Materials used for industrial pipe work

The material polyethylene (PE)

PE properties (reference values)

	PE 80	PE 100		
Characteristics	Value	Value	Units	Test Standard
Density	0.93	0.95	g/cm³	EN ISO 1183-1
Yield stress at 23 °C	18	25	N/mm²	EN ISO 527-1
Tensile e-modulus at 23 °C	700	900	N/mm²	EN ISO 527-1
Charpy notched impact strength at 23 °C	110	83	kJ/ m²	EN ISO 179-1/1eA
Charpy notched impact strength at -40 °C	7	13	kJ/ m²	EN ISO 179-1/1eA
Ball indentation hardness (132N)	37		MPa	EN ISO 2039-1
Crystallite melting point	131	130	°C	DIN 51007
Thermal expansion coefficient	0.15 ... 0.20		mm/m K	DIN 53752
Heat conductivity at 23 °C	0.43	0.38	W/m K	EN 12664
Water absorption at 23 °C	0.01 - 0.04		%	EN ISO 62
Colour	9005		-	RAL
Limiting oxygen index (LOI)	17.4		%	ISO 4589-1

General

Polymers which consist only of carbon and hydrogen (hydrocarbons) are called polyolefins.
Polyethylene (PE) belongs to this group. It is a semi-crystalline thermoplastic. Polyethylene is the best known standard polymer.
The chemical formula is: $(CH_2\text{-}CH_2)_n$. It is an environmentally friendly hydrocarbon product.

PE and PP belong to the non-polar materials. Because of this, the material does not dissolve in common solvents and, in addition, hardly swells. As a result, PE pipes cannot be solvent cemented. The appropriate jointing method for this material is welding. For piping installations we offer three welding techniques in our product range: butt fusion, socket welding and electrofusion.

The latter jointing technique is preferred for piping systems transporting gas, water, compressed air or other less aggressive media. Butt and socket welding are preferably used on a diameter-specific basis.

High molecular PE grades of medium to high density have become state of the art for industrial piping installations. The grades are classified in accordance with their internal pressure resistance in PE80 (MRS 8 MPa) and PE100 (MRS 10 MPa).

In this context, we also talk about PE grades of the 3rd generation. PE80 grades belong, in most cases, to the 2nd generation. PE grades of the 1st generation – PE63 according to current classifications— have practically no application anymore.

In piping construction, PE is mostly used for buried gas and water lines. For this range of applications, polyethylene has become the dominant material in numerous countries. But also building technology and industrial piping installations make use of the advantages of this material.

The advantages include:

- low weight
- outstanding flexibility
- good abrasion resistance
- corrosion resistance
- high impact resistance even at very low temperatures
- good chemical resistance
- safe and easy jointing by welding
- excellent cost-performance ratio

Mechanical properties

Modern PE100 grades show a bimodal molecular weight distribution, i. e. they consist of two different kinds of molecular chains (short and long). These polyethylenes combine a high tensile strength with a high resistance against fast and slow crack propagation. In addition, the short molecular chains provide a good processability.

Similar to ABS, PE also shows a very high impact strength, even at low temperatures. For this test, a specimen is weakened with a sharp notch and then struck. In doing this the impact energy absorbed by the material is measured. This test proves that polyethylene is insensitive to surface damage with subsequent impact stress. A robust behaviour like this, combined with a high elongation to break, is of big advantage in a lot of applications, e.g. in regions that have a high risk of earthquakes.

The long-term behaviour for internal pressure resistance is provided by the hydrostatic strength curve based on the EN ISO 15494 standard (see the Calculation and Long-Term Behaviour section for PE). The application limits for pipes and fittings, as shown in the pressure-temperature diagram, can be derived from these curves.

Chemical, weathering, and abrasion resistance

Due to its non-polar nature as a hydrocarbon of high molecular weight, polyethylene shows a high resistance against chemical attack. PE is resistant to acids, alkaline solutions, solvents, alcohol and water. Fat and oil swell PE slightly. PE is not resistant against oxidising acids, ketones, aromatic hydrocarbons and chlorinated hydrocarbons.

For detailed information, please refer to the detailed list of chemical resistance from GF or contact your local GF subsidiary.

