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FIP

PRESSURE FITTINGS

PE 100

Short and long fittings for butt welding and electrofusion

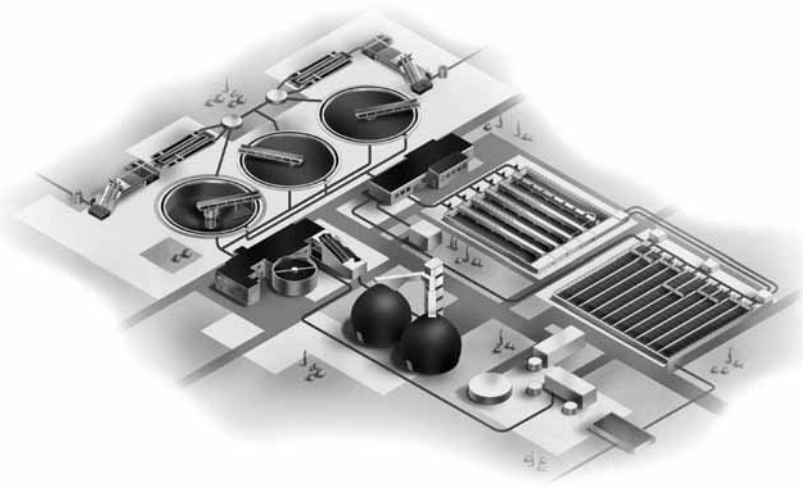
General foreword: Application of FIP PE pressure fittings

FIP PE pressure fittings have been used for years in areas of application where the pipe system has to meet high standards of durability and reliability. These standards are met by combining the excellent material properties of PE with homogeneous welded joints.

Water treatment installations
Their high impact resistance, wide temperature range and outstanding chemical resistance make PE pressure pipe systems extremely suitable for the transport of waste water in water treatment installations. As well as standard fittings for this application, special fabricated fittings, dismantling joints and wall ducts are available.

Waste water transport
Good flexibility, high impact resistance and wide temperature range make PE pressure pipe systems extremely suitable for the use in pressure sewage systems such as public sewers, culverts etc. As well as standard fittings for this area of application, long radius bends made from pipe, special electrofusion couplers and customer made inspection chambers and pump pits are available.

Swimming pool constructions
The already mentioned properties high impact resistance, wide temperature range and excellent chemical resistance make PE pressure pipe systems extremely suitable for application in high quality swimming pool installations. As well as standard fittings for this application, special fabricated fittings, dismantling joints and wall ducts are available.



Industrial process pipe systems
The outstanding chemical resistance and wide temperature range make PE pressure pipe systems extremely suitable for installations in e.g. the process and food process industry. As well as standard fittings for this area of application, screw couplings and union ends for connection to valves and pumps are available.

Transport of solids
The high wear resistance, good flexibility and the smooth internal wall make PE pressure systems extremely suitable for the transportation of solids in amongst others sand & gravel dredging and mining industry. As well as standard fittings for this area of application, long radius bends made from pipe, flanged joints and electrofusion sockets are available.



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FIP

SPECIFICATION MANUAL

Foreword Specification Manual

The economic and technical advantages of plastic as opposed to conventional materials (such as steel) have caused builders and project developers to become strongly interested in the applications of such materials. For this reason, thermoplastics are an increasingly more frequent component of many community and industrial facilities. High demands on quality and comparatively low costs are therefore factors that cause planners and fabricators to use plastics in projects with ever increasing frequency. Nowadays, plastic has become an indispensable substance employed in all areas of modern life. Associated with the term "plastic" is a variety of synthetic polymers that, due to their different qualities, are used in many sectors, such as engineering, medicine, clothing industry and the building trades. This list of industries is only meant to have an exemplary character and does not represent any indication of value, as the industrial areas in which plastic is an essential material could be lengthened in any number of ways. However, when mention is made of plastic in this Specification Manual, it is primarily the PE100 (polyethylene) polymer employed by FIP S.p.A. that is meant.

This Specification Manual is a useful tool providing extensive information for both the engineer and contractor.
Extensive planning and fabrication requires users to be sufficiently familiar with material-specific qualities, have this information clearly and comprehensively presented to them and have a variety of possibilities indicated. FIP is able to present with pride an up-to-date Specification Manual for PE100. This is a revised version of the Akatherm Technical Manual for PE/PP Pipe Systems compiled under the technical and editorial supervision of Dipl.-Ing. (FH) Jürgen Thielen (Akatherm FIP GmbH) in collaboration with PM Engineering in Leimen, a firm involved in polymer engineering and the design of industrial facilities. The process has yielded a manual in which tables, diagrams, variables, guidelines and installation tips are partly reprinted and partly are reformulated, always in compliance with all the, EN, ISO and other national and international standards that were important and valid at the time of printing, while also taking other guidelines and regulations applicable to pipe construction into account.

The result is a Specification Manual that provides the engineer and contractor with the appropriate calculation and dimensioning principles, as well as installation instructions applicable from the beginning of the planning stage to the completion of a pipe system.

This Specification Manual is to be viewed as a contribution to customer service in association with the wish to standardise the use of plastic materials and to make their applications generally understandable. For cases involving special applications, as experienced FIP S.p.A. employee will always be placed at your disposal. The data contained in various chapters corresponds to the current state of our knowledge and is essentially based on standards involving plastics or pipe construction. Nevertheless, the content of the Specification Manual is only of an informative nature, and its use does not entail any legal obligation.

There are no claims concerning certain product qualities or their appropriateness for a specific requirement connected with the data in the Specification Manual. All liability for deviations from existing standards, deficiencies or errors, as well as infringement of third party industrial rights is excluded. The responsibility of and warranties offered by users for proper planning and construction of thermoplastic components and facilities are not limited by the use of this manual. For its part, FIP S.p.A. guarantees the faultless quality of its own products in accordance with its terms of delivery and sale. Reproduction and copying even of extracts of this Specification Manual can only occur with the written consent of FIP S.p.A.

1 "Plastic" material

Plastic is a familiar term and a frequently-used material both in engineering and in daily life. Since this material is employed in almost all areas of our everyday lives, it has become indispensable. Although we use it on a daily basis, most people are forced to admit that they actually know little about the substance itself.
Planners and manufacturers in the fields of pipe construction, mechanical engineering and the manufacture of special parts are also increasingly confronted with plastic materials. It is at this point that questions of the following type arise:
What is plastic? How do I handle the material? What advantages does the material have over conventional materials such as concrete, ductile iron, etc.?
To lighten the introduction to plastics we have compiled the most important information about plastics and polymer processing machinery. As a result, this chapter is purely informative.

1.1 Classification of plastics

Plastics are subdivided into three large groups. Figure 1.1 provides an overview of the polymer groups and figure 1.2 presents their structural models.

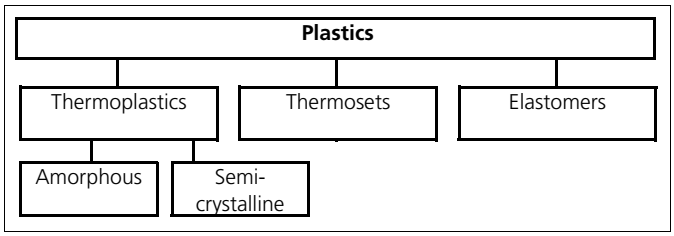


Figure 1.1 Classification of plastics into main categories: thermoplastics, thermosets and elastomers

1.2 Thermosets and elastomers

Thermosets and elastomers play a rather secondary role in plastic pipe construction and are therefore only discussed briefly in this Specification Manual.

Thermosetting plastics have a close-meshed macromolecular structure (figure 1.2). As a consequence, these plastics are usually hard, brittle and no longer meltable. For this reason manufacturers mix the molten mass with fillers that not only have a "filler" (i.e. material saving) function but are primarily added to improve material properties.
Areas of application relating to pipe construction are plant engineering (fibre-glass reinforced containers, flanges, etc.).
Elastomers (better known as "vulcanised rubber") are made from natural or synthetic rubber by means of an interlinking reaction (vulcanisation). The vulcanisation of rubber creates a broad-meshed, loose interweaving, which gives the material its typical rubbery qualities under the normal conditions of its use. Elastomers are used in pipe construction as seals (O-rings, flat gaskets, etc.) between connected elements.

1.3 Thermoplastics

Thermoplastics are by far and away the most important for pipe construction. The plastic often used in pipe fabrication is polyolefin, of which the most important representatives are polyethylene and polypropylene. They belong to the category of semi-crystalline thermoplastics. As a rule, thermoplastics are produced by one of the three following processes:
- Polymerisation
- Polyaddition
- Polycondensation

The different processes produce various plastics with various properties. Within each individual manufacturing process, there are special procedures that influence the appearance and characteristics of the specific plastics. Thermoplastics can be further subdivided into two groups: a distinction is made between amorphous and semi-crystalline thermoplastics. It should be further mentioned that plastics are seldom used in their pure form but usually as mixtures in what are known as blends or compounds. The composition of which depends on their purpose and area of application. Blends allow new or altered characteristics (mechanical, physical or chemical properties) to be produced.
It is however not possible to combine just any type of plastic with any other type. Very often, bonding agents or other additives are needed to create any bond at all.

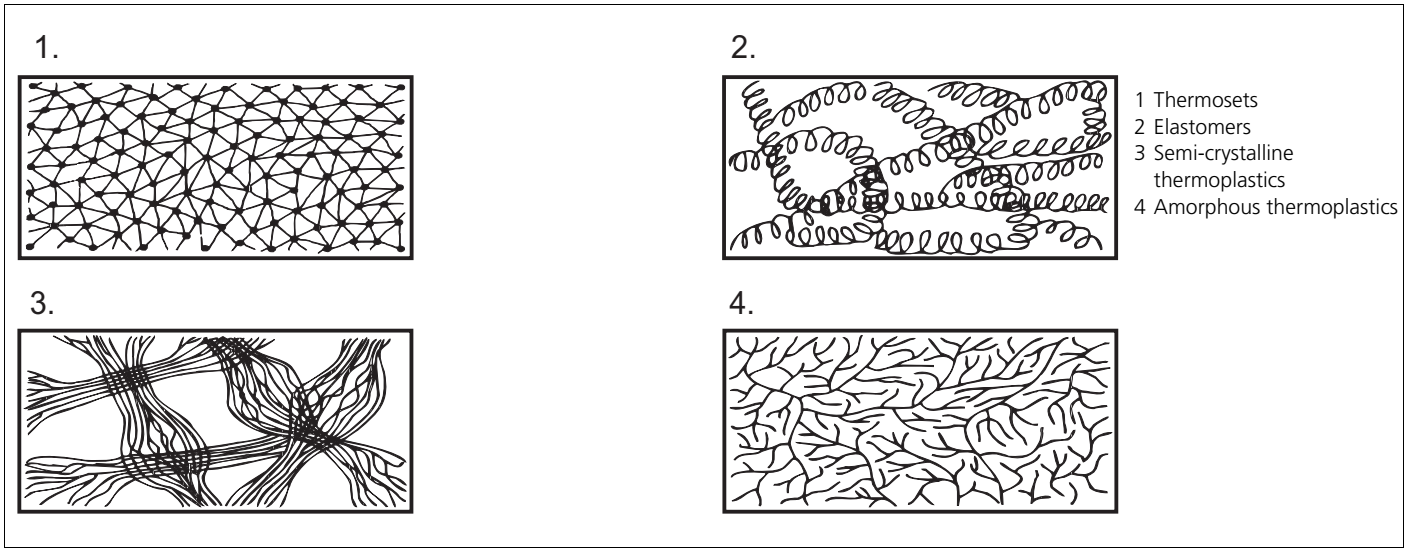


Figure 1.2 Structural model of thermosets, elastomers and semi-crystalline and amorphous thermoplastics

1.3.1 Amorphous thermoplastics

The arrangement of the molecular bond depends on several factors. Especially important is the chemical structure of the chain molecule (or the macro-molecular structure). An ordered spatial structure is impeded by long and cumbersome lateral chains. Since the molecular bond occurs amidst what amounts to perfect disorder, the structure resembles the structure that of a cotton wad. The best known representatives of the group are:
- polystyrene (PS)
- polycarbonate (PC)
- polymethyl methacrylate (PMMA -> plexiglas)
- polyvinyl chloride (PVC)

In uncoloured state, amorphous thermoplastics are as clear as glass.

1.3.2 Semi-crystalline thermoplastics

Semi-crystalline thermoplastics develop both chemically-uniform as well as geometrically-structured regions (figure 1.2), which means that there are regions in which crystals form. Crystals are understood to be parallel groupings of molecular segments or folds in molecular chains. Some chain molecules can therefore partly traverse the crystalline and amorphous regions, or they can even belong to several crystallites at the same time. Semi-crystalline thermoplastics are white in colour. Due to the dense arrangement of molecules in crystalline bonds, crystallites refract light.
The degree of crystallisation greatly influences the properties and transparency of plastic in its uncoloured state. The use of an accelerated cooling rate significantly affects the crystallisation tendency of the material. Important types of semi-crystalline thermoplastic are:
- polyethylene (PE)
- polypropylene (PP)
- polyoxymethylene (POM)

1.4 Characteristics of amorphous and semi-crystalline thermoplastics

A comparison of amorphous and semi-crystalline thermoplastics reveals a few distinctive properties. The most important qualitative distinctions are contrasted below.
In contrast to semi-crystalline thermoplastics, amorphous thermoplastics display:
- greater strength
- greater rigidity
- greater surface hardness
- better surface quality
- less thermal expansion
- less distortion

In contrast to amorphous thermoplastics, semi-crystalline thermoplastics display:
- greater resilience
- less impact sensitivity
- greater flexibility and elasticity

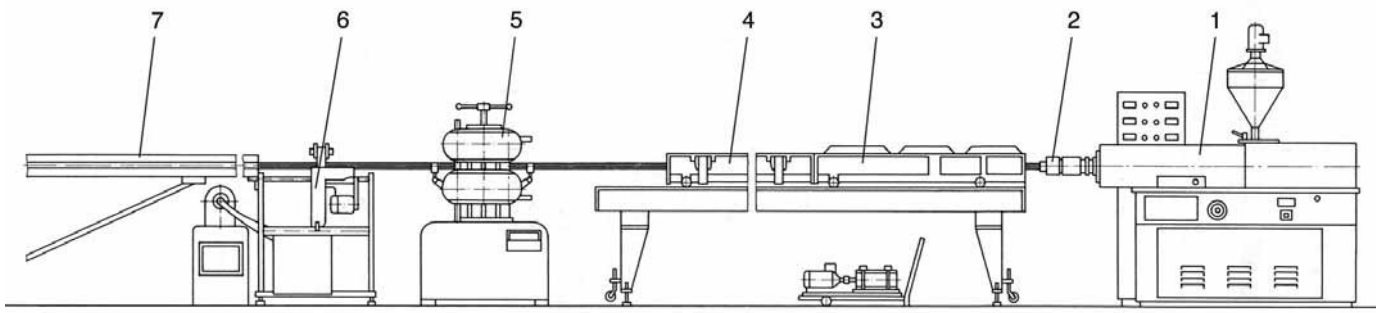
1.5 Plastic processing machines

Plastic processing machines are used to transform raw plastic (mostly in granular form) into semi-finished products. The following section briefly sketches the most important plastic processing machines and explains their functions and applications in simple terms. Emphasis will be placed on machines that are important for the manufacture of plastic pipes and fittings.

1.5.1 Extruder

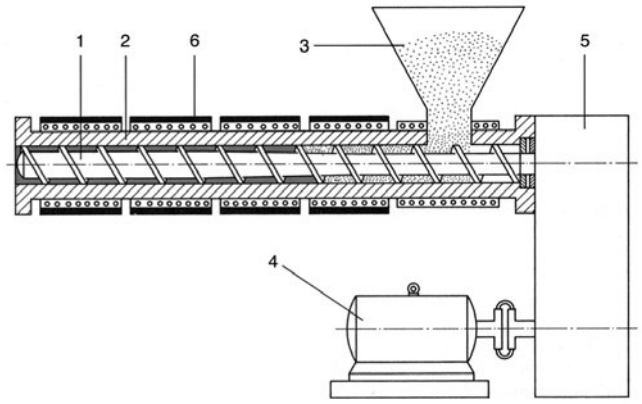
Extruders are used to manufacture pipes, along with associated dies, cooling units, extractor units and cutters. Due to increased quality standards, a modern extrusion installation now includes connected inline measuring systems (e.g. wall thickness metres) that enable immediate responses to irregularities during the production process. The functional principle of the extruder involves melting (i.e. plasticising) raw material (e.g. granulate) and shaping it into a new form by pressing it through a die linked to a cooling unit.

An extruder (figure 1.4) can be equipped with one, two or several screws (also known as worm shafts). Depending on the material being processed and the semi-finished product being manufacture, special extruders are individually made to suit the needs of the production process. Especially important for the actual plasticising processes (i.e. the melting of the supplied raw material) are the screws, the screw geometry and the temperature of the heated cylinders. Due to the shear force in the material, it is plasticised at the corresponding cylinder temperature and pressure build-up by the extruder screw geometry and the die, and then transported further along the screw channels. Material to be plasticised (melted) is fed into the extruder, usually in granular form. Often, three-section screws are used in standardised single-screw extruders, along with barrier screws. The plasticised material is pressed through the die and cooled in a sizing and cooling section. The fitting (e.g. pipe, profile, solid bar) is fixed in the sizing unit. As a result of this process, the plastic, specifically the macromolecule chains, are forced into an arrangement and alignment. In technical terminology, this is called "orientation". Extrusion involves a continuous process (i.e. the process is uninterrupted unless the machine is switched off or not supplied with new material).



