeline speed:**

$$v_p = \frac{4 \cdot 10^6 \cdot Q_{max}}{\pi \cdot D_p^2} = \frac{4 \cdot 10^6 \cdot 30}{\pi \cdot 3000^2} = 4.2\text{m/s}$$

**Water hammer:**

$$\Delta P = \frac{L \cdot v_p}{t_{ef} \cdot g} = \frac{25 \cdot 4.2}{2.4 \cdot 9.81} = 4.5\text{m}$$