If polyethylene is exposed to direct sunlight over a long period of time, it will, like most natural and plastic materials, be damaged by the short wave UV portion of sunlight together with oxygen in the air, causing photo-oxidation. Because of this, our black polyethylene grades are effectively stabilised against UV light by adding carbon black.

As with ABS, PE also has excellent resistance against abrasion. As a result, PE piping systems are used in numerous applications for transporting solids and slurries. Experience has shown that PE as well as ABS offers considerable advantages over metal and other plastics for many such applications.

Please contact GF if you are planning such an application. We would be glad to advise you about the suitability of our PE, ABS and other materials for your media.

Thermal properties

Polyethylene pipes can be used at temperatures ranging from -50 °C to +60 °C.

At higher temperatures, the tensile strength and stiffness of the material are reduced. Therefore, please consult the pressure-temperature diagram. For temperatures below 0 °C it must be ensured, as for every other material, that the medium does not freeze, consequently damaging the piping system.

Like all thermoplastics, PE shows a higher thermal expansion than metal. Our PE has a coefficient of linear thermal expansion of 0.15 to 0.20 mm/m K, which is 1.5 times greater than that of e. g. PVC. As long as this is taken into account during the planning of the installation, there should be no problems in this regard.

The thermal conductivity is 0.38 W/m K. Because of the resulting insulation properties, a PE piping system is notably more economical in comparison to a system made of a metal like copper.

Combustion behaviour

Polyethylene belongs to the flammable plastics. The oxygen index amounts to 17 %. (Materials that burn with less than 21 % of oxygen in the air are considered to be flammable).

PE drips and continues to burn without soot after removing the flame. Basically, toxic substances are released by all burning processes. Carbon monoxide is generally the combustion product most dangerous to humans. When PE burns, primarily carbon dioxide, carbon monoxide and water are formed.

The following classifications in accordance with different combustion standards are used: According to UL94, PE is classified as HB (Horizontal Burning) and according to DIN 53438-1 as K2. According to DIN 4102-1 and EN 13501-1, PE is listed as B2 (normally flammable). In the French classification of building materials, polyethylene corresponds to M3 (of average flammability rating).

The self-ignition temperature is 350 °C.

Suitable fire-fighting agents are water, foam, carbon dioxide or powder.

Electrical properties

Because of the low water absorption of PE, its electrical properties are hardly affected by continuous water contact.

Since PE is a non-polar hydrocarbon polymer, it is an outstanding insulator. These properties, however, can be worsened considerably as a result of pollution, effects of oxidising media or weathering. The specific volume resistance is $>10^{17}$ Ωcm; the dielectric strength is 220 kV/mm.

Because of the possible development of electrostatic charges, caution is recommended when using PE in applications where the danger of fires or explosion is given.

Physiological properties

The black material types from GF are authorised for use in food applications. The fittings are odourless and tasteless as well as physiologically inert. Usage in all related areas is thus possible.

Design of metric industrial piping systems

Long-term behaviour of thermoplastics materials

Long-term behaviour of PE

Calculation (based on EN ISO 15494:2003)

The following diagrams show the long-term behaviour of PE80 and PE100. For the temperature range from 10 °C to 80 °C fracture lines are displayed. They are designated as LCL curves (Lower Confidential Limit), that means, according to the definition, 97.5 % of all fracture points are on or above the curves.

Typically for semi-crystalline thermoplastics like PE, the hydrostatic strength diagram shows a knee.

The curves are plotted in a double logarithmic scale (not linear), please take this into account when reading out values for stress or time.

The pressure/temperature diagram, which we indicate for pipes and fittings made of PE80 and PE100, is derived from the hydrostatic strength diagram with the design factor incorporated and a lifetime of 25 years.

The hydrostatic strength diagram was determined with the extrapolation method according to EN ISO 9080. With the following equation (3-parameter model) stress, temperature or time can be calculated in the temperature range of 10 °C to 80 °C.

First branch (i. e. the left-hand portion of the curves as shown in the following figures).