1 Extruder
2 Die head
3 Sizer
4 Water bath
5 Caterpillar
6 Cutting saw
7 Tip unit

Figure 1.3 Principle layout of a pipe extrusion installation



1 Screw
2 Cylinder
3 Hopper
4 Motor
5 Drive
6 Heater

Figure 1.4 Layout of an extruder

1.5.2 Injection moulding machine

The layout of an injection moulding machine (figure 1.5) resembles the extruder in its structure. The most important distinction between the two machines involves the motion of the screw. In addition to the rotary motion already described for the extruder, it also makes an axial movement.
In contrast to extruders, the injection moulding machine is involved in a discontinuous process. A discontinuous production process makes special demands on the machine, the mould and the associated and necessary mould cooling. There are three important parameters for the manufacture of an injection moulded part.
- temperature
- time
- pressure

These three parameters have an extremely important impact on the injection moulding process, which is organised into three functional steps:
- plasticisation
- injection
- cooling

The plastic to be processed is plasticised while moving along the screw through the heated cylinder. The actual plasticising process corresponds essentially to extrusion. The plasticising material is moved forward by the screw in the direction of the screw tip.

The plasticising material is simultaneously pre-compressed. Once there is sufficient material in the "accumulator", which is at the end of the plasticising unit, the material is squeezed through an injector into the mould. To prevent material shrinkage, plasticised material is compressed for a certain time during the cooling phase. The machine parameters depend on the material being worked and the fitting being manufactured. At the end of the injection cycle, the process begins again.

1.6 Mechanical properties

1.6.1 Assessing creep behaviour

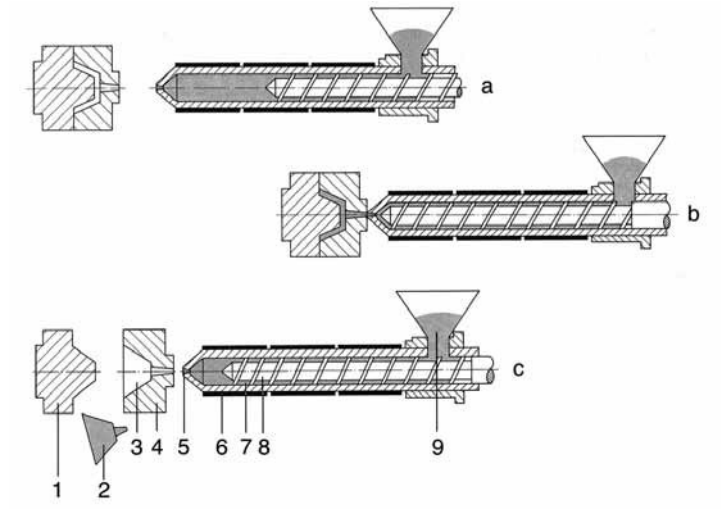
Creep behaviour is among the most important tested factors for pipes and fittings. It indicates the life expectancy possessed by the plastic pipe or fitting when it is subject to internal pressure. The internal pressure involved generates stress in the pipe wall. An appropriate reference stress (σ_r) is based on the relationship of internal pressure (ρ_i), the safety coefficient (SF) and the diameter - wall thickness ratio (SDR). The reference stress (σ_r) can be calculated using the well-known boiler formula. It reads:

$$\sigma_{acc} = p_i \cdot \frac{(SDR - 1)}{20} \text{ with } \sigma_{acc} = \frac{\sigma_r}{SF}$$

Equation 1.1

σ_{ref} = Reference stress (N/mm^2)
σ_{acc} = Acceptable stress (N/mm^2)
ρ_i = Internal pressure (bar)
SDR = Standard dimension ratio
SF = Safety factor = General design coefficient "C"

The reference stress (σ_r) conforms, in practice, to the stress on the circumference of the internal pipe surfaces. In contrast to this stress, the stress in the axial direction of the pipe is only half as large. In applying the boiler formula, the acceptable stress (σ_{acc}) of the corresponding material provides the basis for dimensioning the plastic pipe. Additionally extremely important is the fact that the stress at break has a very large dependence on the thermal load and period of load. Usually, tests are



a) The turning screw takes extracted granulate from the bulk hopper and feeds it along the screw channel to the screw tip.
b) The mould is closed, the injection unit moves against the feed bush, the screw operates as a piston to press plasticised moulding material into the mould.
c) The cooled injected material drops out of the opened mould, the screw moves new moulding material to the screw tip, the injection unit withdraws from the tip.

1 Movable mould part
2 Injection-formed component
3 Mould cavity
4 Fixed part of the mould
5 Nozzle
6 Heating band
7 Material cylinder
8 Screw
9 Bulk material hopper

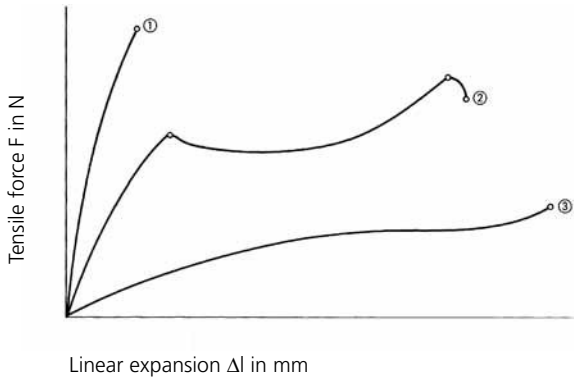
Figure 1.5 Functional principle of a injection moulding machine

conducted on water-filled sections of standardised pipe. During the tests, the test sample is placed in a water bath.

Special applications require the testing of pipe sections filled with the intended flow medium. The results of such tests are shown on a double-logarithm diagram in which the reference stress is plotted over time. The tests are conducted at various temperatures. The bend in the curve indicates when pipe failure is to be expected. Results of the tests at higher temperatures allows an interpolation of the creep behaviour for a pipe at lower temperatures. This provides an indication of the life expectancy of a pipe under certain conditions. Time curves for PE100 are displayed in appendix A1.

1.6.2 Assessing the mechanical variables

The tensile test is described in EN-ISO 527-1, EN-ISO 527-2 and EN-ISO 527-3.
In the tensile test, precisely defined samples are stretched to the breaking point and the required force measured. This usually involves a 1-axial load on the sample. The force used for this purpose is applied in a time-dependent manner. An adjustment screw on the tensile testing machine is used to plot the relationship between force and length change in the test, enabling a force-linear expansion diagram to be made, which can be converted into a stress-elongation diagram.



Curve 1: hard brittle plastic without yield range, e.g. polystyrene (PS)
Curve 2: ough hard plastic, e.g. polyethylene (PE)
Curve 3: flexible elastic plastic, e.g. plasticised polyvynil chloride (PVC-P)

Figure 1.6 Force-linear expansion diagram (tensile force)

The diagram provides information on the following characteristic variables:
- Elongation (ε) - linear expansion (Δl) as a percentage of the initial length (l_0) at each time interval in the test.
- Tensile strength (σ_B) - which is the tensile stress at maximum load.
- Breaking strength (σ_B) - which is the tensile stress at the moment of breakage.
- Yield stress (σ_Y) - which is the stress at which the increase in the stress-elongation curve is first equal to null.

The mechanical variables are very strongly dependent on the test conditions. The tests are therefore conducted under normal climate conditions (23°C and 50% relative humidity). The tensile test is one of the short-term tests and the knowledge gained does not indicate anything about the behaviour of material under a long-term mechanical load. Semi-crystalline materials such as PP and PE mostly display a distinct yield stress and a high degree of elongation (figure 1.6).

1.6.3 Assessing the elasticity modulus (creep modulus)

Short-term values
The elasticity modulus (E-modulus) is the ratio of stress (σ) to elongation (ε):

$$E = \frac{\sigma}{\varepsilon} \qquad E = \frac{\sigma_1 - \sigma_2}{\varepsilon_1 - \varepsilon_2}$$

$$\sigma = \frac{F}{A_0} \qquad \varepsilon = \frac{\Delta l}{l_0}$$

Equation 1.2

σ_1 = Normal stress at 0.05% elongation (N/mm^2)
σ_2 = Normal stress at 0.25% elongation (N/mm^2)
ε_1 = Elongation of 0.05 (%)
ε_2 = Elongation of 0.25 (%)
F = Force (N)
A_0 = Starting section (mm^2)
Δl = Change of length due to force (F) (mm)
l_0 = Starting length (mm)
E = E-modulus (N/mm^2)

DIN 53457 describes the determination of the E-modulus from the tensile test (E_t), the compressive test (E_d), from the 3-point flexural test (E_{F3}) and the 4-point flexural test (E_{F4}).

Long-term values
The E-modulus under tensile load is determined by means of the creep tensile test specified in EN-ISO 899-1. The creep tensile test allows calculation of the creep modulus (E_{cR}). In general, the tensile test is given preference over the flexural or compressive tests, as its performance is usually easier. The test items are non-axially stressed in a controlled test environment by a force that remains constant throughout the test period. If these tests are conducted at temperatures resembling the subsequent application temperature range, the diagram provides the engineer with important data to assess the behaviour of the corresponding material.

1.6.4 Impact resistance

The procedures for the impact flexural and notched impact flexural tests are described in DIN 53453 and DIN 53753. The tests are used to determine impact behaviour, otherwise known as the resilience of the plastic. The variable measured is the quantity of absorbed impact energy in relation to the cross-sectional areas that results in breakage of the bar or plate-shaped test specimen, which may be notched. Force is generated by a pendulum impact tester, which strikes the specimen at high speed. In Europe, two test procedures (notched and unnotched) are most commonly performed: one known as "Charpy" uses a pendulum impact tester as specified in EN-ISO 179 and the other, which is called "Izod", uses a Dynstat apparatus as specified in EN-ISO 180. Three defined notch types are used to determine notched impact resistance.

1.6.5 Surface hardness

Surface hardness indicates the resistance that a defined specimen displays in order to prevent it from being penetrated. The Shore test, specified in NEN-EN-ISO 868, may make use of two procedures to determine Shore hardness: these are known as Shore A and Shore D. The two procedures differ in the geometry of the test specimen used (test needle). Figure 1.7 shows the two different test objects. Shore hardness is dimensionless, and the range of hardness varies between values of 0 and 100. The Shore A procedure is predominantly applied to soft plastics, while Shore D is used with hard ones.
In addition to the Shore hardness test, the hardness of a material can be determined as specified in EN-ISO 2039-1 in terms of its ball indentation hardness. This method is mostly used when the hardness of a material can no longer be established by the Shore procedure. A ball with a 5 mm diameter serves as the test object, which is subject to a defined load for 30 seconds.

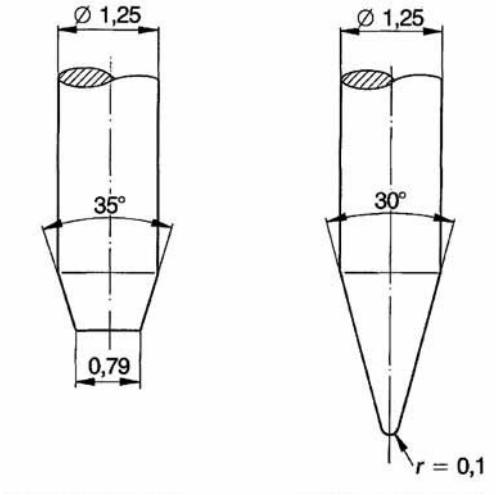


Figure 1.7 Test objects for Shore A and Shore D hardness tests

1.7 Thermal properties

1.7.1 Heat expansion coefficient

In determining the heat expansion coefficient, a distinction is made between the linear expansion coefficient (thermal length expansion coefficient (a_ϑ)) and the cubic expansion coefficient (spatial expansion coefficient (β_ϑ)). The linear expansion coefficient (α_ϑ) indicates the amount that a material with a standard length of one metre will lengthen or shorten under a temperature change of 1 K. The spatial expansion coefficient (β_ϑ) indicates the amount that a cubic meter of material will lengthen or shorten under a temperature change of 1 K. DIN 53752 describes the tests for the linear and cubic expansion coefficients. The unit of the expansion coefficient is (1/K), (K^{-1}) or (mm/mK).

1.7.2 Deformation resistance to heat

All property changes are important to the engineer and especially behaviours in response to heat effects. For this reason, various tests are conducted to ascertain the approximate boundary temperatures below which deformation does not occur. EN-ISO 75-1 and EN-ISO 75-2 describe methods of determining heat resistance.

Three procedures are used to determine deformation resistance:
1. Martens (DIN 53462)
2. Vicat
3. ISO/R 75 (ASTM D 640)

The determined variables do not, however, permit any conclusions to be drawn about the working temperature of the tested plastics. Values ascertained for plastics are only comparable when they are tested under identical conditions and procedures. The outside temperature effects of air or fluid as well as the form and manufacturing method of the samples have a large influence on the measured results.

1.7.3 Heat conductivity

The heat conductivity or the heat coefficient (λ), measured as (W/mK), is a temperature dependent material characteristic that indicates something about the capacity of a material to conduct heat. An indication of heat conductivity or insulation capacity (negative thermal conductivity) of a material can be provided by tests specified in DIN 52612-1 or DIN 52613 (ISO/DIS 8497-1988). The heat conductivity of a substance can be significantly influenced by the filling, reinforcements, auxiliary materials, and colouring.

1.7.4 Heat transfer coefficient

The Heat transfer coefficient (α_ω) is an important factor needed to calculate the heat transition coefficient (λ) as well as specific heat conductivity (l) of a material. The heat conductivity, like the heat transfer coefficient, is strongly dependent on other influences, such as separation plane, geometry and flow rate of the medium.

1.7.5 Heat transition coefficient

The heat transition coefficient (k) provides information about the insulation capacity of a material. The unit is (W/m^2K). The smaller the k-value is, the higher the insulation capacity of the material. The heat transition coefficient is computed with the equation:

$$k = \frac{1}{\frac{1}{\alpha_{w1}} + \frac{d_w}{\lambda} + \frac{1}{\alpha_{w2}}}$$

Equation 1.3

k = Heat transition coefficient (-)
α_{w1} = Heat transition coefficient of medium 1 to the wall (W/m^2K)
α_{w2} = Heat transition coefficient of the wall to medium 2 (W/m^2K)
λ = Heat conductivity of the wall (W/mK)
d_w = Thickness of the separation wall (m)

1.7.6 Burning behaviour

Plastics are organic compounds that are, by their nature, combustible. The European standard EN 13501-1 defines a classification system for material burning behaviour for building products and building structures. The burning behaviour of finished products (in the manner that they are used) must be described in terms of the extent to which the material contribute to the development and spread of fire and smoke in an area or environment. In the case of fire, building products are exposed to a fire ignited in a given area. This fire can then grow (increase) and finally

Stage 1: Combustibility

Class	Fire tests	Spreading of flames	Contribution	Practice
F	Not tested or does not meet class E	Unclassified	Undefined	Extremely combustible
E	EN-ISO 11925-2 (15 sec-Fs<150 mm-20 sec)	Spreading of flames 100 kW <2 min.	Very high contribution	Very combustible
D	EN 13823, Figra <750 W/sEN-ISO 11925-2 (30 sec-Fs<150 mm-60 sec)	Spreading of flames 100 kW >2 min.	High contribution	Quite combustible
C	EN 13823, Figra <120 W/s + Thr <15 MJEN-ISO 11925-2 (30 sec-Fs<150 mm-60 sec)	Spreading of flames 100 kW >10 min.	Large contribution	Combustible
B	EN 13823, Figra <120 W/s + Thr <7.5 MJEN-ISO 11925-2 (30 sec-Fs<150 mm-60 sec)	No spreading of flames	Very limited contribution	Very difficult to combust
A2	EN ISO 1182 of EN-ISO 1716 plusEN 13823, Figra <120 W/s+ Thr <7,5 MJ	No spreading of flames	Hardly any contribution	Practically incombustible
A1	EN ISO 1182 = IncombustibleEN-ISO 1716 = Caloric values	No spreading of flames	No contribution	Incombustible

Table 1.1

spread. The scenario contains three components of fires that correspond the stages in the development of a fire:
- Combustibility: the starting of a fire by ignition using a small flame on a small surface/product.
- Smoke production: development and potential spread of fire.
- Burning drops/fragments: outbreak of fire when all combustible material contribute to the fire potential.

Combustion classification

Stage 2: Smoke production

Class	Description
s3	Great deal of smoke production
s2	Average smoke production
s1	Little smoke production

Table 1.2

Stage 3: Burning drops/ fragments

Class	Description
d2	Fragments burning longer than 10 sec.
d1	Fragments burning shorter than 10 sec.
d0	No production of burning fragments

Table 1.3

Fire safety
The required fire safety level of a building is not the same in all European member states. Every member state may make its own regulations to determine the products that may be used and the combustion class that is suitable for the circumstances.

1.8 Chemical properties

1.8.1 Chemical resistance
The chemical resistance of PE to contacting media will be treated in detail in Chapter 2 (table 2.3).

1.8.2 Permeation
Permeation is regarded as the diffusion of a medium through a plastic (e.g. container wall, shaft wall or pipe wall). Contact between plastic and chemical medium can, under certain circumstances, result in moisture expansion or dissolution. Problems can also result from the dislodging of material by softening and processing agents, as well as from the bleeding of colouring. Practical testing procedures are presented in DIN 53405 (dislodging) and EN-ISO 183 (bleeding of colouring).

1.8.3 Water absorption
Many plastics tend to absorb water. Due to swelling the dimensional stability changes. PE is water-repellent, which means that it cannot be damaged by swelling. The test procedure is described in EN-ISO 62.

1.9 Processing characteristic: Melt index

Determination of the melt-mass flow rate (MFR) as specified in EN-ISO 1133, also known as the melt flow index (MFI), is a standardised testing method for obtaining a relatively quick and quantitative indication of a plastic's flow behaviour. The MFR value indicates the amount of thermoplastic molten mass pressed through a standardized nozzle during 10 minutes of steady piston force and constant melt temperature. Table 1.4 indicates the test conditions:

Test specification	Test conditions	
ISO 1133	Temperature (°C)	Load (kg)
1	190	2.16
6	190	10.00
12	230	2.16
18	190	5.00
20	230	5.00

Table 1.4 Test specifications and conditions for determining the MFR value

The melt volume flow rate (MVR), also known as the melt volume index (MVI) is used to test the flow behaviour of a molten mass at constant piston force and defined temperature. The unit of the MRV is cm^3/10 min.

