Pressure limitations and safety factors

Pressure curves

Hoop or circumferential stress is the single largest stress present in any piping system under pressure. It is therefore the governing factor in determining the pressure that a pipe section can withstand. The hoop stress in any pipe is calculated by the outcome of an equation that includes internal pressure, pipe diameter and wall thickness.

For most manufacturers, the long-term performance of the piping system has been established through the calculation of the hydrostatic pressure curve for each material. These pressure temperature curves show the correlation between the hoop (or circumferential) stresses of the material, measured in megapascals (Mpa), versus the time to fail in hours (h). The result of this calculation shows how the pressure rating of the piping material will perform over time, in conjunction with increasing temperatures.

Pressure curves for all of our piping materials are available upon request. We can also assist you in helping to calculate the design life of your chosen piping material at elevated temperatures. Please contact us for more information or further assistance.

Safety factors

The published pressure ratings for thermoplastic piping systems take into account the circumferential stress of the individual materials over their expected lifetime. In addition, the published data also includes provision for material specific safety factors. These safety factors are published below, and are based upon a minimum 50 year design life with water at 20°C.

Material	Minimum Safety Factor
PVC-U	2.0
PVC-C	2.0
ABS	2.1
PP-H	2.1
PP-R	2.1
PE80	1.6
PE100	1.25
PVDF	2.0
ECTFE	2.0

Pressure ratings for fittings and valves

Whilst there is usually clear definition of the maximum working pressure for pipes, some care needs to be taken with the choice of fittings and valves. In most cases, thermoplastic pipe fittings carry the same pressure rating as the pipe itself. However, some mechanical pipe fittings and valves may be rated lower than the pipe. Some examples include flanges and threaded fittings:

Flange B54504 (EN1092) PN6:	6 bars maximum
Flange B54504 (EN1092) PN10:	10 bars maximum
Flange ASA 150 (PR EN 1759):	10 bars maximum
BSP threaded fittings (IS0787):	10 or 12 bars maximum

Always consider the item with the lowest pressure rating in any system.

Terminology used to define pressure ratings for thermoplastic piping systems

Nominal Pressure (PN)

The most common method of defining pressure ratings for thermoplastic piping systems is to group together pipes, fittings and valves according to a single nominal pressure rating. This method can simplify the selection process, and its use is internationally widespread. The PN rating is the maximum permitted operational pressure in bars calculated at 20°C, for example PN6 indicates a maximum working pressure of 6 bars.

The 'Class' system of pressure ratings

PVC-U Pipes according to BS 3505/3506 (BS EN1452), PVC-U fittings according to BS 4346, ABS pipes according to BS 5391, and ABS fittings according to BS 5392 all use the 'class' system of pressure rating their components. Regardless of size, pipes and fittings are rated for use at a maximum working pressure according to the 'class'. Care must be taken to ensure that the integrity of the system is not compromised through the incorrect match of pipes and fittings from different pressure 'classes'. The pressure ratings of PVC-U and ABS pipes and fittings according to the pressure 'class' system is as follows:-

Class B	6 Bar
Class C	9 Bar
Class D	12 Bar
Class E	15 Bar

PVC-U and ABS pipes with a heavy wall 'Class T' (sometimes referred to as 'Class 7') rating are also produced as threading quality piping materials, or for use in installations requiring special support, temperature or pressure handling capabilities. Note that threading plastic pipes reduces the maximum operating pressure of the system by 50%.

The 'Schedule' system of pressure ratings

PVC-U and PVC-C thermoplastic piping systems manufactured in accordance with ASTM requirements use a 'schedule' system of pressure ratings. Pipes are produced in three different 'schedules', 40, 80 & 120. Under this system the pressure rating of the pipe changes according to the pipe nominal bore size.

Unlike pipe, there is presently no industry standard that specifies a working pressure for fittings. Moulded pipe fittings are manufactured to meet the minimum burst pressure requirements to that of schedule 40 and schedule 80 pipe. In common with the pipe, the pressure rating of the fittings decreases as the nominal pipe sizes increases. By way of example, the range of pressure ratings for 'schedule' pipes is as follows:-

Schedule 40 (PVC & PVC-C)	56 Bar (1/8") - 8.2 Bar (24")
Schedule 80 (PVC & PVC-C)	85 Bar (1/8") - 14.5 Bar (24")
Schedule 120 (PVC)	70 Bar (1/2") - 25.5 Bar (6")

Schedule 40, 80 and 120 pipes are manufactured to ASTM D1784 for materials and ASTM F 441 for pipe dimensions. PVC-U schedule 40 fittings are manufactured according to ASTM D2466, whilst PVC-U Schedule 80 fittings are manufactured according to ASTM D2467. PVC-C Schedule 80 fittings are manufactured according to ASTM F439.

