In order to determine the resistance of the pipe material to the water hammer phenomenon, the total occurring pressure (surge pressure + working pressure) should be calculated and compared to the maximum allowable total occurring pressure in each pipe material. The resistance of HDPE pipes depends on the nature of the water hammer. In case of recurring water hammer shock waves, HDPE pipes are limited to a maximum total occasional pressure of only 1.5 times the working pressure. Because of the flexibility and resilience of PEX pipes, the surge pressures caused by the water hammer are much reduced. Furthermore, because of the cross-linked structure, the PEX pipe can withstand a total transient pressure (recurring or occasional surge pressure + working pressure) at least 2.5 times the design pressure in the relevant temperature.

Comparison culculations for other pipe materials:

The following examples show the pressure surges caused by the water hammer for various pipes, which are considered for the same application. In all following examples:

The line is horizontal; line length is 2,200m.

The flow rate is 150 cubic meters per hour, head losses are 5%. The line is designed for a pump pressure of 11 bar.

The pipes calculated for this application are as follows:

1. Steel pipe 6" schedule 40, buried pipeline or above-ground installation.
2. PE 3408 6" DR 11, buried pipeline.
3. PEX 160mm SDR 13.6 Class 12, buried pipeline.
4. PE 4710 6" DR 13.5, buried pipeline
5. PEX 180mm SDR 11 Class 15, Above ground installation, ambient temperature 20°C, design temperature is 40°C.
6. PEX 180mm SDR 9 Class 19, Above ground installation, ambient temperature 40°C, design temperature is 60°C.

1. Steel pipe 6" sch.40

Buried pipeline or above ground installation.

OD 6.625" (168.3mm), w.t. 7.11mm, d = 154mm , V= 2.2m/sec, E= 210,000 MPa

$$a = \frac{1440}{\sqrt{1 + 2{,}070 \times \frac{154}{7.11 \times 2.1 \times 10^5}}}$$

a= 1307m/sec t = 2L/a =2x2200/1307= 3 sec

$$P = 0.1 \times 1307 \times \frac{2.2}{9.81} = 29 \text{ bar}$$

The results are: surge pressure: 29 bar.

Total transient pressure: surge pressure (29 bar) + pump pressure in the line (11 bar) is 40 bar.

2. PE 3408 6" DR 11

Buried pipeline:

Maximum allowable working pressure of the pipe is 11 bar (160 psi) at 20°C.

Max. allowable total transient pressure: 16.5 bar (240 psi).

OD 6.625" (168.3mm), w.t. 0.602" (15.3mm), d=137.7mm, V=2.8m/sec

E=827 MPa at 20°C

$$a = \frac{1440}{\sqrt{1 + 2070 \times \frac{137.7}{15.3 \times 827}}}$$

a=297m/sec t=2L/a=2x2200/297=15sec

$$P = 0.1 \times 297 \times \frac{2.8}{9.81} = 8.5 \text{ bar}$$

The results are: surge pressure: 8.5 bar, total transient pressure: 11+8.5= 19.5 bar

The total transient pressure exceeds the max. allowable total transient pressure for this pipe material.

3. Pexgol 160mm SDR 13.6 Class 12

Buried pipeline:

Maximum allowable working pressure of the pipe is 12 bar at 20°C.

Max. allowable total transient pressure: 30 bar.

OD 160mm, w.t. 11.8mm, d=136.4mm, V=3m/sec

E=465 MPa at 20°C

$$a = \frac{1440}{\sqrt{1 + 2070 \times \frac{136.4}{11.8 \times 465}}}$$

a=199m/sec t=2L/a=2x2200/199=22sec

$$P = 0.1 \times 199 \times \frac{3}{9.81} = 6 \text{ bar}$$

The results are: surge pressure: 6 bar, total transient pressure: 12+6=18 bar

The total transient pressure is much lower than the maximum allowable total transient pressure (30 bar).

4. PE 4710 6" DR 13.6

Buried pipeline:

Maximum allowable working pressure of the pipe is 11 bar (160 psi) at 20°C.

Allowable total pressure during Recurring surge is 16.5 bar.

OD 6.625" (168.3mm), w.t. 0.491" (12.5mm), d=143.4mm, V=2.6 m/sec

E=827 MPa at 20°C

$$a = \frac{1440}{\sqrt{1 + 2070 \times \frac{143.4}{12.5 \times 827}}}$$

a=264m/sec t=2L/a=2x2,200/264=17sec

$$P = 0.1 \times 264 \times \frac{2.6}{9.81} = 7 \text{ bar}$$

The results are: surge pressure: 7 bar, total transient pressure: 11+7=18 bar.

The total transient pressure exceeds the max. allowable total transient pressure for this pipe material.

5. Pexgol 180mm SDR 11 Class 15

Above ground installation: ambient temperature is 20°C, design temperature is 40°C.

Maximum allowable working pressure of the pipe is 12 bar at 40°C.

Max. allowable total transient pressure: 30 bar.

OD 180mm, w.t. 16.4mm, d= 147.2mm, V= 2.5 m/sec

E=228 MPa at 40°C

$$a = \frac{1440}{\sqrt{1 + 2070 \times \frac{147.2}{16.4 \times 228}}}$$

a=159m/sec t=2L/a=2x2,200/159=28 sec

$$P = 0.1 \times 159 \times \frac{2.5}{9.81} = 4 \text{ bar}$$

The results are: surge pressure – 4 bar, total transient pressure: 12+4=16 bar

The total transient pressure is much lower than the maximum allowable total transient pressure (30 bar).

6. Pexgol 180mm SDR 9 Class 19

Above ground installation: ambient temperature is 40°C, design temperature is 60°C.

Maximum allowable working pressure of the pipe is 12 bar at 60°C.

Max. allowable total transient pressure: 30 bar.

OD 180mm, w.t. 20mm, d=140mm, V=2.7m/sec

E=136 MPa at 60°C

$$a = \frac{1440}{\sqrt{1 + 2070 \times \frac{140}{20 \times 136}}}$$

a=139m/sec t=2L/a=2x2,200/139=32 sec

$$P = 0.1 \times 139 \times \frac{2.7}{9.81} = 4 \text{ bar}$$

The results are: surge pressure: 4 bar, total transient pressure: 11+4=15 bar

The total transient pressure is much lower than the maximum allowable total transient pressure (30 bar).

Conclusions:

1. The surge pressure caused by the water hammer in steel pipes is at least three times higher than the surge pressure in PEX pipes.

2. The surge pressure caused by the water hammer in HDPE pipes could sometimes be too high.

3. PEX pipes have a high margin for surge pressures in all temperature range and pipe classes.

The expression for a = the velocity of pressure wave is a function of the short term Modulus E and the dimension ratio d/e, which is the same for each pipe class: d/e=(D-2xe)/e=(D/e)-2=SDR-2

It is possible to calculate the values for a for each pipe class.

In the following table (32.1), the values of the pressure velocity a were calculated for the following design temperatures:

20°C – for buried pipes

40°C – for above ground pipes at ambient temp of 20°C

60°C – for above ground pipes at ambient temp of 40°C

The values of P were calculated for line velocity of 1.0 m/sec.

Table 32.1 shows the low surge pressures expected in PEX pipes.