1.10 Physics of plastics

1.10.1 Residual stress
All plastic components possess a certain residual stress potential, which is not attributable to external forces but exists on account of manufacturing and cooling conditions. In the process of extruding plates, pipes and profiles, molten mass is pressed through a die, causing the macromolecule to be stretched. Subsequently, it is cooled and fixed in a sizing unit. Since the pipe is cooled from the outside in, the pipe wall cools at substantially different rates.
This cooling behaviour has consequently effects on the structure and/or thickness of the pipe shell.
In the pipe wall results at the initially cooled side residual compressive stress (δ_D) and at the subsequently cooled side residual tensile stress (δ_T) (figure 1.8). These stresses may be significantly reduced by means of tempering (i.e. reheating the pipe to a defined temperature). The subsequent heating reduces the existing residual stresses, which have substantial effects on the dimensional stability, retraction, shrinkage and service life of the pipe. Dimensional stability is extremely important for pipes and components, since a change in diameter can have negative consequences for the leak tightness of connections. Usually, PE pipes are tempered.

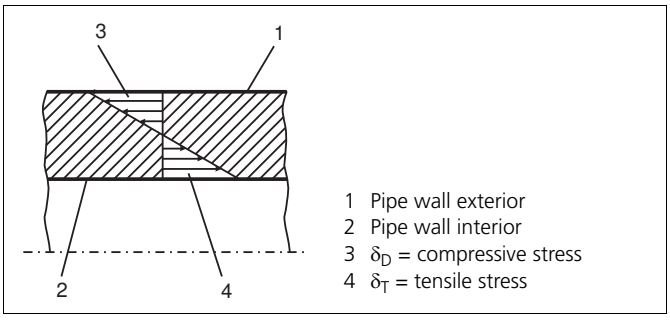


Figure 1.8 Stress in the pipe wall

The stresses normally equally offset each other. If external or internal influences cause the stresses to fall into disequilibrium, the component can be deformed.
However, the cooling procedure is not the only cause of residual stresses in a plastic component. The following sections describe other types of stress that have residual effects on a pipe or fitting.

- Residual orientation stress
This strongly depends on cooling patterns. The speed with which the orientation in longitudinal and transverse directions is fixed ("frozen" in the technical terminology), which is to say the strength with which heat dissipation acts on both orientation states, raises or lowers the level of orientation, causing stresses to be increased or decreased.

- Residual after-pressure stress
Residual after-pressure stress mostly occurs in injection-moulding components, although it can also be caused by extrusion processes. For example, an extrusion process is typically involved in the manufacture of solid bars, which have to be subject to after-pressure in order to prevent cavities (holes) or bubbles (empty spaces) from forming. If the pressure during cooling of the fittings is too high, a residual pressure remains in the fitting that can lead to its deformation.

- Residual crystallisation stress
This stress originates in the crystallisation phase of semi-crystalline thermoplastics. Crystallites forming when the molten mass is cooling are subject to contraction (volume change). Cooling that occurs in an uneven manner and results in a temporarily irregular crystallisation process can cause structural strains.

- Stress reduction
A remedial measure to abate frozen stresses (residual stresses) is the tempering of the pipe. Besides reducing residual stress, tempering can instigate an after-crystallisation process (in semi-crystalline plastics), which can have a positive effect on the properties of plastic.
Tempering is a special temperature control or heat treatment, the parameters of which depend on the plastic involved. During tempering, care must be taken not to set the heat high enough to generate reset forces and cause deformation. As a rule, the parameters depend on the thickness of the tempered fittings and the level of the stress profile.
It is important that the products are slowly cooled after storage to prevent stresses from recurring as a result of local temperature differences.

1.10.2 Flexural, thermal, tensile and compressive stresses
These types of stress are discussed in detail in chapter 6, as they represent important criteria in planning and constructing pipe systems. They are basic elements in the construction and manufacture of plastic building supplies.

1.10.3 Orientation
Orientation designates the arrangement of macromolecules in a plastic component.
Initially, the macromolecules of a plastic are in a disordered state ("knotted ball"). The processing procedures (e.g. extrusion or injection moulding) force the macromolecules through dies, moulds, extractor units, cooling processes, etc., aligning them in a certain direction. They can be arranged both longitudinally (in the case of extrusion in the direction that the fitting is extracted) or transversely to the centre line. The nature and alignment of the orientations have very great effects on the mechanical properties and stability of the product. Orientation results from shear and expansion forces.
Shear forces are created in both injection moulding and extrusion processes. They are produced by the shear strain of adjacent strata of molten material flowing at different velocities, for example when molten material is clinging to the wall of the mould. Expansion forces are caused by the flow of molten material through constrictions or flow channels, such as nozzles. In extruded semi-finished products (e.g. plates, pipes, profiles), the preferred orientation is longitudinal to the extrusion direction and less optimally in the transverse direction. In opposition to the pressed semi-finished products in which no distinct orientation is the result, the properties of extruded semi-finished products are anisotropic, which means strongly dependent on orientation. Mechanical properties such as strength, impact resistance and impact strength are better in anisotropic semi-finished products oriented in the direction of extrusion and poorer in the case of transverse orientation such as isotropic semi-finished products. Since thermal elasticity is only utilised in temperatures above freezing (or crystallite melting temperature), it is not possible to remedy orientation by tempering.

1.10.4 Retraction
The term "retraction" is understood as a change in the fitting as a result of forced length changes of the macromolecule. This process occurs especially in extrusion procedures. The molecule is consequently stretched by the extrusion die and/or extractor unit, usually in a axial (i.e. longitudinal) direction. As soon as the macromolecule again has the opportunity to resume its original shape, a length change counteracts the stretching orientation. This is called the "memory effect". Rapid cooling of the molten plastic fixes it in a given (frozen) state. Heating the plastic above the "freezing temperature" activates the above-mentioned "memory effect" and the macromolecule attempts to return to its original ("knotted") state. Retraction is therefore a pure contraction in length (length change) as a consequence of orientation of the macromolecule in the fitting.

1.10.5 Contraction
The term shrinkage designates a volume contraction of the plastic fittings. Like other materials, a volume increase occurs when plastic is exposed to a temperature rise.
The cooling of the material instigates the inverse process. Since this effect is well-known, this phenomenon must be considered when constructing tools and fittings if a manufacturer wishes to produce technically high-grade products. There are two kinds of shrinkage:
- processing shrinkage
- after-shrinkage

1.10.6 Notch effect
The calculation of component stresses is ideally based on tensile and flexural stresses. The stresses that actually occur are however influenced by a number of factors (e.g. scratches, material inhomogeneities, structural composition of the fitting, etc.), all of which result in deviation from the ideal state. The size of notches, the radius of notch bases and the types of load have important effects on the strength of a fitting. The deeper and sharper that a notch is formed, the higher the stress peak at the notch base and, consequently, the greater the danger of damage to the component. It is therefore advisable to make the smallest possible notches that are round (circular) shaped.

"Plastic" material

1.11 Chapter summary

Plastic	Plastic is divisible into three main groups: thermoplastics, thermosets and elastomers.
Elastomers	Elastomers are better known as rubber. They are wide-meshed, spaciously interlinked synthetic or natural rubber compounds. Interlinking is enhanced by vulcanisation.
Thermosets	Thermosets possess a close-meshed interlinked macromolecular structure. They are hard, brittle and no longer plasticisable (meltable).
Thermoplastics	Thermoplastics can be divided into amorphous and semi-crystalline thermoplastics.
Polyolefin	This compound belongs to the group of semi-crystalline thermoplastics. Its most important representatives are polyethylene (PE) and polypropylene (PP).
Plastic processing machines	Extruders, injection moulding machines and calendars (not discussed in this manual) are machines used to manufacture plastic semi-finished products.
Extruder	An extruder is responsible for plasticising raw materials. Used, for example, in the manufacture of pipes, profiles and plates. Continuous process.
Injection moulding machine	Injection moulding involves a discontinuous manufacturing process. The screw performs both a rotational and an axial motion. Important parameters for injection moulding are: temperature, time and pressure. Process steps are: plasticisation, injection and cooling.
Internal pressure creep test	Simulates the life expectancy of a plastic pipe under an internal pressure load. The associated reference stress (σ_{ref}) is a function of the internal pressure, mean pipe diameter and wall thickness. It is calculated using the boiler formula.
Short-term tensile test	The short-term tensile test involves stretching a sample bar to the breaking point. The result provides an indication of the mechanical values of the tested material. The most important mechanical values are: expansion, tensile strength, breaking strength and breaking strain.
Elasticity modulus (Creep modulus)	The elasticity modulus is the ratio of stress to expansion.
Creep tensile test	The creep tensile test is used to determine the creep modulus.
Impact resistance	Impact resistance is determined by means of the impact flexural test and the notched impact flexural test (the latter involving defined notches in the sample). Most important test methods are the "Charpy" and "Izod" tests.
Surface hardness	Designates the resistance against the penetration of the test specimen. Most important procedures are Shore A, Shore D and ball indentation hardness.
Heat expansion coefficient	The heat expansion coefficient is an important parameter in plastics. A statement of this mechanical value is usually accompanied by an indication of the linear expansion coefficient (α_ϑ) (in literature, this is mostly expressed as the mean linear longitudinal expansion coefficient α).
Heat resistance	This term designates the temperature limits of thermoplastics under the effects of heat. Testing procedures are Martens, Vicat and ISO/R 75. No conclusions about working temperatures are possible.
Heat conductivity	Variable indicating the capacity of a material to conduct heat. Filling, reinforcements, auxiliary material and colouring affect heat conductivity.
Heat transfer coefficient	This variable is used to calculate the heat transition coefficient. It depends on the separation plane, geometry and flow speed of the medium.
Heat transition coefficient	The heat transition coefficient (k) provides information about the insulating capacity of a material.
Burning behaviour	Plastics are organic compounds and therefore combustible by nature.
Permeation	Diffusion tendency of a material, which is the permeability of fluids or gaseous elements through the plastic.
Water absorption	Many plastics tend to absorb water (swelling). This means that the stability of the plastic is no longer assured. PE has hardly any tendency to absorb water.
Melt index	The melt index indicates the flow capacity of a plasticised plastic. Previously known as the MFI value, it is now referred to as the MFR value.
Residual stress	During an extrusion process, residual stresses build up in pipes as a result of cooling procedures at high extraction speeds, for example. These stresses can be reduced in pipes by adopting special temperature controls or heat treatments (tempering).
Residual orientation stress	Dependent on cooling conditions. Increasing cooling speed raises the stress potential in pipes.
Residual after-pressure stress	Phenomenon in injection moulding components. Residual after-pressure stress can also occur in extrusion components when, for example, after pressure has to be used in manufacturing solid bars to prevent bubbles and cavities.
Residual crystallisation stress	This occurs in semi-crystalline plastics (e.g. PE) due to crystallite formation during the cooling phase.
Tempering	Heat treatment to reduce or eliminate residual stress potentials.
Orientation	Alignment of the macromolecules by external forces (e.g. extraction speed).
Retraction	Retraction designates a longitudinal contraction (negative length change) in the direction in which the macromolecules are oriented.
Shrinkage	In contrast to retraction, shrinkage designates a volume contraction (negative volume change) as a result of cooling processes. In contrast to retraction, a volume change is discernible in every plastic component. These volume changes are seen in the fitting structure and in the die or mould structure.
Notch effect	The notch effect affects the strength of the component. Grooves, scratches, inhomogenities or a component's structural form can have adverse affects on the fittings.

2 Material properties of PE

2.1 General material properties of polyethylene (PE)

Thermoplastics are sub-divisible into two groups: amorphous and semi-crystalline thermoplastics. Polyethylene is a polyolefin, which forms a separate group among the semi-crystalline thermoplastics. Polyethylene, abbreviated PE, is an umbrella term for a group on individually distinctive PE types.
In specific, the following PE types are distinguished:
- PE-LD (Density: 0.9 - 0.91 g/cm^3)
- PE-LLD (Density: 0.91 - 0.93 g/cm^3)
- PE-MD (Density: 0.93 - 0.94 g/cm^3)
- PE-HD (Density: 0.94 - 0.965 g/cm^3)

It is PE-HD that is of primary interest for use in plastic pipe construction, although PE-MD is also used in the gas-pipe sector. The characteristics of PE-MD will, however, not be further detailed in this Specification Manual.
PE-HD (high density) has a high density with an average molar mass (MM) between 40,000 and 400,000 g/mol (depending on the manufacturing process and the process parameters). In comparison, PE-LD (low density) has a lower density and therefore a molar mass of up to 600,000 g/mol. PE-HD is manufactured as a polymer either by using a medium pressure procedure (Phillips) or a low pressure procedure (Ziegler). Polymers based on ethylene offer semi-finished product manufacturers a great deal of latitude in making modifications. For pipe and fitting manufacture, it is the mechanical properties of PE that are foregrounded (elastic stiffness).
As mentioned at the beginning of this chapter, PE is to be understood as an umbrella term for a thermoplastic group. For instance, PE includes the substance PE100.

More attention will be paid to the significance of the numerical values (e.g. PE100) in the course of chapter 4. For the sake of simplification, the label "PE" will be used throughout the rest of this manual to designate PE-HD. PE is resistant to acids, bases, saline solutions, water, alcohol and oil. Under 60°C, it is practically insoluble in nearly all organic solvents. PE can readily withstand ionised rays if they are not too strong and will not become radioactive itself. It is furthermore readily weldable, although there are problems involved in gluing and decorating PE. The surfaces will allow imprinting or painting to adhere only after physical or chemical pre-treatment. Bonding can only be done with the help of contact glue, although such adhesive bonds cannot be subject to very high mechanical loads.

2.2 Properties of PE100

	Unit	Test method	Value
Density at 23°C	g/cm^3	ISO 1183	0.958
Elasticity modulus	N/mm^2	ISO 527	900
Tensile creep modulus	N/mm^2	ISO 899	850
Bending creep modulus	N/mm^2	DIN 54852-Z4	1200
Tensile strength at 23°C	N/mm^2	ISO 527	23
Elongation at break	%	ISO R 527	>600
Linear expansion coefficient	mm/mK	DIN 53752	0.13 - 0.19
Indentation hardness	N/mm^2	ISO 2039	36 - 46
Ignition temperature	°C	-	~350
Thermal conductivity	W/m . K	DIN 52612	0.23
Shore hardness		ISO 868	65
Crystallite melting range	°C		~130
Operational temperature range	°C	-	-40 - +100
Melt flow rate MFR 190/5	g/10min	ISO 1133	0.43

Table 2.1

Material properties of PE

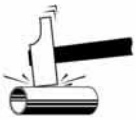
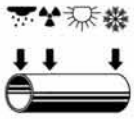
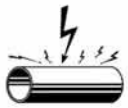
	Properties PE	Benefits
	Impact-resistant and tough	Unbreakable at temperatures > 5°C
	Elastic	Suitable for underground pipes through adjustment to local ground movement
	Thermal resistant	Application possible between -40°C and 100°C
	Smooth internal wall	Low blockage risk due to low deposit/residue effects
	Wear resistant	Lower costs due to relatively long life
	Weather-resistant / UV resistant	Application in open air unrestricted through colouring with carbon black
	Chemical Resistance	Suitable for the transport of polluted waste water
	Poor heat conductivity	No condensation during short periods of cooling
	Non-toxic	Environmentally friendly
	Insulating	Non-conductive
	Highly suitable for welding	Easy installation using butt-welding and electrofusion techniques
	Homogeneous welded joints	End load resistant and leak proof
	Prefabrication	Reduces on-site installation times
	Light in weight	Cost-saving in transport and handling

Table 2.2

2.3 Chemical resistance

Table 2.3 indicates the chemical resistance of PE to various media at a number of temperatures.

In transporting chemicals, consideration needs to be given to the following factors:
- the medium
- concentration of the medium
- temperature
- duration of the load
- flow volume

The elastomer resistance list is intended as an aid for determining the suitability of a given seal. The indicated values refer to the volume of swelling for the rubber compound, which is only one of the indications concerning resistance. Chemical damage to the polymer chain can also lead to changes in mechanical properties such as tensile strength, elasticity at break, etc. The most commonly indicated values are measured at a temperature of 20°C. A longer exposure to a higher temperature can create more aggressive conditions that reduce the life-span of elastomers.

Explanation of symbols used for PE pipes and fittings:	
+	Resistant: based on performed tests, PE is in general a suitable material for this application
/	Limited resistance: further research required
-	Non-resistant

Empty field = The material has not been tested on this medium at this temperature.

1 Little of no effect: volume change <10%, the elastomer can display slight swelling and/or loss of physical characteristics under heavy conditions.
2 Possible change of physical qualities: volume change of 10-20%, the elastomer can display swelling and a change of physical characteristics, can be suitable for structural applications.
3 Substantial change in physical characteristics: the elastomer displays a substantial change in volume and physical qualities.
4 Excessive change: elastomer is unsuitable.

Empty field = The elastomer has not been tested on this medium.