PE100:

$$\log t = -38.9375 + 24482.4670\ \frac{1}{T} - 38.9789\ \log\sigma$$

PE80:

$$\log t = -40.9578 + 23596.3495\ \frac{1}{T} - 37.5758\ \log\sigma$$

PE63:

$$\log t = -41.4173 + 22008.5722 \cdot \frac{1}{T} - 35.0987 \cdot \log\sigma$$

Second branch (i. e. the right-hand portion of the curves as shown in the following figures).

PE100:

$$\log t = -20.3159 + 9342.693\ \frac{1}{T} - 4.5076\ \log\sigma$$

PE80:

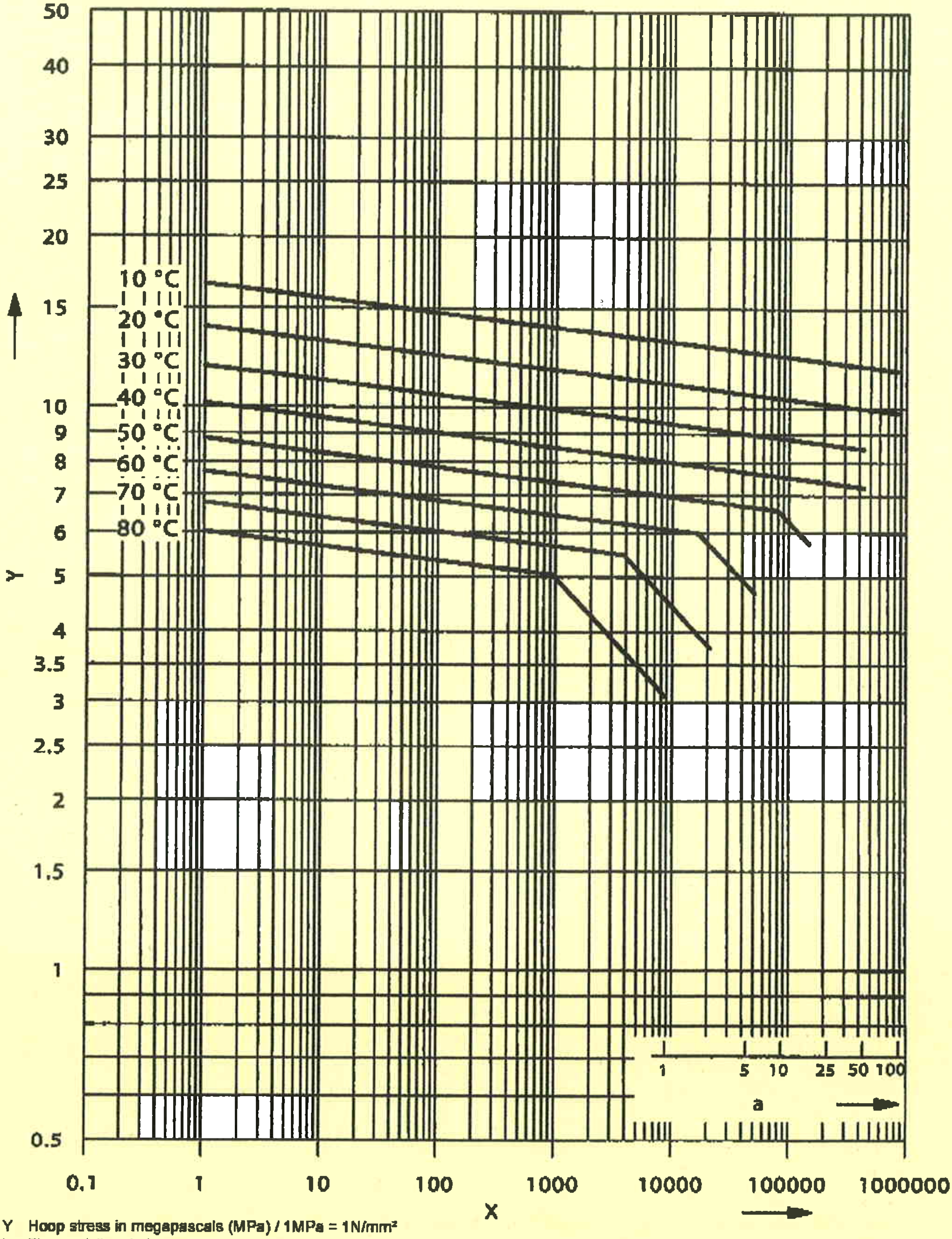
$$\log t = -19.9417 + 8804.4333\ \frac{1}{T} - 3.3219\ \log\sigma$$