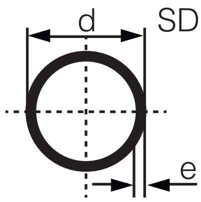
Terminology used to define pressure ratings for thermoplastic piping systems

Standard Dimensional Ratio (SDR)

Standard Dimensional Ratio (SDR) is used to define thermoplastic pipes in a variety of materials including polypropylene, polyethylene, and PVC-U. Taken from ISO 4065, SDR is described as being 'the ratio of the nominal outside diameter of a pipe to its nominal wall thickness'. To calculate the SDR according to ISO 4065 the following equation can be used:

$$SDR = \frac{d}{e}$$

where:
SDR = Vlaue to be calculated
e = Thickness of the pipe wall (mm)
d = Pipe outside diameter (mm)



However, although pipes in different materials might share the same SDR number, there may be distinct differences in both outside diameter and wall thickness. Unlike the `PN' or `S' Series' methods they will not share the same nominal pressure rating. This is because the hoop stress differs from one material to another.
When selecting thermoplastic piping systems, it is recommended that in addition to the material type, the pipe dimensions, wall thickness, pipe series and SDR numbers are all referenced.

'S' Series: ISO 4065

ISO 4065 specifies the relationship between the nominal wall thickness and the nominal outside diameter of thermoplastic pipe. Defined under this method, pipes of the same material with the same series or `S' number have the same pressure rating. According to ISO 4065, `S' is a dimensionless number that can be calculated from the following equation:

$$S = \frac{SDR - 1}{2}$$

Example: SDR 11 Polypropylene

$$S = \frac{SDR - 1}{2}$$

$$S = \frac{11 - 1}{2}$$

$$S = 5$$

Comparison of SDR value with nominal pressure rating for common materials

	Nominal Pressure Rating (PN) by Material					
SDR	PE 80	PE 100	PP	PVDF	PVC-U	PVC-C
51	2.5	3.2	-	-	4	-
41	3.2	4	2.5	-	-	-
33	4	5	3.2	10	6	-
26	5	6.3	4	-	-	-
22	6	7.6	-	-	-	-
21	6.3	8	-	16	10	10
17,6	7.6	9.7	6	-	-	-
17	8	10	-	-	-	-
13,6	10	12.5	-	-	16	16
11	12.5	16	10	-	-	-
9	16	20	-	-	25	25
7,4	20	25	16	-	-	-
6	25	-	-	-	-	-

Calculating the allowable pressure and pipe wall

The vessel formula

The vessel formula is used to calculate the minimum pipe wall thickness for a thermoplastic pipe subject to a given internal pressure:

$$e = \frac{p \cdot d}{20 \cdot \sigma + p}$$

where:

e = Thickness of the pipe wall (mm)
d = Pipe outside diameter (mm)
p = Permissible operating pressure at 20°C (bar)
o = Permissible hoop (circumferential) stress with safety factor (N/mm2)
20 = Constan

This formula can be used to calculate the pipe wall thickness for a variety of thermoplastic materials, however in smaller dimensions the actual production sizes of pipes may have increased wall thickness because of manufacturing constraints.

Plastic pipes for vacuum or external pressure

When subjected to vacuum or to an external fluid pressure, plastic pipes are subjected to stresses that can lead to the collapse of the pipe.

As a general guide, the following formula can be used to determine the collapse pressure dependent an the pipe size and operating temperature:

$$P_c = \frac{20 \times E \times (e/D)^3}{0.84}$$

where

P_c = Collapse Pressure (bar)
E = Modulus of Elasticity (N/mm2)
e = Wall Thickness (mm)
D = Nominal Pipe Size - usually taken as the outside diameter (mm)
0.84 - Constant

The modulus of elasticity can be obtained from the E modulus diagrams. Note that account must be taken of the operating temperature and service life. Pipe dimensions may be found in each material section.

Using the result from this calculation, the maximum allowable negative pressure can now be calculated using the following formula:

$$P_e = \frac{P_c}{c}$$

where

P_c = Collapse Pressure (bar) from calculation above
P_e = Maximum Allowable Negative Pressure (bar)
C = Safety Factory (usually 2)

If P_e is greater than 1, the pipe is suitable for full vacuum under the calculated conditions.

Calculating the allowable pressure and pipe wall

Example: Can a 200 mm O.D. DIN 8061/2 PVC-U PN10 pipe withstand a vacuum at 20°C and 50°C?