Abbreviations used:
PE = polyethylene
NBR = acrylonitrile butadiene
EPDM = ethylene propylene
FPM = fluorocarbon
SBR = styrol butadiene

Material properties of PE

Fluid			Concentration	Pipe and fittings			Elastomeric seals			
				HDPE			NBR	EPDM	FPM	SBR
Name	Formula	Remark		°C			°C	°C	°C	°C
				20	40	60	20	20	20	20
Acetaldehyde	CH_3CHO	Aqueous solution	40%	+	+	/	4	2	4	3
Acetaldehyde	CH_3CHO	Technically pure	100%	+	/	/	4	2	4	3
Acetic Acid	CH_3COOH	Aqueous solution	10%	+	+	+	4	3/4	4	4
Acetic Acid	CH_3COOH	Aqueous solution	30%	+	+	+	4	4	4	4
Acetic Acid	CH_3COOH	Aqueous solution	60%	+	+	+	4	4	4	4
Acetic Acid	CH_3COOH	Aqueous solution	80%	/	/	-	4	4	4	4
Acetic Acid	CH_3COOH	Technically pure	100%	+	+	/	4	4	4	4
Acetic Acid Anhydride	$(CH_3CO)_2O$	Technically pure	100%	+	/		4	2	4	2
Acetone	CH_3COCH_3	Aqueous solution	10%	+	+	+	4	1	4	2/3
Acetone	CH_3COCH_3	Technically pure	100%	/	/		4	1	4	2/4
Acetophenone	$CH_3COC_6H_5$	Technically pure	Indetermined	+	+	+	4	1	4	4
Acrylonitrile	CH_2=CH-CN	Technically pure	100%	+	+	+	4	4	4	3
Adipic Acid	$HOOC(CH_2)_4COOH$	Aqueous solution	Saturated	+	+	+	1	1	1	1
Alcohol			40%	+						
Alcoholic Spirits			Comm. Comp.	+	+					
Allyl Alcohol	CH_2=CH-CH_2OH	Aqueous solution	96%	+	+	+				
Alum	$Al_2(SO_4)_3K_2SO_4\ _4H_2O$	Aqueous solution	Solution	+	+	+	2	1	1	1
Alum	$Al_2(SO_4)_3K_2SO_4\ _4H_2O$	Aqueous solution	Saturated	+	+	+	2	1	1	1
Aluminium Acetate	$(CH_3COO)_3Al$	Aqueous solution	Saturated	+	+	+	2	1	4	4
Aluminium Bromide	$AlBr_3$	Aqueous solution	Saturated	+	+	+	1	1	1	1
Aluminium Chloride	$AlCl_3$	Aqueous solution	All	+	+	+	2	1	1	1
Aluminium Fluoride	AlF_3	Aqueous solution	Saturated	+	+	+	2	1	1	1
Aluminium Nitrate	$Al(NO_3)_3$	Aqueous solution	Saturated	+			1	1	1	1
Aluminium Sulfate	$Al_2(SO_4)_3$	Aqueous solution	10%	+	+	+	2	1	1	1
Aluminium Sulfate	$Al_2(SO_4)_3$	Aqueous solution	Saturated	+	+	+	2	1	1	1
Ammonia	NH_3	Aqueous solution	Solution	+	+	+	2	1	3	2
Ammonia Gas	NH_3	Aqueous solution	Saturated	+	+	+	2	1	3	2
Ammonia Gas	NH_3	Technically pure	100%	+	+	+	2	1	3	2
Ammonium Acetate	CH_3COONH_4	Aqueous solution	Saturated	+	+	+				
Ammonium Bifluoride	NH_4FHF	Aqueous solution	Saturated	+	+	+				
Ammonium Carbonate	$(NH_4)_2CO_3$	Aqueous solution	100%	+	+	+	2	1	2	2
Ammonium Chloride	NH_4Cl	Aqueous solution	Saturated	+	+	+	1	1	1	1
Ammonium Fluoride	NH_4F	Aqueous solution	25%	+	+	+	1	1	1	1
Ammonium Fosfate	$(NH_4)_3PO_4$ X H_2O		All	+	+	+	1	1	1	1
Ammonium Hydroxide	NH_4OH	Aqueous solution	Solution	+	+	+	4	1	2	4
Ammonium Hydroxide	NH_4OH	Aqueous solution	Saturated	+	+	+	4	1	2	4
Ammonium Nitrate	NH_4NO_3	Aqueous solution	Saturated	+	+	/	2	1	1	1
Ammonium Sulfate	$(NH_4)_2SO_4$	Aqueous solution	All	+	+	+	1	1	1	1
Ammonium Sulfhydrate	$NH_4OH(NH_4)_2SO_4$	Aqueous solution	Solution	+						
Ammonium Sulfhydrate	$NH_4OH(NH_4)_2SO_3$	Aqueous solution	Saturated	+						
Ammonium Sulfide	$(NH_4)_2S$	Aqueous solution	10%	+	+	+	1	1	1	1
Ammonium Sulfide	$(NH_4)_2S$	Aqueous solution	Saturated	+	+	+	1	1	1	1
Amyl Acetate	$CH_3COO(CH_2)_4CH_3$	Technically pure	100%	+	+	+	4	2	4	3
Amyl Alcohol	$CH_3(CH_2)_3CH_2OH$		100%	+	+	/	2	2	2	1
Amyl Chloride	$CH_3(CH_2)_4Cl$	Technically pure	100%	-				4	1	4
Aniline	$C_6H_5NH_2$	Technically pure	100%	/			4	2/3	1	3
Aniline Chlorhydrate	$C_6H_5NH2HCl$	Aqueous solution	Saturated	/	/	/	2	2	1	1
Anthraquinone Sulfonic Acid			Solution	+						
Antimony Trichloride	$SbCl_3$	Aqueous solution	90%	+	+	+	1	1	1	1
Aqua Regia	$_3HCl+_1HNO_3$		100%	-	-	-	4	4	2/3	4
Arsenic Acid	H_3AsO_4		Saturated	+	+					
Barium Carbonate	$BaCO_3$	Aqueous solution	All	+	+	+				
Barium Chloride	BaCl2	Aqueous solution	All	+	+	+	1	1	1	1
Barium Hydroxide	$Ba(OH)_2$	Aqueous solution	Saturated	+	+	+	1	1	1	1
Barium Nitrate	$Ba(NO_3)_2$	Aqueous solution	Saturated	+	+	+				
Barium Sulfate	$BaSO_4$	Aqueous solution	Saturated	+	+	+	1	1	1	1
Barium Sulfide	BaS	Aqueous solution	Saturated	+	+	+	1	1	1	2
Beer			100%	+	+	+	1	1	1	1
Benzaldehyde	C_6H_5CHO	Aqueous solution	Saturated	+	+	+	4	2	4	3
Benzene	C_6H_6	Technically pure	100%	/	-	-	4	4	3	4
Benzene + Benzine			20/80%	/	-	-	2/3	4	2	4

Fluid			Concentration	Pipe and fittings			Elastomeric seals			
				HDPE			NBR	EPDM	FPM	SBR
Name	Formula	Remark		°C			°C	°C	°C	°C
				20	40	60	20	20	20	20
Benzene Sulfonic Acid	$C_6H_5SO_3H$	Aqueous solution	10%	-			4	4	1	4
Benzine (Free Of Pb And Aromatic)	$C_5H_{12}÷C_{12}H_{26}$	Technically pure	100%	+	+	/	4	4	1	4
Benzoic Acid	C_6H_5COOH	Aqueous solution	Saturated	+	+	+	4	4	1	4
Benzyl Alcohol	$C_6H_5CH_2OH$	Technically pure	100%	+	+	/	4	1	1	4
Bleaching Lye	NaClO+NaCl		12,5% Cl	/	/		4	1	1	4
Borax	$Na2B_4O_7$	Aqueous solution	All	+	+	+	1	1	1	1
Boric Acid	H_3BO_3	Aqueous solution	Saturated	+	+	+	1	1	1	1
Brine			Comm. Comp.	+						
Bromic Acid	$HBrO_3$		10%	+	+	+	4	1	1	4
Bromine,Liquid	Br_2	Technically pure	100%	-			4	3	2	4
Bromine,Liquid	Br_2		High	-			4	4	1	4
Butadiene	CH_2=CH-CH=CH_2	Gas	100%	+			3	4	2	4
Butane Gas	$CH_3CH_2CH_2CH_3$		100%	+	+	+	2	4	2	4
Butanediol	$OHCH_2CH_2CH_2CH_2OH$	Aqueous solution	10%	+	+	+				
Butanediol	$OHCH_2CH_2CH_2CH_2OH$	Aqueous solution	Concentrated	/	-	-				
Butyl Acetate	$CH_3COOCH_2CH_2CH_2CH_3$	Technically pure	100%	/	/	/	4	2	4	4
Butyl Alcohol	$CH_3(CH_2)_3OH$	Technically pure	100%	+	+	+	1	2	1	1
Butyl Ether	$(CH_3(CH_2)_3)2O$	Technically pure	100%	/	-	-	4	3	4	4
Butyl Phenol	$C_4H_9C_6H_4OH$	Technically pure	100%	-			4	4	2	4
Butyl Phthalate	$HOOCC_6H_4COOC_4H_9$	Technically pure	100%	+	/	/				
Butylene	CH_2=CH-CH_2CH_4	Liquid	100%	-			2	4	1	4
Butylene Glycol	$OHCH_2$-CH=CH-CH_2OH	Technically pure	100%	+	+	+	1	1	1	1
Butylene	CH_2=CH-CH_2CH_3	Technically pure	100%	-			2	4	1	4
Butyric Acid	$CH_3CH_2CH_2COOH$	Aqueous solution	20%	+	+	/				
Butyric Acid	$CH_3CH_2CH_2COOH$	Technically pure	100%	+	+	/				
Calcium Acetate	$Ca(CH_3COO)_2$	Aqueous solution	Saturated	+	+	+	2	1	4	4
Calcium Bisulfite	$Ca(HSO_3)_2$	Aqueous solution	Saturated	+	+	+	2	1	2	2
Calcium Carbonate	$CaCO_3$	Aqueous solution	All	+	+	+	1	1	1	1
Calcium Chlorate	$Ca(ClO_3)_2$	Aqueous solution	Saturated	+	+	+	1	1	1	1
Calcium Chloride	$CaCl_2$	Aqueous solution	All	+	+	+	1	1	1	1
Calcium Hydroxide	$Ca(OH)_2$	Aqueous solution	All	+	+	+	1	1	1	1
Calcium Hypochloride	$Ca(ClO)_2$	Aqueous solution	Saturated	+	+	+	4	1	1	4
Calcium Nitrate	$Ca(NO_3)_2$	Aqueous solution	50%	+	+	+	1	1	1	1
Calcium Sulfate	$CaSO_4$	Aqueous solution	Saturated	+	+	+				
Calcium Sulfide	CaS	Aqueous solution	Saturated	/	/	/	1	1	1	2
Camphor Oil			Comm. Comp.	-	-					
Carbon Dioxide	CO_2+H_2O	Aqueous solution	Indetermined	+	+	+	1	1	1	1
Carbon Dioxide	CO_2	Gas	100%	+	+	+	1	1	1	1
Carbon Disulfide	CS_2	Technically pure	100%	/	-		4	4	1	4
Carbon Monoxid	CO	Gas	100%	+	+	+	2	2	1	2
Carbon Tetrachloride	CCl_4	Technically pure	100%	-						
Carbonic Acid	H_2CO_3	Aqueous solution	Saturated	+	+	+				
Chloramine	$C_6H_5SO_2NNaCl$	Aqueous solution	Solution	+						
Chloric Acid	$HClO_3$	Aqueous solution	20%	/						
Chlorine	Cl_2	Wet	All	/	-		4	3	1	4
Chlorine	Cl_2	Gas	100%	/	/	-	4	2	4	4
Chlorine	Cl_2	Technically pure	100%	-						
Chlorine Water	Cl_2+H_2O		Saturated	/	/					
Chloro Benzene	C_6H_5Cl	Technically pure	100%	/	-	-				
Chloro Sulfonic Acid	$HClSO_3$	Technically pure	100%	-	-	-				
Chloroform	$CHCl_3$	Technically pure	100%	-			4	4	2	4
Chrome Alum	$KCr(SO_4)_2$	Aqueous solution	Saturated	+	+	+				
Chrome Alum	$KCr(SO_4)_2$		Indetermined	+	+	+				
Chromic Acid	CrO_3+H_2O	Aqueous solution	10%	/	-	-	4	2/3	1	4
Chromic Acid	CrO_3+H_2O	Aqueous solution	30%	/	-	-	4	2/3	1	4
Chromic Acid	CrO_3+H_2O	Aqueous solution	50%	/	-	-	4	2/3	1	4
Citric Acid	$C_3H_4(OH)(COOH)_3$	Aqueous solution	50%	+	+	+	2	1	1	2
Compressed Air with Oil			100%	+	+					
Copper Acetate	$Cu(COOCH_3)_2$		Saturated	+			2	1	4	4
Copper Chloride	$CuCl_2$	Aqueous solution	Saturated	+	+	+	1	1	1	1
Copper Fluoride	CuF_2	Aqueous solution	All	+	+	+	2	1	1	1
Copper Nitrate	$Cu(NO_3)_2$	Aqueous solution	Indetermined	+	+	+	2	1	1	1

Material properties of PE

Fluid			Concentration	Pipe and fittings			Elastomeric seals			
				HDPE			NBR	EPDM	FPM	SBR
Name	Formula	Remark		°C			°C	°C	°C	°C
				20	40	60	20	20	20	20
Copper Sulfate	$CuSO_4$	Aqueous solution	Solution	+	+	+	1	1	1	1
Copper Sulfate	$CuSO_4$	Aqueous solution	Saturated	+	+	+	1	1	1	1
Cresol	$CH_3C_6H_4OH$	Aqueous solution	>=90%	+	+	/				
Cresol	$CH_3C_6H_4OH$	Aqueous solution	Solution	+	+	/				
Croton Aldehyde	CH_3-CH=CH-CHO	Technically pure	100%	/						
Cryolite	Na_3AlF_6	Aqueous solution	Saturated	/	/	-				
Cyclohexane	C_6H12	Technically pure	100%	+	+	+	2	4	1	4
Cyclohexanol	C_6H11OH	Technically pure	100%	+	/	/	2	4	2	3
Cyclohexanone	$C_6H_{10}O$	Technically pure	100%	+	/	/	4	3	4	4
Decalin (Decahydronaf-talene)	$C_{10}H_{18}$	Technically pure	100%	+	/	/				
Detergents		Aqueous solution	Comm. Comp.	+	+	+				
Dextrine			Comm. Comp.	+	+	+				
Dextrose	$C_6H_{12}O_6$	Aqueous solution	All	+	+	+				
Dextrose	$C_6H_{12}O_6$	Aqueous solution	Saturated	+	+	+				
Dextrose	$C_6H_{12}O_6$	Aqueous solution	All	+	+	+	1	1	1	1
Dibutyl Phthalate	$C_6H_4(COOC_4H_9)_2$	Technically pure	100%	-			4	2	2	4
Dibutyl Sebacate	$C8H_{16}(COOC_4H_9)_2$	Technically pure	100%	+			4	2	2	4
Dichloro Benzene	$C_6H_4Cl_2$	Technically pure	100%	/			4	4	2	4
Dichloroacetic Acid	$Cl_2CHCOOH$	Aqueous solution	50%	+	+	+	2	2	2	2
Dichloroacetic Acid	$Cl_2CHCOOH$	Technically pure	100%	+	+	/	3	2	3	3
Dichloroacetic Acid Methyl Ester	$Cl_2CHCOOCH_3$	Technically pure	100%	+	+	+				
Dichloroethylene	CHCl=CHCl	Technically pure	100%	-			2		2	4
Diesel Oil			100%	+	/	/	1	4	1	4
Diethylether	$C_2H_5OC2H_5$	Technically pure	100%	-	-		4	4	4	4
Diglycolic Acid	$HOOCCH_2OCH_2COOH$	Aqueous solution	Saturated	+						
Di-Isobutyl Ketone	$(CH_3)_2CHCH_2COCH_2CH(CH_3)_2$	Technically pure	100%	+	/	-	4	2	4	2/3
Dimethyl Amine	$(CH_3)_2NH$	Technically pure	100%	/	-					
Dimethyl Formamide	$HCON(CH_3)_2$	Technically pure	100%	+	+	/	4	2	4	3
Dioctyl Phthalate	$C_6H_4(COOC_8H_{17})_2$	Technically pure	100%	+	/	/	4	2	2	4
Dioxane	$(CH_2)_4O2$	Technically pure	100%	+	+	+	4	2/3	4	4
Ethyl Acetate	$CH_3COOCH_2CH_3$	Technically pure	100%	+	/	-	4	2/3	4	4
Ethyl Alcohol	CH_3CH_2OH	Aqueous solution	96%	+	+	/	2	1	2	1
Ethyl Benzene	$C_6H_5C_2H_5$	Technically pure	100%	/	/	/	4	4	2	4
Ethyl Chloride	CH_3CH_2Cl	Technically pure	100%	/	-		2/3	4	2	4
Ethyl Ether	$CH_3CH_2OCH_2CH_3$	Technically pure	100%	/			3	3	4	4
Ethylene Chlorohydrin	$ClCH_2CH_2OH$	Technically pure	100%	+	+	/	4	2	2	2
Ethylene Diamina	$NH_2CH_2CH2NH_2$	Technically pure	100%	-	-	-	2	1	4	2
Ethylene Dichloride	CH_2ClCH_2Cl	Technically pure	100%	/	/		4	4	2/3	4
Ethylene Glycol	$HOCH_2$-CH_2OH	Technically pure	100%	+	+	+	1	1	1	1
Ethylene Oxide	C_2H_4O	Technically pure	100%	-			3	3	4	4
Exhaust fumes			Traces	+	+	+				
Fatty Acids	$R>C_6$	Technically pure	100%	+	+	/				
Ferric Chloride	$FeCl_3$	Aqueous solution	Saturated	+	+	+	2	1	1	2
Ferric Nitrate	$Fe(NO_3)_3$		Indetermined	+	+	+				
Ferric Sulfate	$Fe_2(SO_4)_3$	Aqueous solution	Saturated	+	+	+				
Ferrous Chloride	$FeCl_2$	Aqueous solution	Saturated	+	+	+	2	1	1	2
Ferrous Nitrate	$Fe(NO_3)_2$	Aqueous solution	Saturated	+	+	+				
Ferrous Sulfate	$FeSO_4$	Aqueous solution	Saturated	+	+	+	2	1	1	2
Fertilizer Salts		Aqueous solution	10%	+	+	+				
Fertilizer Salts		Aqueous solution	Saturated	+	+	+				
Fluoboric Acid	HBF_4	Technically pure	100%	+	+	+	1	1		1
Fluorine Gas Dry	F_2		100%	-			4		1	4
Fluosilicic Acid	H2SiF6	Aqueous solution	32%	+	+	+				
Formaldehyde	CH_2O	Aqueous solution	37%	+	+	+	1	1	1	1
Formamide	$HCONH_2$	Technically pure	100%	+	+	+	2	2	1	1
Formic Acid	HCOOH	Aqueous solution	50%	+	+	+	4	2	4	2
Formic Acid	HCOOH	Technically pure	100%	+	+	+	4	2	4	2
Freon F-12	CCl_2F_2	Technically pure	100%	-			2	2/3	2	4
Fruit pulp and juice			Comm. Comp.	+						
Furfuryl Alcohol	$C_5H_6O_2$	Technically pure	100%	+	+	/	4	2		4