PE63:

$$\log t = -19.8823 + 8619.3570\ \frac{1}{T} - 3.0390\ \log\sigma$$

with
t: Time to failure in hours (h)
T: Medium temperature in Kelvin
σ: Hoop stress in MPa (1 MPa = 1 N/mm²)

Hydrostatic strength curve PE100 (EN ISO 15494:2003)



Y Hoop stress in megapascals (MPa) / 1MPa = 1N/mm²
X Time to failure in hours (h)
a Years

Design of metric industrial piping systems

Application area of pipes and fittings

Pressure/temperature diagram for PE

PE 100

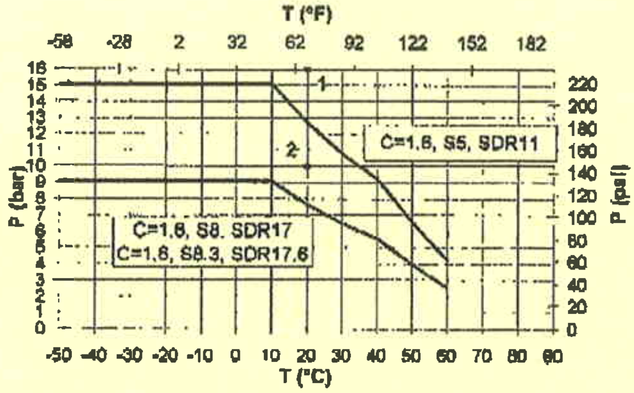
The following pressure/temperature diagram for PE100 pipes and fittings is valid for a lifetime of 25 years.

The design factor of 1.6 (respective 1.25) recommended by GF is incorporated.

It can be used for water or media resembling water, in other words, media which have no derating factor regarding the chemical resistance.

Remark: Please take into account the pressure/temperature diagrams for valves and special fittings. Because of the construction and/or sealing material used, differences are possible when compared with pipes and fittings. This information can be found in the planning fundamentals of the relevant types of valves, respectively special fittings.

In case of long-term applications at continuous pressure with temperatures above 40 °C, please contact your GF representative.



1 Design Factor C = 1.25, S5, SDR11 for 20 °C water, 50 years

2 Design Factor C=1.25, S8.3, SDR17.6 and S8, SDR17 for 20 °C water, 50 years

P Permissible pressure in bar, psi

T Temperature in °C, °F

PE 80

The following pressure/temperature diagram for PE80 pipes and fittings is valid for a lifetime of 25 years.

The design factor of 1.6 recommended by GF is incorporated.

It can be used for water or media resembling water, in other words, media which have no derating factor regarding the chemical resistance.

Remark: Please take into account the pressure/temperature diagrams for valves and special fittings. Because of the construction and/or sealing material used, differences are possible when compared with pipes and fittings. This information can be found in the planning fundamentals of the relevant types of valves, respectively special fittings.

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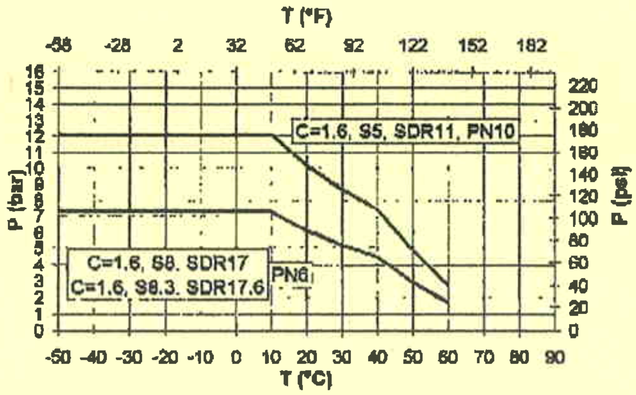


P Permissible pressure in bar, psi

T Temperature in °C, °F

Comparison of nominal pressure for SDR17 and SDR17.6

Ascertaining the nominal pressure (PN)

According to the standard, the nominal pressure is a numeric measure of the size of a pipeline part, which refers to the mechanical properties of that pipeline part. Besides the geometric sizes such as SDR, the creep strength/dimensioning tension and the minimum design factor are also taken into consideration.