Pipe size (D):	200 mm
Wall thickness (e):	9.6mm
Modulus of elasticity (E):	1420 N/mm² at 20°C (from diagram)
	580 N/mm² at 50°C (from diagram)

At 20°C: Collapse pressure $P_c = \frac{20 \times 1420 \times (9.6/200)^3}{0.84} = 3.74$ bar

Maximum negative pressure $Pe = \frac{3.74}{2} = 1.87$ bar

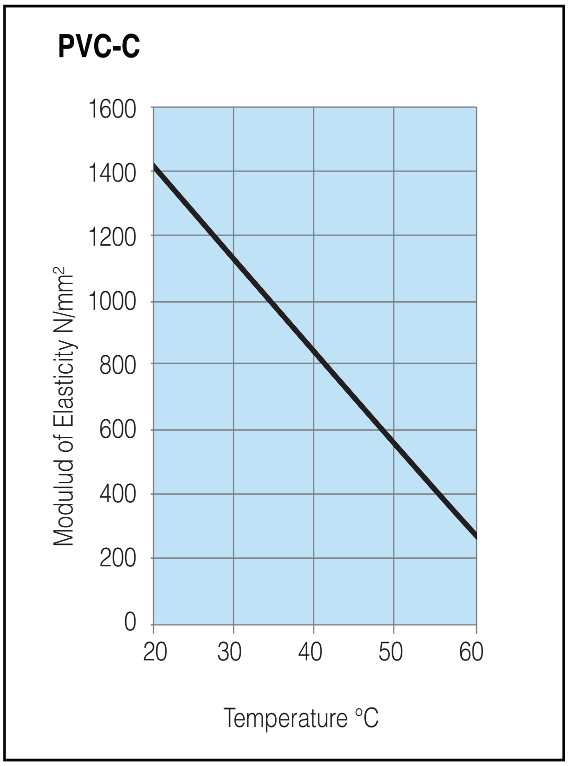
Answer: Pe = 1.87 > 1 so the pipe will support full vacuum at 20°C.

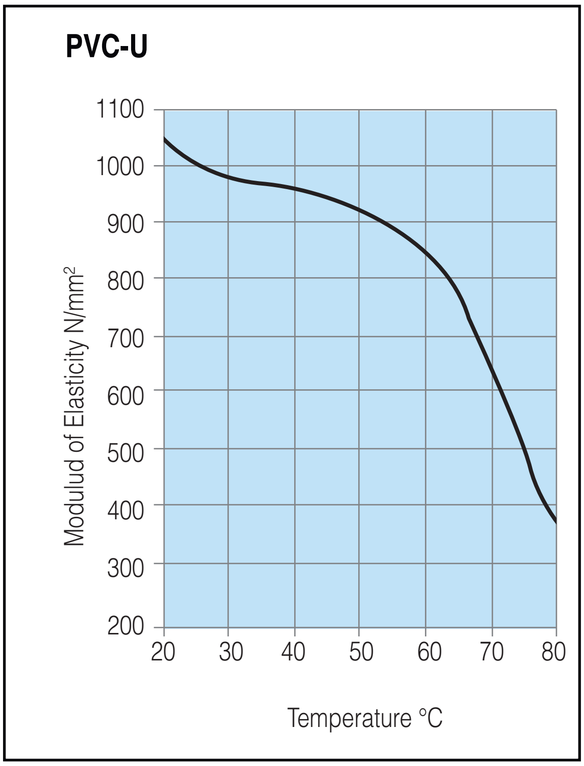
At 50°C: Collapse pressure $P_c = \frac{20 \times 580 \times (9.6/200)^3}{0.84} = 1.60$ bar

Maximum negative pressure $P_e = \frac{1.60}{2} = 0.80$ bar

Answer: P_e = 0.80 < 1 so the pipe will not support full vacuum at 50°C.