Fluid			Concentration	Pipe and fittings			Elastomeric seals			
				HDPE			NBR	EPDM	FPM	SBR
Name	Formula	Remark		°C			°C	°C	°C	°C
				20	40	60	20	20	20	20
Gelatine			100%	+	+	+	1	1	1	1
Glycerine	$C_3H_5(OH)_3$	Aqueous solution	All	+	+	+	1	1	2	1
Glycocoll	NH_2CH_2COOH	Aqueous solution	10%	+	+					
Glycolic Acid	$HOCH_2COOH$	Aqueous solution	37%	+	+	+				
Gas containing:										
- Carbon Dioxide	CO_2	Gas	All	+	+	+				
- Carbon Monoxid	CO	Gas	All	+	+	+				
- Hydrochloric Acid	HCL	Gas	All	+	+	+				
- Hydrochloric Acid	HCL	Gas	All	+	+	+				
- Hydrofluoric Acid	HF	Gas	< 0,1 %	+	+	+				
- Nitrous Vapours	NO, NO_2, $N2O_3$, NOx	Gas	< 0,1 %	+	+	+				
- Nitrous Vapours	NO, NO_2, $N2O_3$, NOx	Gas	5%	+	+	+				
- Oleum	$H_2SO_4 + SO_3$	Gas	< 0,1 %	-	-	-				
- Oleum	$H_2SO_4 + SO_3$	Gas	5%	-	-	-				
- Sulphur Dioxide Liquid	SO_2	Gas	All	+	+	+				
- Sulphur Trioxide	SO_3	Gas	< 0,1 %	-	-	-				
- Sulphuric Acid	H_2SO_4	Gas	All	+	+	+				
Heptane	C_7H_{16}	Technically pure	100%	+	/	-	1	4	1	4
Hexane	C_6H_{14}	Technically pure	100%	+	/	/	1	4	1	4
Hydrazine Hydrate	NH_2-NH_2 H_2O	Aqueous solution	Solution	+	+	+	2	1	1	
Hydrobromic Acid	HBr		10%	+	+	+	3	2	1	3
Hydrobromic Acid	HBr		48%	+	+	+	4	1	1	4
Hydrochloric Acid	HCl	Aqueous solution	10%	+	+	+				
Hydrochloric Acid	HCl	Aqueous solution	30%	+	+	+	2/3	1	2	2/3
Hydrochloric Acid	HCl	Aqueous solution	5%	+	+	+				
Hydrochloric Acid	HCl	Aqueous solution	Saturated	+	+	+				
Hydrocyanic Acid	HCN	Aqueous solution	Solution	+	+	+	2	2	1	2
Hydrocyanic Acid	HCN	Technically pure		+	+	+	2	2	1	2
Hydrofluoric Acid	HF	Aqueous solution	10%	+	+	/	4	3	2/3	3
Hydrofluoric Acid	HF	Aqueous solution	40%	+	/	/	4	3	2/3	3
Hydrofluoric Acid	HF	Aqueous solution	70%	+	/	/	4	3	2/3	3
Hydrogen Gas	H_2		100%	+	+	+	2	1	1	4
Hydrogen Peroxide	H_2O_2	Aqueous solution	10%	+	+	+	2	1	1	2
Hydrogen Peroxide	H_2O_2	Aqueous solution	50%	+	+	/	2	1	1	2
Hydrogen Peroxide	H_2O_2	Aqueous solution	90%	+	-	-	2	1	1	2
Hydrogen Sulfide	H_2S	Aqueous solution	Saturated	+	+	+				
Hydrogen Sulfide	H_2S		100%	+	+	/				
Hydroquinone	$C_6H_4O_2$	Aqueous solution	Saturated	+	+	+	3	4	2	4
Hydroxylamine Sulphate	$(NH_2OH)_2$-H_2SO_4	Aqueous solution	All	+	+	+				
Iodine Dry And Wet	I_2		3%	/	-		1	2	1	1
Iso-Octane	C_8H_{18}		100%	/	/	-	1	4	1	4
Isopropyl Alcohol	$(CH_3)_2CHOH$	Technically pure	100%	+	+	+	2	1	1	2
Isopropyl Ether	$(CH_3)_2CHOCH(CH_3)_2$	Technically pure	100%	/	-	-	2/3	3	4	4
Lactic Acid	$CH_3CHOHCOOH$	Aqueous solution	<=28%	+	+	+	2	1	1	3
Lanoline			Comm. Comp.	+	+	+	1	4	1	4
Lard Oil			Comm. Comp.	+						
Lead Acetate	$Pb(CH_3COO)_2$	Aqueous solution	Saturated	+	+	+	1	1	4	4
Lead Chloride	$PbCl_2$	Aqueous solution	Saturated	+	+					
Lead Nitrate	$Pb(NO_3)_2$	Aqueous solution	Saturated	+			1	1	1	1
Lead Sulfate	$PbSO_4$	Aqueous solution	Saturated	+	+	+				
Linseed Oil			Comm. Comp.			/	1	3	1	4
Lubricating Oils			Comm. Comp.	-			2	4	1	4
Lubricating Oils,Free Of Aromatic			Comm. Comp.	+	+	/	1	4	1	4
Magnesium Carbonate	$MgCO_3$	Aqueous solution	All	+	+	+	1	1	1	1
Magnesium Chloride	$MgCl_2$	Aqueous solution	Saturated	+	+	+	2	1	1	1
Magnesium Nitrate	$Mg(NO_3)_2$	Aqueous solution	Indetermined	+	+	+				
Magnesium Sulfate	$MgSO_4$		Saturated	+	+	+	2	1	1	1
Maize Oil			Comm. Comp.	+	+	/	1	1	1	4
Maleic Acid	HOOC-CH=CH-COOH	Aqueous solution	Saturated	+	+	+	1	1	1	1
Malic Acid	$HOOCCH_2CHOHCOOH$	Aqueous solution	Saturated	+			1	4	1	2
Mercuric Chloride	$HgCl_2$	Aqueous solution	Saturated	+	+	+	1	1	1	1

Material properties of PE

Fluid			Concentration	Pipe and fittings			Elastomeric seals			
				HDPE			NBR	EPDM	FPM	SBR
Name	Formula	Remark		°C			°C	°C	°C	°C
				20	40	60	20	20	20	20
Mercuric Cyanide	$Hg(CN)_2$	Aqueous solution	All	+	+	+				
Mercuric Sulfate	$HgSO_4$	Aqueous solution	Saturated	+	+	+				
Mercurous Nitrate	$HgNO_3$	Aqueous solution	Saturated	+	+	+				
Mercury	Hg	Technically pure	100%	+	+	+	1	1	1	1
Methane	CH_4		100%	+			1	3	1	3
Methanesulfonic Acid	CH_3SO_3H	Aqueous solution	50%	/	/					
Methanesulfonic Acid	CH_3SO_3H	Technically pure	100%	-	-					
Methyl Acetate	CH_3COOCH_3	Technically pure	100%	+			4	2	4	4
Methyl Alcohol	CH_3OH	Technically pure	100%	+	+	+				
Methyl Amine	CH_3NH_2	Aqueous solution	32%	/			4	1	4	2
Methyl Bromide	CH_3Br	Technically pure	100%	/			4	4	1	4
Methyl Chloride	CH2Cl	Technically pure	100%	/			4	3	1	4
Methyl Ethyl Ketone	$CH_3COCH2CH_3$		100%	+	/	-	4	2	4	4
Methylene Chloride	CH_2Cl_2		100%	/			4	4	3	4
Milk			100%	+	+	+	1	1	1	1
Mineral oil			Comm. Comp.	/	/	-	1	4	1	4
Mixed Acids (Chromic, Sulphuric)	$H_2CrO_4/H_2SO_4/H_2O$		50/15/35%	-						
Mixed Acids (Sulphuric, Nitric)	$H_2SO_4/HNO_3/H_2O$		10/20/70%	/	/	/				
Mixed Acids (Sulphuric, Nitric)	$H_2SO_4/HNO_3/H_2O$		48/49/3	-	-	-				
Mixed Acids (Sulphuric, Nitric)	$H_2SO_4/HNO_3/H_2O$		50/50%	-	-	-				
Mixed Acids (Sulphuric, Phosphoric)	$H_2SO_4/H_3PO_4/H_2O$		30/60/10%	+	/					
Molasses			Comm. Comp.	+	/	/	1	1	1	1
Monochloracetic Acid	$ClCH_2COOH$	Aqueous solution	50%	+	/	/	4	2		4
Monochloroacetic Acid Ethyl Ester	$ClCH_2COOCH_2CH_3$	Technically pure	100%	+	+	+				
Naphthalene	C10H8	Technically pure	100%	+	/	/				
Nickel Chloride	$NiCl_2$	Aqueous solution	All	+	+	+	1	1	1	1
Nickel Nitrate	$Ni(NO_3)_2$	Aqueous solution	Saturated	+	+	+				
Nickel Sulfate	$NiSO_4$	Aqueous solution	Solution	+	+	/	1	1	1	1
Nickel Sulfate	NiSO4	Aqueous solution	Saturated	+	+	+	1	1	1	1
Nicotine	$C_{10}H1_4N_2$		Indetermined	+	+	+				
Nitric Acid	HNO_3	Aqueous solution	20%	+	/	/	4	4	2/3	4
Nitric Acid	HNO_3	Aqueous solution	40%	/	-	-	4	4	2/3	4
Nitric Acid	HNO_3	Aqueous solution	70%	-	-	-	4	4	2/3	4
Nitric Acid	HNO_3	Technically pure	100%	-			4	4	2/3	4
Nitrobenzene	$C_6H_5NO_2$		100%	+	/	/				
Nitroethane	$CH_3CH_2NO_2$	Technically pure	100%	+	/	/	4	2	4	2
Nitromethane	CH_3NO_2	Technically pure	100%	+	/	/	4	2	4	2
Nitrotoluene	$CH_3C_6H_4NO_2$	Technically pure	100%	+	+	/				
Nitrous Gases	NOx	Anhydrous	Solution	+	+	+	1	1	1	1
Oleic Acid	$C_{17}H_{33}COOH$	Technically pure	100%	+	+	/	2	3	1	4
Oleum	$H_2SO_4+SO_3$		10%	-			4	4	1	4
Oleum	$H_2SO_4+SO_3$		High	-			4	4	1	4
Oleum	$H_2SO_4+SO_3$		Traces	-			4	4	1	4
Olive Oil			Comm. Comp.	+	+	/	1	4	1	4
Oxalic Acid	HOOCCOOH	Aqueous solution	10%	+	+	+	1	1	1	1
Oxalic Acid	HOOCCOOH	Aqueous solution	Saturated	+	+	+	1	1	1	1
Oxygen	O_2		All	+	+	/	2	1	1	4
Ozone Gas	O_3	Aqueous solution	Saturated	/	-		4	1	1	4
Ozone Gas	O_3		>2%	/	-		4	1	1	4
Palmitic Acid	$CH_3(CH_2)1_4COOH$		70%	/	-	-				
Paraffin Emulsion		Water-emulsie	Comm. Comp.	/	/	/	1	4	1	4
Paraffin Oil			Comm. Comp.	+	+	+	1	4	1	4
Peanut Oil			Comm. Comp.	+			1	3	1	4
Perchloric Acid	$HClO_4$	Aqueous solution	10%	+	+	+	4	1	1	4
Perchloric Acid	$HClO_4$	Aqueous solution	70%	+	/	-	4	1	1	4
Perchloric Acid	$HClO_4$	Aqueous solution	10%	+	+		4	1	2	4

Fluid			Concentration	Pipe and fittings			Elastomeric seals			
				HDPE			NBR	EPDM	FPM	SBR
Name	Formula	Remark		°C			°C	°C	°C	°C
				20	40	60	20	20	20	20
Petroleum		Technically pure	100%	+	+	/	1	4	1	4
Petroleum Ether		Technically pure	100%	+	/	/	1	4	1	4
Phenol	C_6H_5OH	Aqueous solution	1%	+	/		4	4	2	4
Phenol	C_6H_5OH	Aqueous solution	90%	+	+		4	4	1	4
Phenylhydrazine	$C_6H_5NHNH_2$	Technically pure	100%	/	/	/	3	3	2	4
Phenylhydrazine Hydrochloride	$C_6H_5NHNH_2HCl$	Aqueous solution	Saturated	+						
Phosphoric Acid	H_3PO_4	Aqueous solution	25%	+	+	+	1	1	1	1
Phosphoric Acid	H_3PO_4	Aqueous solution	50%	+	+	+	1	1	1	1
Phosphoric Acid	H_3PO_4	Aqueous solution	85%	+	+	/	1	1	1	1
Phosphorous Penta-Trichloride	PCl_5-PCl_3	Technically pure	100%	+	/	/				
Phosphorous Pentoxide	P_2O_5	Technically pure	100%	+	+	+				
Photographic Developer			Comm. Comp.	+			1	2	1	2
Photographic Emulsion			Comm. Comp.	+	+					
Phthalic Acid	$C_6H_4(COOH)_2$	Aqueous solution	50%	+	+	+				
Picric Acid	$C_6H_2(OH)(NO_2)_3$	Aqueous solution	1%	+	+	/	2	1	1	2
Potassium Acetate	CH_3COOK	Aqueous solution	Saturated	+	+	+	1	1	2	4
Potassium Bicarbonate	$KHCO_3$	Aqueous solution	Saturated	+	+	+	1	1	1	1
Potassium Bichromate	$K_2Cr_2O_7$	Aqueous solution	Saturated	+	+		2	1	1	2
Potassium Bisulfate	$KHSO_4$	Aqueous solution	Indetermined	+	+	+	1	1	1	1
Potassium Borate	K_3BO_3	Aqueous solution	Saturated	+	+	+				
Potassium Bromate	$KBrO_3$	Aqueous solution	Saturated	+	+	/	1	1	1	1
Potassium Bromide	KBr	Aqueous solution	Saturated	+	+	+	1	1	1	1
Potassium Carbonate	K_2CO_3	Aqueous solution	Saturated	+	+	+	1	1	1	1
Potassium Chlorate	$KClO_3$	Aqueous solution	Saturated	+	+	+	4	1	1	2
Potassium Chloride	KCl	Aqueous solution	Saturated	+	+	+	1	1	1	1
Potassium Chromate	K_2CrO_4	Aqueous solution	Saturated	+	+		2	1	1	2
Potassium Cyanide	KCN	Aqueous solution	Saturated	+	+	+	1	1	1	1
Potassium Ferricyanide	$K_4Fe(CN)_{63}H_2O$	Aqueous solution	Saturated	+	+	+				
Potassium Fluoride	KF	Aqueous solution	Saturated	+	+	+				
Potassium Hydroxide	KOH	Aqueous solution	<=60%	+	+	+	2	1	2/3	1
Potassium Hypochlorite	KClO	Aqueous solution	Indetermined	+	/	/				
Potassium Iodide	KI	Aqueous solution	Saturated	+	+	+				
Potassium Nitrate	KNO_3	Aqueous solution	Saturated	+	+	+	1	1	1	1
Potassium Perborate	KBO_3	Aqueous solution	Indetermined	+	+	+				
Potassium Perchlorate	$KClO_4$	Aqueous solution	Saturated	+	+	+	3	1	1	3
Potassium Permanganate	$KMnO_4$	Aqueous solution	10%	+	+	+				
Potassium Permanganate	$KMnO_4$	Aqueous solution	Saturated	+	+	/				
Potassium Persulfate	K_2S_2O8	Aqueous solution	Saturated	+	+	+				
Potassium Phosphates Acids	K_2HPO_4 KH_2PO_4	Aqueous solution	All	+	+	+				
Potassium Sulfate	K_2SO_4	Aqueous solution	Saturated	+	+	+	1	1	1	1
Propane Gas	$CH_3CH_2CH_3$		100%	+			1	4	1	4
Propane Gas	$CH_3CH_2CH_3$		100%	+			1	4	1	4
Propionic Acid	CH_3CH_2COOH	Aqueous solution	50%	+	+	+	2	4	1	4
Propyl Alcohol	C_3H_7OH	Aqueous solution	97%	+	+	+				
Propylene Glycol	$CH_3CHOHCH_2OH$	Technically pure	100%	+	+	+	2	1	1	1
Propylene Oxid		Technically pure	100%	+			4	1	4	4
Pyridine	C_5H_5N	Technically pure	100%	+	/	/	4	4	4	4
Silicic Acid	H_2SiO_3	Aqueous solution	All	+	+	+				
Silicone Oil			Comm. Comp.	+	+	/	1	1	1	1
Silver Cyanide	AgCN	Aqueous solution	All	+	+	+				
Silver Nitrate	$AgNO_3$	Aqueous solution	Saturated	+	+	+	1	1	1	1
Silver Sulfate	Ag_2SO_4	Aqueous solution	Saturated	+	+	+				
Soap		Aqueous solution	All	+	+	+	1	1	1	2
Sodium Acetate	CH_3COONa	Aqueous solution	Saturated	+	+	+	2	1	4	4
Sodium Alum	$NaAl(SO_4)_2$	Aqueous solution	Saturated	+	+	+				
Sodium Benzoate	C_6H_5COONa		Saturated	+	+	+				
Sodium Bicarbonate	$NaHCO_3$	Aqueous solution	Saturated	+	+	+	2	1	1	1
Sodium Bichromate	Na_2Cr_2O7	Aqueous solution	Saturated	+	+	+				