For plastic piping systems intended to carry water, the nominal pressure value indicates the maximum permitted operating pressure in bar, at a temperature of 20°C, and 50 years in water, referenced to the minimum value of the total (calculation) coefficients. It is calculated using the following equation:

$[PN] = 10 \cdot \sigma_s / [S] = 20 \cdot \sigma_s / (SDR - 1)$ (σ_s in MPa, PN in bar)

Minimum required strength (MRS):

The value of σ_{LCL} at 20°C and 50 years in water, rounded down to the next value in the R10 standard series of numbers.

σ_{LCL} is understood to mean the equivalent stress ascertained for a given period and a given temperature from the time-dependent creep diagram. LCL stands for Lower Confidence Limit. The R10 standard series of numbers is a Renard standard series of numbers as per ISO 3 and ISO 497.

Design stress (σ_s):

The permitted stress for a particular application or operating conditions stated in megapascal. It is derived by dividing the MRS by coefficient C and is calculated as shown in the equation below:

$\sigma_s = MRS / C$

The calculated value is rounded down to the next value in the R10 standard series of numbers.

Total operating (calculation) coefficient (C):

A total coefficient having a value greater than one, which takes into account both the operating conditions and also the characteristics of the pipeline component that have not yet been entered into the lower confidence limit σ_{LCL}.

If we use the above definition to calculate the relevant nominal pressure for both SDR classes, the result for a PE 100 pipe is as follows:

SDR17	SDR17.6
MRS = 10 MPa	MRS = 10 MPa
C = 1.25 (minimum factor)	C = 1.25 (minimum factor)
σ_s = 8.0 MPa	σ_s = 8.0 MPa
PN = 10 bar	PN = 9.6 bar

The above definitions thus produce a difference of 0.4 bar in PN, but in actual practice this does not matter, as shown below:

1.) Industrial pipelines are normally designed for a service life of 25 years. If from the time-dependent creep diagrams we ascertain for ELTEX TUB 121 or CRP 100 an equivalent stress of σ_{LCL} for the operating point of 25 years and 20°C, we obtain a tension of 10.6 MPa (minimum value of both PE100 materials as per manufacturer's data).

2.) If we use this tension to ascertain the dimensioning tension σ_s, and do not round it down, we obtain the value of 8.48 MPa.

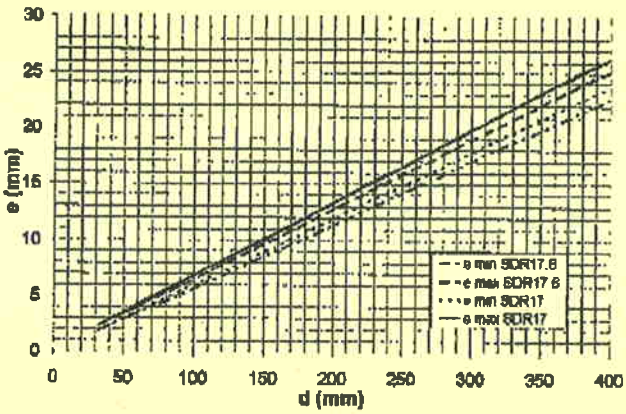
3.) Thus the actual nominal pressure in practice is:

for SDR 17 => PN = 10.6 bar and for
SDR 17.6 => PN = 10.2 bar.

To summarise: Both SDR classes comply with requirements for industrial applications mentioning a PN10 system.

Comparison of geometric dimensions

The two SDR classes differ only slightly in wall thickness, as can be seen from the diagram below. This shows that there is an area where the wall thickness complies with both requirements of both SDR classes.



d Outside pipe diameter
e Wall thickness

For butt fusion the wall thickness gap may not exceed 10 %. Looking at the differences of the wall thicknesses of SDR17 and SDR17.6 the resulting gap is much lower, that means butt fusion of both SDR's is no problem.