E-modulus diagrams

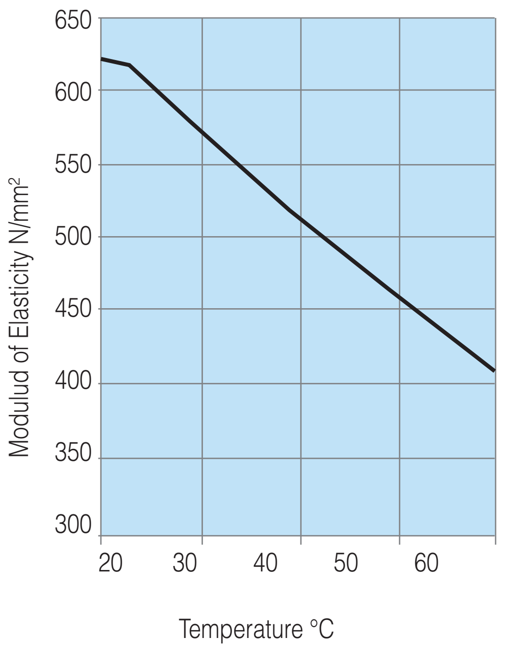




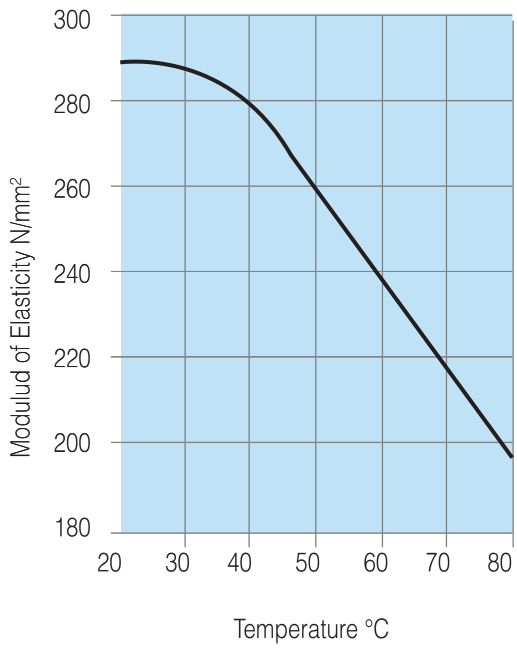
Calculating the allowable pressure and pipe wall

E-modulus diagrams

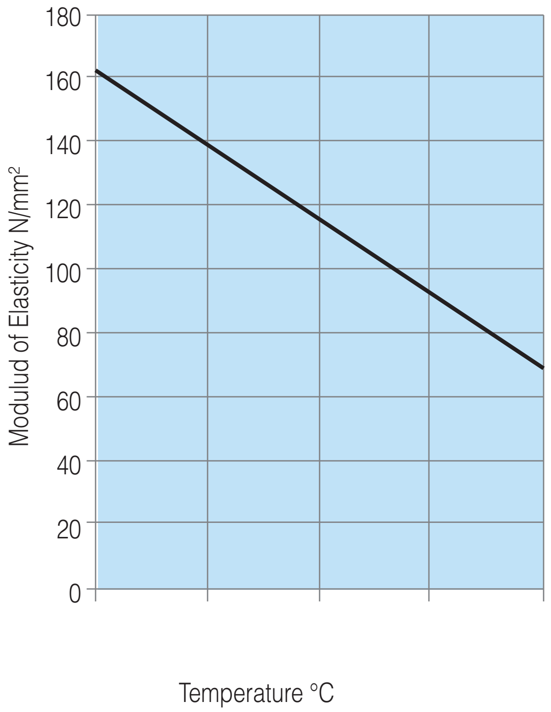
ABS



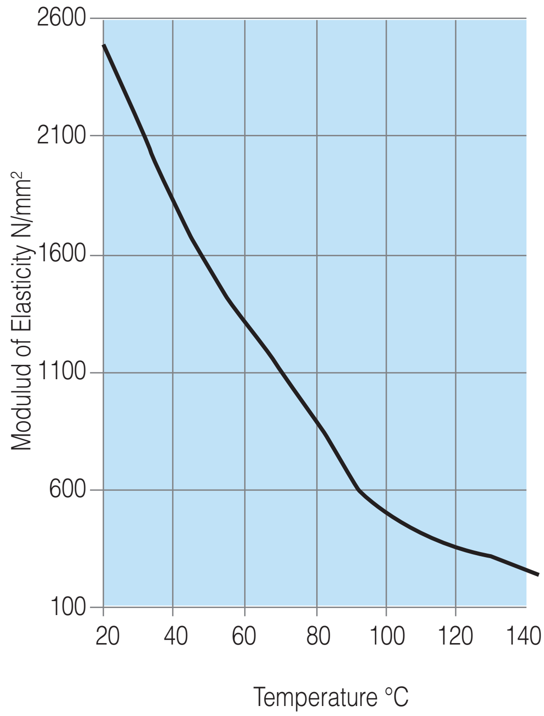
PP-H



PE 80*



PVDF



* PE100: There are no e-modulus diagrams available yet for PE100, however as a guide it is recommended to raise the values of PE80 by 10%.