Material properties of PE

Fluid			Concentration	Pipe and fittings			Elastomeric seals			
				HDPE			NBR	EPDM	FPM	SBR
Name	Formula	Remark		°C			°C	°C	°C	°C
				20	40	60	20	20	20	20
Sodium Bisulfate	$NaHSO_4$	Aqueous solution	10%	+	+	+	1	1	1	2
Sodium Bisulfite	$NaHSO_3$	Aqueous solution	100%	+	+	+	1	1	1	2
Sodium Bromate	$NaBrO_3$	Aqueous solution	All	+	/					
Sodium Bromide	NaBr	Aqueous solution	Saturated	+	+	+				
Sodium Carbonate (Soda)	Na_2CO_3	Aqueous solution	Saturated	+	+	+	2	1	1	1
Sodium Chlorate	$NaClO_3$	Aqueous solution	All	+	+	+	2/3	2	1	4
Sodium Chloride	NaCl	Aqueous solution	Solution	+	+	+	1	1	1	1
Sodium Chloride	NaCl	Aqueous solution	Saturated	+	+	+	1	1	1	1
Sodium Chromate	Na_2CrO_4	Aqueous solution	Solution	+						
Sodium Cyanide	NaCN	Aqueous solution	All	+	+	+	2	1	1	1
Sodium Disulphite	$Na_2S_2O_5$	Aqueous solution	All	+			1	1	1	2
Sodium Ferrocyanide	Na_4FeCN_6	Aqueous solution	Saturated	+	+					
Sodium Fluoride	NaF	Aqueous solution	Saturated	+						
Sodium Hydroxide	NaOH	Aqueous solution	10%	+	+	+	3	1	2	2
Sodium Hydroxide	NaOH	Aqueous solution	30%	+	+	+	4	1	3	2
Sodium Hydroxide	NaOH	Aqueous solution	50%	+	+	+	1	1	3	2
Sodium Hypochlorite	NaClO	Aqueous solution	12,50%	/	-		4	1	1	4
Sodium Hypochlorite	NaClO	Aqueous solution	3%	+	/	/	4	1	1	4
Sodium Iodide	NaI	Aqueous solution	All	+						
Sodium Metasilicate	Na_2SiO_3	Aqueous solution	<5%	+	+	+				
Sodium Metasilicate	Na_2SiO_3	Aqueous solution	Saturated	+	+	+	1	1	1	1
Sodium Nitrate	$NaNO_3$	Aqueous solution	Saturated	+	+	+	1	1	1	1
Sodium Nitrite	$NaNO_2$	Aqueous solution	Saturated	+						
Sodium Oxalate	$Na_2C_2O_4$	Aqueous solution	Saturated	+						
Sodium Perborate	$NaBO_3$	Aqueous solution	All	+			2	1	1	2
Sodium Perchlorate	$NaClO_4$	Aqueous solution	Indetermined	+						
Sodium Peroxide	Na_2O_2		Solution	+			2	1	1	2
Sodium Persulphate	Na_2S_2O8	Aqueous solution	Saturated	+	+	+				
Sodium Phosphate	Na_3PO_4	Aqueous solution	Saturated	+	+	+	1	1	1	1
Sodium Phosphate Monoacid	Na_2HPO_4	Aqueous solution	Saturated	+	+		1	1	1	
Sodium Sulfate	Na_2SO_4	Aqueous solution	Saturated	+	+	+	1	1	1	1
Sodium Sulfide	Na_2S	Aqueous solution	Solution	+	+	+	2	1	1	3
Sodium Sulfide	Na_2S	Aqueous solution	Saturated	+	+	+	2	1	1	3
Sodium Sulfite	Na_2SO_3	Aqueous solution	Saturated	+	+	+				
Sodium Thiocyanate	NaSCN	Aqueous solution	Indetermined	+	+	+				
Sodium Thiosulphate	$Na_2S_2O_3$	Aqueous solution	Saturated	+	+	+	3	1	1	2
Stannic Chloride	$SnCl_4$	Aqueous solution	Saturated	+	+	+	1	1	1	2
Stannous Chloride	$SnCl_2$	Aqueous solution	Saturated	+	+	+	1	1	1	1
Stearic Acid	$C_{17}H_{35}COOH$	Technically pure	100%	+		/	1	1	1	1
Styrene	$C_6H_5CH=CH_2$		100%	/	-	-	4	4	1	4
Sugar Syrup			Saturated	+	+	+	1	1	1	1
Sulfamic Acid	HSO_3NH_2	Aqueous solution	20%	-						
Sulphur	S		100%	+	+	+				
Sulphur Dioxide Liquid	SO_2	Aqueous solution	Saturated	+	+	+				
Sulphur Dioxide Liquid	SO_2	Technically pure	100%	-						
Sulphur Dioxide Liquid	SO_2	Technically pure	100%	+	+	+				
Sulphur Trioxide	SO_3		100%	-						
Sulphuric Acid	H_2SO_4	Aqueous solution	10%	+	+	+	2	1	2	2
Sulphuric Acid	H_2SO_4	Aqueous solution	50%	+	+	+	4	1	2	4
Sulphuric Acid	H_2SO_4	Aqueous solution	80%	+	+	/	4	2	2	4
Sulphuric Acid	H_2SO_4	Aqueous solution	90%	/	/	-				
Sulphuric Acid	H_2SO_4	Aqueous solution	96%	-	-	-	4	4	2	4
Sulphuric Acid	H_2SO_4	Aqueous solution indetermined	98%	-	-	-				
Sulphuric Acid	H_2SO_4	Technically pure	100%	-	-	-				
Sulphurous Acid	H_2SO_3	Aqueous solution	Saturated	+	+	+	2	2	1	2
Tallow Emulsion			Comm. Comp.	+	/	/	2	2	1	4
Tannic Acid	$C_{76}H_{52}O_{46}$	Aqueous solution	All	+	+	+	2	2	2	2
Tartaric Acid	$COOH(CHOH)_2COOH$	Aqueous solution	All	+	+	+				
Tetrachloroethane	$CHCl_2CHCl_2$		100%	/	-		4	4	1	4

Fluid			Concentration	Pipe and fittings			Elastomeric seals			
					HDPE		NBR	EPDM	FPM	SBR
Name	Formula	Remark			°C		°C	°C	°C	°C
				20	40	60	20	20	20	20
Tetrachloroethylene	$Cl_2C=CCl_2$		100%	/	-		4	4	2	4
Tetraethyl Lead	$Pb(C_2H_5)_4$	Technically pure	100%	+			2	4	1	4
Tetrahydrofurane	$(CH_2)_4O$		100%	/	-		4	4	4	4
Tetrahydronaphthalene	$C_{10}H_{12}$		100%	/						
Thionyl Chloride	$SOCl_2$	Technically pure	100%	-			2/3	1	1	2/3
Thiophene	C_4H_8S		100%	/	/	/	4	4	4	4
Toluene	$C6H_5CH_3$	Technically pure	100%	/	-	-	4	4	2	4
Toluic Acid	CH_3C6H_4COOH		50%	/						
Transformer Oil			Comm. Comp.	+	/	/	2	4	2	4
Tributylphosphate	$(C_4H_9)_3PO_4$	Technically pure	100%	+	+	+	4	2	3	4
Trichlorethylene	$ClCH=CCl_2$	Technically pure	100%	-	-	-	4	4	2	4
Trichloroacetic Acid	CCl_3COOH	Aqueous solution	50%	+	/	/	2	2	4	4
Trichloroacetic Acid	CCl_3COOH	Technically pure	100%	+	/	-	2	2	4	4
Trichloroethane	CH_3CCl_3	Technically pure	100%	/			4	4	1	4
Tricresylphosphate	$(CH_3C6H_4O)_3PO_4$	Technically pure	100%	+	+	+	4	2	2	4
Triethanolamine	$N(CH_2CH_2OH)_3$	Technically pure	100%	+	+	/	3	1	4	2
Trioctylphosphate	$(C_8H_{17})_3PO_4$	Technically pure	100%	/			4	1	2	4
Turpentine Oil		Technically pure	100%	/	-	-	2	4	1	4
Urea	NH_2CONH_2	Aqueous solution	<=10%	+	+	+	1	1	1	1
Urea	NH_2CONH_2	Aqueous solution	33%	+	+	+	1	1	1	1
Urine			Indetermined	+	+	+				
Vaseline Oil			Comm. Comp.	+	+	/	1		1	4
Vegetable Oils and fats			Comm. Comp.	+	/		1	4	1	3
Water	H_2O		100%	+	+	+	1	1	1	1
Water	H_2O		100%	+	+	+	1	1	1	1
Water	H_2O		100%	+	+	+	1	1	1	1
Water	H_2O		100%	+	+	+	2	1	2	2
Water	H2O		100%	+	+	+	2	1	2	2
Water, Rain	H_2O		100%	+	+	+	1	1	1	1
Water, Salt	H_2O+NaCl		Saturated	+	+	+	1	1	1	1
Water, Sea			100%	+	+	+	1	1	1	1
Wine			Comm. Comp.	+	+	+	1	1	1	1
Wine Vinegar		Technically pure	Comm. Comp.	+	+	+				
Xylene	$C_6H_4(CH_3)_2$		100%	-			4	4	2	4
Zinc Acetate	$Zn(CH_3COO)_2$		Indetermined	+	+	+	2	1	4	4
Zinc Chloride	$ZnCl_2$	Aqueous solution	Solution	+	+	+	2	1	1	2
Zinc Chloride	$ZnCl_2$	Aqueous solution	Saturated	+	+	+	2	1	1	2
Zinc Chromate	$ZnCrO_4$	Aqueous solution	Indetermined	+	+	+				
Zinc Cyanide	$Zn(CN)_2$	Aqueous solution	All	+	+	+				
Zinc Nitrate	$Zn(NO_3)_2$	Aqueous solution	Indetermined	+	+	+				
Zinc Sulfate	$ZnSO_4$	Aqueous solution	Solution	+	+	+	1	1	1	1
Zinc Sulfate	$ZnSO_4$	Aqueous solution	Saturated	+	+	+	1	1	1	1

Table 2.3 Chemical resistance. The data is based on the latest knowledge. When in doubt please contact Technical Support.

2.5 Chapter summary

Polyethylene	Polyethylene is abbreviated "PE". PE is a semi-crystalline thermoplastic belonging to the polyolefin group. Depending on the average molar mass, the compound produced may be PE-LD (low density PE), PE-LLD (linear low density PE), PE-MD (medium density PE) and PE-HD (high density PE).

Material properties of PE

3 Planning criteria

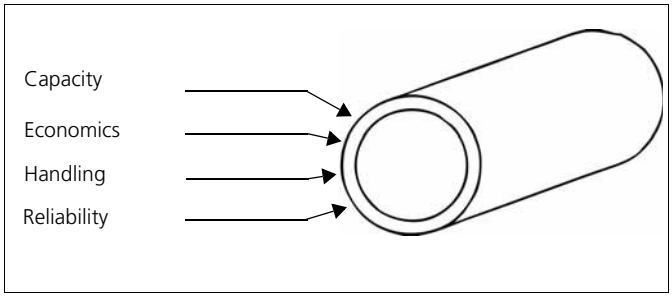


Figure 3.1

3.1 Selection criteria for PE pipe systems

For a professional and economic construction of plastic pipe systems a series of parameters and criteria have to be considered in planning. To employ plastic pipe systems made of PE the following has therefore to be included in the general considerations.

Economics
Economics is one of the most important factors that tip the balance concerning the use of materials in planned applications. The question of price is not the only crucial factor included under the term "economics", but equally decisive in assessing economic considerations are life-span, flexibility, ease of installation, handling and increasingly stronger concerns about environmental impact as well. A cost comparison of pipe installations usually involves facilities made from plastic with those made from other materials such as metal, concrete or clay. Due to shortened installation times and ease of handling, plastic pipe systems enable important cost savings.
A further factor involving economic considerations of using PE plastic pipe systems is the reduced maintenance with respect to corrosion protection. The costs of preserving and maintaining an installation are regarded as a cost-intensive part of an overall project and therefore affect the investment decision after the fact.

The advantages and disadvantages of PE in pipe and equipment construction will be discussed on the basis of some practical applications. The potential of PE as a problem solutions will be indicated in subsequent parts of this Specification Manual. Based on more than 40 years of experience with PE, FIP S.p.A. possesses fundamental knowledge about installation techniques and solutions to the problems that arise in plastic pipe construction.
We are pleased to share this expertise with our customers. FIP will, however, restrict itself in this Specification Manual to application techniques and resulting problem solutions involving the use of PE in plastic pipe systems.

Capacity
There are many requirements in industrial pipe construction, and process-related details frequently necessitate the manufacture of components of various geometries and configurations.
FIP places a great deal of value on the continuous contact with its customers in order to maintain regular exchanges of information. Years of experience with our products as well as their continuous adaptation to the needs of our customers has led to steady development and expansion of our product range. We have a large range of injection moulding components from our own production facility at disposal. The product range PE100 spigot fittings consists of:
- Short spigot fittings for butt-weld
- Elongated fittings for butt-weld and electrofusion
- Fittings made from pipe
- Flanges and gaskets

On account of these components, FIP is capable of offering a solution for every connection of PE pressure pipes.

Reliability
Every malfunction, if only of short duration, incurs costs and reduces confidence in the reliability of facilities. Users should therefore make sure ahead of time that their decisions in choosing the right materials involve sufficient attention to quality assurance. The demands of operational reliability begin in the earliest project stage and must be comprehensively realised in compliance with rules and regulations as well as the available testing methods. Incisive knowledge, professional advice and optimal processing are important pre-requisites for reliable and proper-functioning plastic pipe systems.

Handling
In employing PE materials, attention must always be paid to the fact that, beside all the advantages over conventional materials, there are also some disadvantages and therefore certain rules have to be followed. Just as in processes involving other materials, the use of plastic in pipe systems requires appropriate expertise and care. In contrast with conventional materials, the mechanical factors of PE are significantly affected by internal and external influences (e.g. medium and environmental temperatures). In contrast to concrete or other materials employed in pipe construction, PE pipe systems possess a comparably small surface hardness, which is compensated by high flexibility and long life-span. A positive property worth mentioning is the good chemical resistance of PE against many aggressive media. Conventional pipe materials such as concrete are unsuitable. Unlike conventionally employed materials, appropriate exploitation of the offered advantages yields more technical possibilities for solving numerous problems during installation. In most cases resolved in an uncomplicated manner. The handling of plastic materials is relatively easy to learn, but basic manual training is nevertheless beneficial.

The following rules are to be observed when working with PE pipes:
- Pipes are to be transported in appropriate vehicles and carefully loaded and unloaded.
- During transport, they should not be exposed to impact loads.
- Surfaces are to be protected against mechanical influences and their effects (such as grooves, scratches, notches and the like).
- Storage should occur in such a manner that the products are not exposed to the effects of heat, solar radiation, UV radiation or other adverse atmospheric and/or environmental influences for any length of time.
- The products should not be soiled any more than is necessary. The supporting surfaces for the pipes and fittings must remain free of stones and level under all conditions.
- Deformations of the pipes can be prevented by restricting stacking heights. As a rule, do not stack PE pipes higher than 1 metre.

3.2 User instructions

Loads to which pipe systems are exposed during installation or operations are indispensable variables for the engineer. The reasons for this information need involve the behaviour of plastic, which is directly affected by external and internal parameters such as internal pressures as well as temperature fluctuations of the environmental and the flow medium. These influences have a great deal of significance for the life expectancy of a plastic pipe system. The necessary information about the expected loads that could affect the pipe system have therefore to be considered even in the planning phase.
For this purpose a selection of recurring considerations regarding material application and processing is gathered into the form of a checklist.

3.3 Checklist for pipe and equipment contractors

What is to be considered?	Pipework	Equipment
Are the dimensions of the pipes and fittings (connecting dimensions) as well as the material data clear and complete?	x	x
Are the requirements of the fittings appropriately indicated (dimensions, load, chemical resistance)?	x	x
Is the standard length of pipe sufficient or are custom lengths possibly more economical?	x	
Given the component dimensions based on the indicated catalogue sizes, is a prefabricated part more appropriate?	x	
Does the external and internal pipe diameter conform to the chosen nominal size?	x	x
Is statistic evidence to be provided? Should or must an engineer be brought in?	x	x
Do the flanged connecting dimensions indicated in DIN 2501 or ASTM correspond to the pressure ratings for armatures and components?	x	
Are special product requirements demanded by the operator, agency or authorities?	x	x
Are acceptance tests required or must test reports be issued in accordance with EN 10204?	x	x
When are the delivered fittings required on the construction site? Are there adequate storage facilities or are on-demand deliveries to be agreed?	x	x
What are the possibilities for transport to the construction site? Is packaging of products required or possible?	x	
During installation work, is there surveillance by a neutral agency?	x	x
Are there certified welders for the welding work and are they available?	x	x
Does the welding and auxiliary equipment meet the requirements of current standards?	x	x
What are the local conditions?		x
If applicable, do the components have to be manufactured on site?	x	x
Are facilities available for a final pressure or leakage test?	x	x
Must these be documented?	x	x
Are suppliers and/or manufacturers aware of the operating conditions?	x	x
Important information includes:		
- the medium or nature of the flow substance in order to determine the chemical resistance (if applicable, additional information must be obtained from the pipe manufacturer!)	x	x
- the temperature limits ($T_{i\ min}$) and ($T_{i\ max}$), the load duration, and the medium that loads the pipe or fitting	x	x
- the environmental temperature ($T_{i\ min}$) and ($T_{i\ max}$)	x	x
- the internal pressure ($p_{i\ min}$) and ($p_{i\ max}$)	x	x
- the negative pressure (p_u)	x	x
- the external pressure (p_a) (e.g. soil loads, etc.)	x	x
- does the data involve conditions of continuous load or intermittent operation?	x	x
- does the system to be installed involve an aboveground or an underground system?	x	x
- could there be long periods of disuse with unfilled pipes?	x	
- are pressure surges resulting from pump operation to be expected? Size?	x	x
- are the respective weld parameters known?	x	x
- must special manufacturing guidelines or instructions be followed as well?	x	x

Table 3.1

4 Standards

4.1 General

Harmonisation of European standards for plastic piping systems is an ongoing process. Plastic pressure pipe systems are subject to:

prEN 15014 Pressure Drainage & Sewerage
This harmonised European standard contains only the performance characteristics needed to meet the essential requirements of EU Directive(s). It does not cover all the characteristics of the products. These are specified in the product standards listed in table 4.1 "European product standards for PE pipe systems" and other appropriate product specifications. This listing represents the situation at the time this document was published and may be changed if new standards are developed.

The harmonised European standard belongs to a family or cluster of standards aimed at plastic pipe systems. The relationship is shown in figure 4.1.

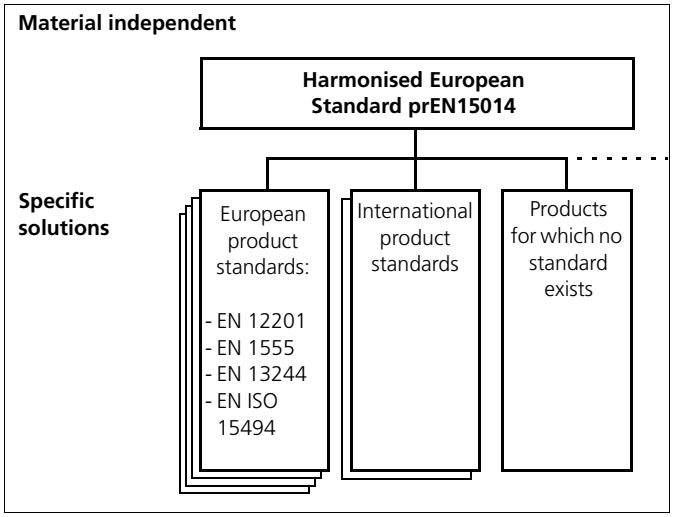


Figure 4.1

For the harmonisation of pressure plastic pipe systems figure 4.2 applies:

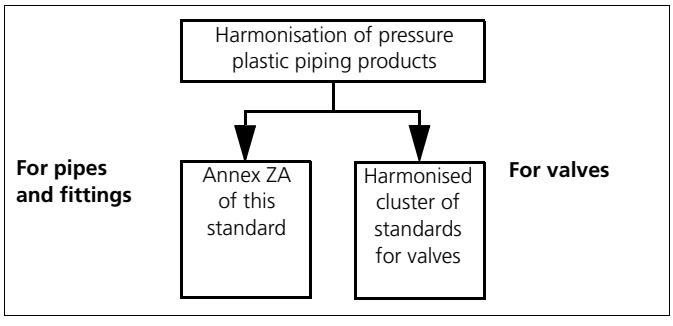


Figure 4.2

The harmonised European standard prEN 15014 specifies performance requirements for plastic pipes, fittings and their joints for buried or above ground pressure applications involving general purpose water, drainage, sewerage and irrigation, as well as for any other pressure application with other fluids covered by the Construction Products Directive, with the exception of drinking water for human consumption. It gives associated test methods for verification and evaluation of compliance with this standard.

European product standards for PE pipe systems	
EN 12201	Plastic pipe systems for water supply - Polyethylene (PE)
EN 1555	Plastic pipe systems for the supply of gaseous fuels - Polyethylene (PE)
EN 13244	Plastic pipe systems for buried and aboveground pressure systems for general purpose water, drainage and sewerage - Polyethylene (PE) - Part 1: General
EN ISO 15494	Plastic pipe systems for industrial applications - Polybutene (PB), Polyethylene (PE), Polypropylene (PP) - Specifications for components and the system - Metric series

Table 4.1

4.2 Minimum required strength (MRS)

As mentioned in section 1.6.1, the internal pressure creep test is one of the most important indicators of a thermoplastic pipe's capacity. The ISO DIS 12162 classification system was created to classify pipe material in a meaningful manner. The basis for this classification is formed by the measurement and analysis of creep rupture curves according to the standard extrapolation method specified in ISO/TR 9080. For the circumferential stress (measured at a temperature of 20°C, a life-span of 50 years and using water as test medium), this enables us to determine:
- the expectation value for long terms hydrostatic strength (LTHS)
- the 97.5% lower confidence level (LCL)

The LCL value is categorised according to the Renard 10 number series (R10). This standard number series (DIN 323, ISO 30) involves the subdivision of a decade into 10 equal parts, plotted on a logarithmic scale. This produces the following series $(\sqrt[10]{10})^n$ with n = 1, 2, 3, ..., n.
Rounding these values produces the following number series: 1 - 1.25 - 1.6 - 2 - 3.2 - 4 - 5 - 6.3 - 8 - 10. The smooth values result from the fact that these results are rounded down to the next lowest R10 number. The outcome is viewed as the minimum required strength (MRS). The significance of the MRS values will be illustrated using an example involving PE:
MRS 6.3 = σ_{ref} = 6.3 MPa (Mega Pascal) and corresponds to PE63.
MRS 8 = σ_{ref} = 8 MPa and corresponds to PE80.
MRS 10 = σ_{ref} = 10 MPa and corresponds to PE100.

4.3 Pipe series number (ISO-S)

To calculate wall thickness, material-specific variables are reinforced by a safety factor in order to guarantee the permissible internal pressure load for the pipe.
For the transport of water through a pipe system, calculations are performed using an aggregate pipe coefficient (C) = safety factor (SF) $\geq$ 1.25. For the transport of gas in pipe systems an aggregate pipe coeffcient (c) = Safety Factor (SF) > 2.0 is used. The aggregate pipe coefficient is comparable to the safety factor (SF) in its size and significance, as it comprises the safety reserves required under certain circumstances when additional loads affect the pipe. For instance, pressure surges, heat stresses during temperature changes, agitations and ground subsidences can reduce internal pressure load capacity. In contrast to the calculation of minimum values when sizing pipes, which are determined simply by running tests, the calculation of pipe safety factors must resort to empirical values. Dividing the MRS value by the aggregate pipe coefficient (C) yields the reference stress (σ_{ref}), and the acceptable stress (σ_{acc}) is produced by dividing the reference stress (σ_{ref}) by the aggregate pipe coefficient (C) (equation 4.1).

$$\sigma_{ref} = \frac{MRS}{C} \quad \text{c.q.} \quad \sigma_{acc} = \frac{\sigma_v}{C}$$

Equation 4.1

MRS = Minimum required stress (-)
σ_{ref} = Reference stress (N/mm^2)
σ_{acc} = Acceptable stress (N/mm^2)
C = SF = Aggregate pipe coefficient (safety factor) (-)

The safety factor underlying calculations for an entire pipe system has to be established in the context of individual applications (consideration is first given to the weakest pipe elements, such as branches, tees, etc.). The values of the safety coefficient for an entire pipe system are normally always larger than the values indicated in the DIN, which only apply to a straight pipe

4.4 Maximum operating pressure (MOP)

Before introduction of the European standard the internal pressure load capacity of PE pressure pipes and fittings was indicate by the nominal pressure stages of a pipe in terms of a PN rating. For instance, pipes rated PN 6 meant that the permissible internal pressure load capacity of the pipe was 6 bar for water at a temperature of 20°C over a lifespan of 50 years.
According to the present European standard, the designation (PN) is replaced by the designations (SDR) or (ISO-S), whereby:

$$(ISO - S = \frac{SDR - 1}{2})$$

Equation 4.2

The permissible internal pressure load capacity or maximun operating pressure of PE pipes (PE80, PE100) are based on variable safety factors SF = 1.25 (for water supply pipes) and SF = 2.0 (for gas pipes). The significance of these specifications will be investigated further in the rest of this chapter.

4.5 Standard dimension ratio (SDR)

In European standards the notion of nominal pressure "PN" is being largely abandoned. Instead, the previously used pipe series number "ISO-S" and the standard dimension ratio "SDR" are being emphasised. The relationship between ISO-S and SDR is shown in equation 4.3.
This ratio is indicated in the form of an SDR mark (standard dimension ratio). Within a pipe series, this SDR number is constant and corresponds to the value of the rounded outside diameter of the pipe divided by the wall thickness of the pipe.

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

Equation 4.3

SDR = standard dimension ratio (-)
d_e = rounded outside diameter of the pipe (mm)
e = pipe wall thickness (mm)

Application		**Drinking water**	**Gas**
Material		PE100	PE100
Standards		**E DIN 8074**	**E DIN 8074**
σ_{ref} (Water 20°C, 50 years)		10	10
Aggregate pipe coefficient C		**1.25**	**2.0**
σ_{acc} (Water 20°C, 50 years)		8	5
SDR	**ISO-S**		
41	20	4	
33	16	5	
26	12.5	6.3	
17.6	8.3	9.6	
17	8	10	5
11	5	16	10
9	4	20	-
7.4	3.2	25	-

Table 4.2 Internal pressure load capacity for PE100 drinking water and gas pipes

Table 4.2 shows the maximum permissible operating pressure (according to DVGW VP for drinking water and G 472 for gas), the current pipe series as specified in DIN 8074, and their standard dimension ratios (SDR) for the PE100 material classes.

Note on table 4.2
If PE pipes and fittings are used to supply drinking water (e.g. table water, mineral water), an additional test must be conducted regarding any adverse effect on taste. In transporting chemical flow materials (not including gas or tap water), special consideration must be given to the appropriateness of PE with regard to the indicated media. The choice of the appropriate pipe series is fundamentally linked to a consideration of stress reduction factors. Black coloured PE pipes are storable in central European climate zones for 25 years.

4.6 The polyethylene (PE) mark

The continuous development and improvement of plastic also influences its mechanical properties and variables. These are continuously improved due to years of practical experience, as well as efforts in the research departments of pipe manufacturers in improving the capacity of plastic. Improvements in the mechanical properties of the polyolefin used in plastic pipe construction primarily involve PE compounds.
Associated with changes in material characteristics are corresponding changes in material designations. In plastic pipe construction, reference is no longer made to PE-HD but to the PE types PE63, PE80 and PE100.
It must, however, be noted that only PE100 is, in fact, used in this field. The digits indicate the long-term stability of the material, a conventional practice in labelling metal materials. The long-term stability for PE100 is calculated as follows: σ_{ref} = 100/10 = 10 MPa = 10 N/mm^2 and applies to situations where the flow medium is water at 20°C and the load period 50 years. Both German and European standards incorporate the new PE types by adopting the following classification:

- PE63 -> MRS 6,3
- PE80 -> MRS 8,0
- PE100 -> MRS 10,0

Since PE63 has smaller creep strength than PE80 and PE100, it has only limited applications in pressure pipe systems. In terms of strength values, PE80 largely corresponds to PE-HD with partial improvements of material properties.
Due to its greater strength, the use of PE100 is increasingly more common in pipe construction, especially in areas involving high pressure. Initial suspicions with regard to welding have been dispelled, so that manufacturers and contractors can widely benefit from the advantages of PE100.

Standards and application guidelines have been updated so that any impediments in them no longer exist. The new bimodular types of PE80 and PE100 demonstrate, in addition to improvements in strength properties, greater resilience than PE-HD, a quality improvement that yields the following benefits:

- greater creep strength at higher temperatures
- greater resistance to rapid crack growth
- reduced susceptibility to notching

In terms of the service life of the bimodular types, evidence to support assuming it to be 100 years is provided by the standard extrapolation method specified in ISO/TR 9080. Based on years of positive experience, the minimum safety factor (SF) has been established on 1.25 (gas pipe SF = 2.0). The creep rupture curve for calculating strength values can be derived from appendix A1. The important properties and variables of PE are discussed in chapter 2.

4.7 Load capacity of welded PE100 pipe and fittings

PE100 can be welded without restriction. Welding of PE100 onto PE80 components can also be performed unrestricted.
In case of application of welded fittings, a reduced pressure load made from pipe has to be taken in account. Please consult FIP S.p.A. about the internal pressure load capacity.

4.8 Wall thicknesses and acceptable internal pressure load capacity for PE100 pipes

		Wall thicknesses of PE100 pipes and fittings of the corresponding SDR series													
PE100 (SF = 1.25)	**MOP**	**40**	**(31.9)**	**25**	**20**	**16**	**12.5**	**10**	**(9.7)**	**8**	**(7.5)**	**6.3**	**5**	**4**	**3.2**
	ISO-S	**2**	**2.5**	**3.2**	**4**	**5**	**6.3**	**8**	**8.3**	**10**	**10.5**	**12.5**	**16**	**20**	**25**
	SDR	**5**	**6**	**7.4**	**9**	**11**	**13.6**	**17**	**17.6**	**21**	**22**	**26**	**33**	**41**	**51**
d_e		**Wall thickness (e) (mm)**													
10		2.0	1.8												
12		2.4	2.0	1.8											
16		3.3	2.7	2.2	1.8										
20		4.1	3.4	2.8	2.3	1.9	1.8								
25		5.1	4.2	3.5	2.8	2.3	1.9	1.8							
32		6.5	5.4	4.4	3.6	2.9	2.4	1.9	1.8						
40		8.1	6.7	5.5	4.5	3.7	3.0	2.4	2.3	1.9	1.9	1.8			
50		10.1	8.3	6.9	5.6	4.6	3.7	3.0	2.9	2.4	2.3	2.0	1.8		
63		12.7	10.5	8.6	7.1	5.8	4.7	3.8	3.6	3.0	2.9	2.5	2.0	1.8	
75		15.1	12.5	10.3	8.4	6.8	5.6	4.5	4.3	3.6	3.5	2.9	2.3	1.9	1.8
90		18.1	15.0	12.3	10.1	8.2	6.7	5.4	5.1	4.3	4.1	3.5	2.8	2.2	1.8
110		22.1	18.3	15.1	12.3	10.0	8.1	6.6	6.3	5.3	5.0	4.2	3.4	2.7	2.2
125		25.1	20.8	17.1	14.0	11.4	9.2	7.4	7.1	6.0	5.7	4.8	3.9	3.1	2.5
140		28.1	23.3	19.2	15.7	12.7	10.3	8.3	8.0	6.7	6.4	5.4	4.3	3.5	2.8
160		32.1	26.6	21.9	17.9	14.6	11.8	9.5	9.1	7.7	7.3	6.2	4.9	4.0	3.2
180		36.1	29.9	24.6	20.1	16.4	13.3	10.7	10.2	8.6	8.2	6.9	5.5	4.4	3.6
200		40.1	33.2	27.4	22.4	18.2	14.7	11.9	11.4	9.6	9.1	7.7	6.2	4.9	3.9
225		45.1	37.4	30.8	25.2	20.5	16.6	13.4	12.8	10.8	10.3	8.6	6.9	5.5	4.4
250		50.1	41.6	34.2	27.9	22.7	18.4	14.8	14.2	11.9	11.4	9.6	7.7	6.2	4.9
280		56.2	46.5	38.3	31.3	25.4	20.6	16.6	15.9	13.4	12.8	10.7	8.6	6.9	5.5
315		63.2	52.3	43.1	35.2	28.6	23.2	18.7	17.9	15.0	14.4	12.1	9.7	7.7	6.2
355			59.0	48.5	39.7	32.2	26.1	21.1	20.1	16.9	16.2	13.6	10.9	8.7	7.0
400			66.5	54.7	44.7	36.3	29.4	23.7	22.7	19.1	18.2	15.3	12.3	9.8	7.9
450				61.5	50.3	40.9	33.1	26.7	25.5	21.5	20.5	17.2	13.8	11.0	8.8
500				68.3	55.8	45.4	36.8	29.7	28.4	23.9	22.8	19.1	15.3	12.3	9.8
560					62.5	50.8	41.2	33.2	31.7	26.7	25.5	21.4	17.2	13.7	11.0
630						57.2	46.3	37.4	35.7	30.0	28.7	24.1	19.3	15.4	12.3
710						64.5	52.2	42.1	40.2	33.9	32.3	27.2	21.8	17.4	13.9
800							58.8	47.4	45.3	38.1	36.4	30.6	24.5	19.6	15.7
900							66.1	53.3	51.0	42.9	41.0	34.4	27.6	22.0	17.6
1000								59.3	56.7	47.7	45.5	38.2	30.6	24.5	19.6
1200									68.0	57.2	54.6	45.9	36.7	29.4	23.5
1400										66.7	63.7	53.5	42.9	34.4	27.4
1600												61.2	49.0	39.2	31.3

SF = Safety factor (valid for water at 20°C)

Table 4.3 Classification criteria for pressure pipes: PE100 / DIN 8074: 1999-08

Temperature (°C)	Years of service	SDR	51	41	33	26	22	21	17.6	17	13.6	11	9	7.4	6	5
		ISO-S	25	20	16	12.5	10.5	10	8.3	8	6.3	5	4	3.2	2.5	2
			Maximum operating pressure (bar)													
10	5		4.0	5.0	6.3	7.9	9.4	10.1	12.1	12.6	15.7	20.2	25.2	31.5	40.4	50.5
	10		3.9	4.9	6.2	7.8	9.3	9.9	11.9	12.4	15.5	19.8	24.8	31.0	39.7	49.6
	25		3.8	4.8	6.0	7.6	9.0	9.6	11.6	12.1	15.1	19.3	24.2	30.2	38.7	48.4
	50		3.8	4.7	5.9	7.5	8.9	9.5	11.4	11.9	14.8	19.0	23.8	29.7	38.0	47.6
	100		3.7	4.6	5.8	7.3	8.7	9.3	11.2	11.6	14.6	18.7	23.3	29.2	37.4	46.7
20	5		3.3	4.2	5.3	6.6	7.9	8.4	10.2	10.6	13.2	16.9	21.2	26.5	33.9	42.4
	10		3.3	4.1	5.2	6.5	7.8	8.3	10.0	10.4	13.0	16.6	20.8	26.0	33.3	41.6
	25		3.2	4.0	5.0	6.4	7.6	8.1	9.8	10.1	12.7	16.2	20.3	25.4	32.5	40.7
	50		3.2	4.0	5.0	6.3	7.5	8.0	9.6	10.0	12.5	16.0	20.0	25.0	32.0	40.0
	100		3.1	3.9	4.9	6.1	7.3	7.8	9.4	9.8	12.2	15.7	19.6	24.5	31.4	39.2
30	5		2.8	3.6	4.5	5.6	6.7	7.2	8.6	9.0	11.2	14.4	18.0	22.5	28.8	36.0
	10		2.8	3.5	4.4	5.5	6.6	7.0	8.5	8.8	11.0	14.1	17.7	22.1	28.3	35.4
	25		2.7	3.4	4.3	5.4	6.4	6.9	8.3	8.6	10.8	13.8	17.2	21.6	27.6	34.5
	50		2.7	3.3	4.2	5.3	6.3	6.7	8.1	8.4	10.6	13.5	16.9	21.2	27.1	33.9
40	5		2.4	3.0	3.8	4.8	5.8	6.1	7.4	7.7	9.6	12.3	15.4	19.3	24.7	30.9
	10		2.4	3.0	3.8	4.7	5.7	6.0	7.3	7.6	9.5	12.1	15.2	19.0	24.3	30.4
	25		2.3	2.9	3.7	4.6	5.5	5.9	7.1	7.4	9.2	11.8	14.8	18.5	23.7	29.7
	50		2.3	2.9	3.6	4.5	5.4	5.8	7.0	7.2	9.1	11.6	14.5	18.2	23.3	29.1
50	5		2.1	2.6	3.3	4.2	5.0	5.3	6.4	6.7	8.3	10.7	13.4	16.7	21.4	26.8
	10		2.0	2.6	3.2	4.0	4.8	5.2	6.2	6.5	8.1	10.4	13.0	16.2	20.3	26.0
	15		1.9	2.3	2.9	3.7	4.4	4.7	5.7	5.9	7.4	9.5	11.8	14.8	19.0	23.7
60	5		1.5	1.9	2.4	3.0	3.6	3.8	4.6	4.8	6.0	7.7	9.7	12.1	15.5	19.4
70	2		1.2	1.5	1.9	2.4	2.9	3.1	3.7	3.9	4.9	6.2	7.8	9.8	12.5	15.7

Table 4.4 Acceptable operating overpressures for pressure pipes: PE100 with SF = 1.25 (flow medium: water) / DIN 8074: 1999-08

Note to tables 4.3 and 4.4:
The stated values do not apply to pipes exposed to the effects of UV and pressureless drainage and sewerage pipes with maximum operating pressures <1 bar and are not included in the tables.

4.9 Chapter summary

European standards	prEN 15014 Pressure Drainage & Sewerage is the harmonised European standard for buried or aboveground pressure facilities for general purpose water, drainage, sewerage and irrigation, as well as for any other pressure applications involving other fluids. National standards have been revised in order to comply with European standards.
Minimum required strength (MRS)	The minimum required strength corresponds to the reference stress (σ_{ref}) of water at 20°C and a service life of 50 years.
Maximum operating pressure (MOP)	The internal pressure load capacity was formerly used to designate the nominal pressure "PN" of pipes and fittings. In the European standards, the designation has been abandoned and replaced by (SDR) or (ISO-S).
Standard dimension ratio (SDR)	The standard dimension ratio indicates the relationship of the pipe outside diameter to wall thickness.
Pipe series number (ISO-S)	The pipe series number (ISO-S) indicates the internal pressure load capacity of a pipe, while taking a safety factor into account.
Aggregate pipe coefficient (C)	The aggregate pipe coefficient (C) is a safety buffer (safety reserve) to allow for the additional loads that occur in pipe systems. It corresponds to the safety factor (SF). 1.25 for water and 2.0 for gas.
Safety factor (SF)	The safety factor (SF) corresponds to the aggregate pipe coefficient (C).
Welding property of PE100	Demonstrated by extensive research: no problems have been shown to arise in welding PE80 to PE100 pipe elements of identical SDR values. Welding can therefore be done without restriction.

5 Installation

5.1 Pre-requisites

Principle pre-requisites for a professionally designed pipe system are good technical knowledge coupled with many years of experience in application and production techniques. Customers now expect that both the engineering (planning) firm and construction company possesses the appropriate theoretical basis and the correspondingly qualified professional personnel. In addition, they must be able to offer an environmentally-friendly, low-maintenance, economical and long-lasting pipe system, features that a plastic system can provide.

5.2 General

The references to corresponding chapters of the Specification Manual indicated in the figures will serve as guides to passages in which the relevant subjects are discussed in detail and should facilitate the use of this Specification Manual in specific applications.

5.3 Classification criteria

In the project planning and installation of thermoplastic pipe systems, consideration must always be given to material-specific properties. The applicability of general principles to specific applications is only possible when material variables and behaviours display similarities (to the requirements of the given situation). In the age of the PC, modern computer programmes are used to design reliable pipe systems, and graphical planning occurs with the support of modern CAD applications. But these are not sufficient to guarantee the operational reliability of pipes, which still depends on the professional processing and use of plastic. The following instructions should be used, especially in planning, as a guide for the design and construction of PE pipe systems. A general distinction in the classification of plastic pipe systems is based on the method of installation. In general, there are three main groups, which are shown in figure 5.1.

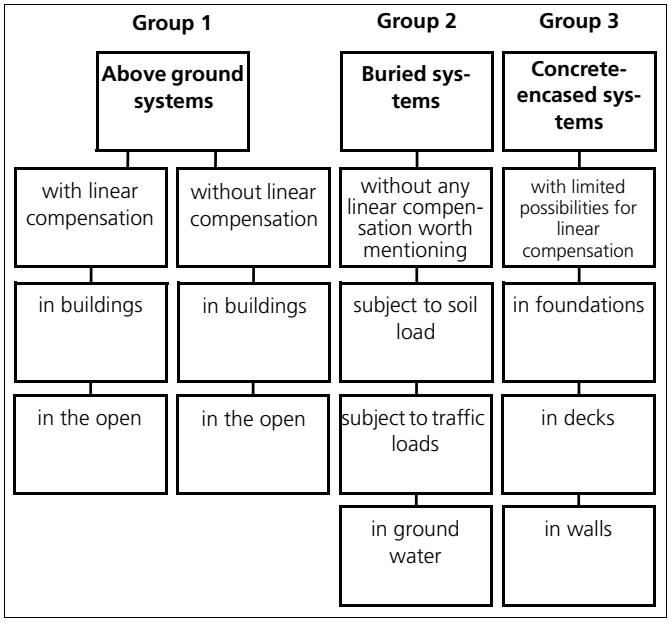


Figure 5.1 Pipe system applications

Group 1 consists of pipe systems with and without linear compensation. These systems require a bracket construction and are predominantly found in chemical or sewage plants, as well as in swimming pool construction. They generally require the largest project outlays. Planning aids and discernible influential factors for these pipe systems can be seen in figures 5.2 and 5.3.

Groups 2 pipe installations are exemplified by the parts of a communal water supply network. They are, however, also frequently used in the area of industrial waste water technology. Due to the flexibility of PE pipes, the costs of groundwork are lower than they are when laying steel, ductile iron or concrete pipes. PE also has distinctive advantages over less flexible plastic pipes (such as PVC). Planning aids and discernible influential factors are shown in figure 5.4.

Group 3 pipe systems constitute exceptional cases, especially as the accessibility for maintenance is limited. If possible, a pipeline should be installed according to the principles of groups 1 or 2, and direct integration into structures be reserved for open channels or discharge pipes, which are subject to lower stress. Planning aids and discernible influential factors are shown in figure 5.5.

5.4 Influence of operating conditions

The influence of pressure and temperature fluctuations depends on the individual system.
Since the possibility of thermal linear compensation is not always available, this limitation must be taken into account when calculating load effects. Stress due to internal pressure, bending, external loads, etc can collectively occur and make it necessary for the individual pipe system to be sized in a system-dependent manner.

5.5 Structural analysis

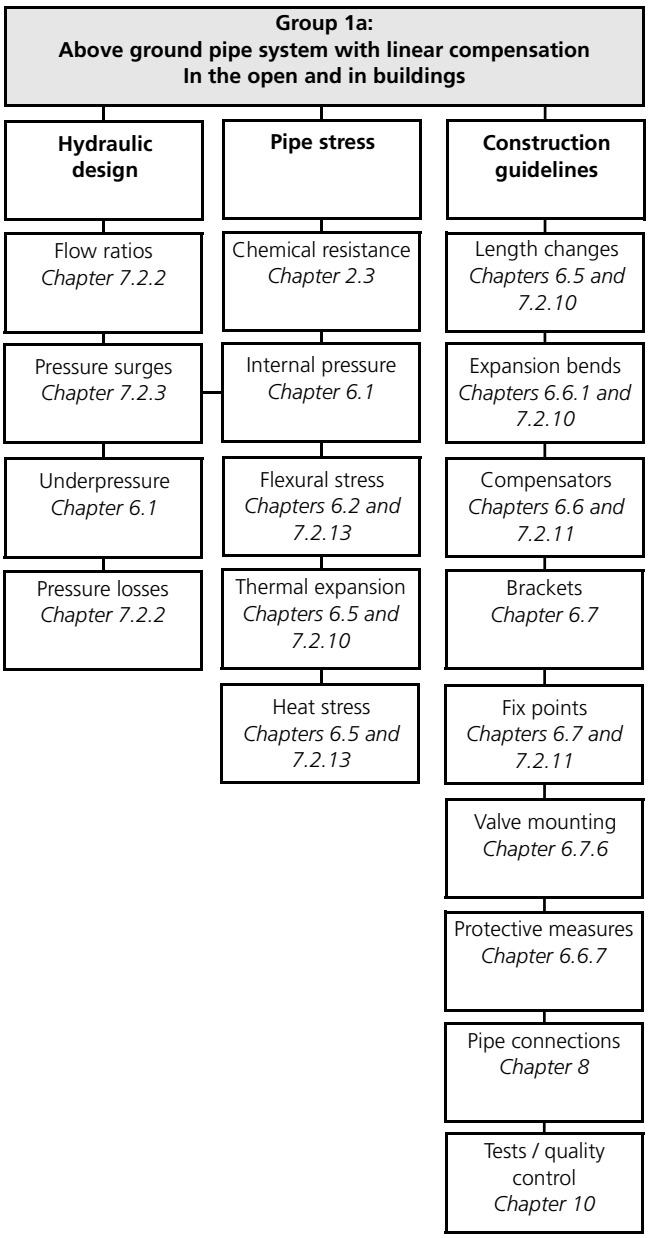
Depending on the nature of the load, various tests can be run on buried pipe systems. In one design, it is the stress and deformation calculation that is important. In another, it is a stability test. A summary of the relevant considerations in this respect is presented in chapters 5.5.1 and 5.5.2.

5.5.1 The stress and deformation calculation

Soil loads and traffic loads give rise to pipe cross-section tensile and compressive stresses. The extent of the stress is influenced by the elasticity of the pipe. In general, increasing the elasticity of the pipe will reduce tension. The testing for stress is therefore to be conducted while considering all inner and outer influential factors (e.g. soil stress, traffic load, water, ground water, chemical resistance internal over- or underpressure). The manner of embedding in the ground is particularly responsible for degrees of pipe deformation. The higher the compression ratio of the surrounding ground, the smaller the deformation. The requirement of locating the pipe zone in compactable soil is derived from this observation. The acceptable vertical deformation of a PE pipe is currently 6% and is based on the average pipe diameter. Stress and deformation calculations are always performed in parallel.

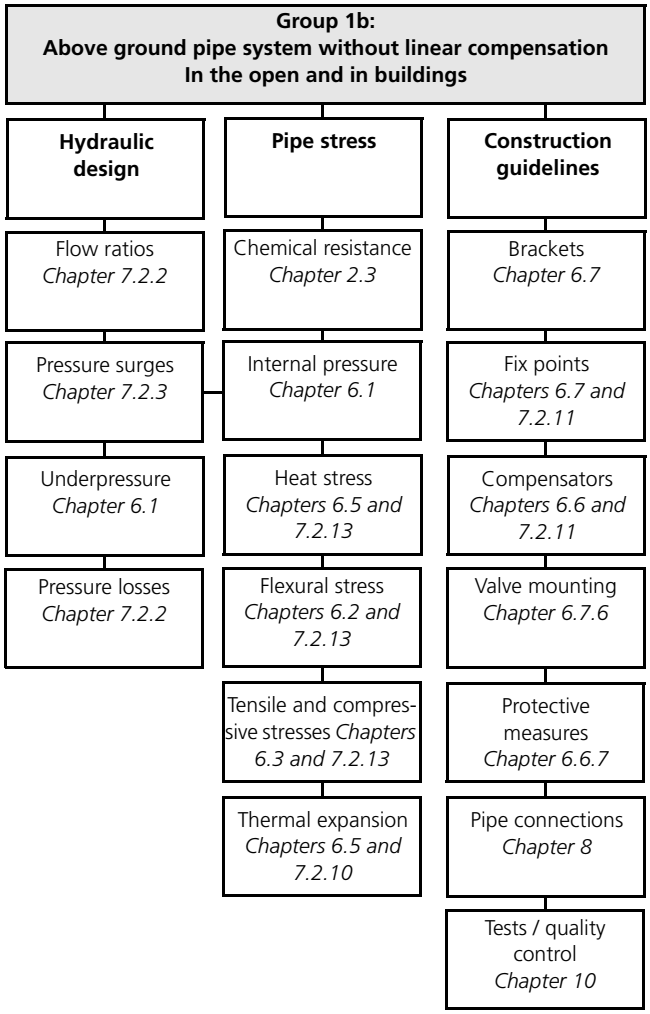
5.5.2 Stability test

In a PE pipe susceptible to deformation, exceeding a critical load will cause the pipe cross section to buckle. This occurs as a result of increased external (external overpressure due to the effects of groundwater, depth of the covering soil, etc) or internal (underpressure) stresses. The stability test is used to document the safety clearance between the critical and actually occurring load. Details and instructions for the calculation and the installation of the pipe systems are provided in the following chapter.



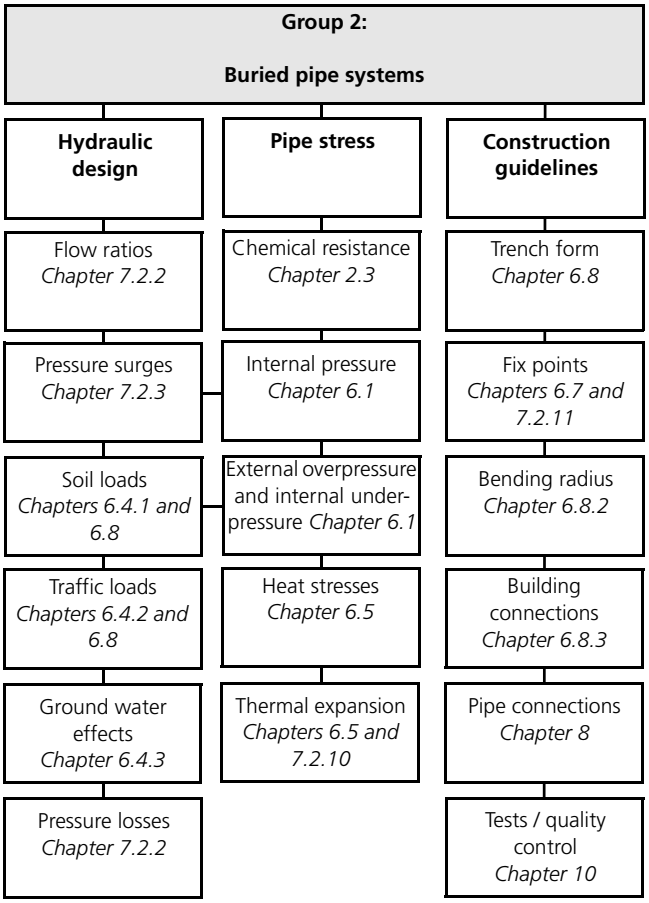
Pipe systems are usually installed so that the pipelines can elongate under the effects of heat. The latitude of movement can be provided by the installations own compensation elements (e.g. expansion bends and compensators) and by properly positioned sliding and guiding brackets. Special consideration needs to be given to ensure adherence to the acceptable support distances and the limiting of flexural loads in pipe bends and branches.

Figure 5.2 Above ground pipe systems with linear compensation



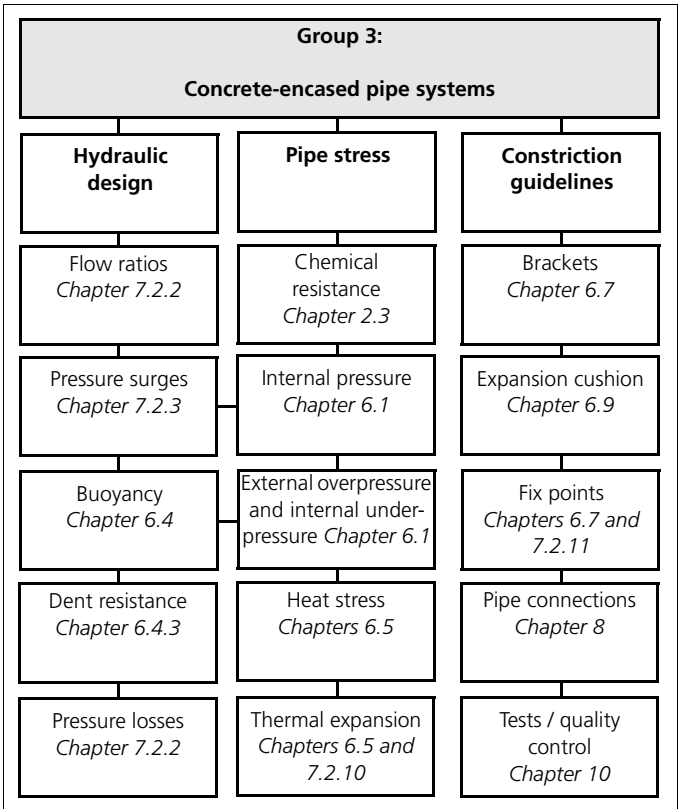
Pipe systems can also be installed without special thermal linear compensation. Pipe systems in which linear movement is impeded must pay special attention to the tensile and compressive stresses that occur, as well as to forces at fixed points. Exposed plastic pipes that are rigidly or firmly clamped (e.g. on a pipe bridge) can be exposed to large temperature variations. For this reason, calculations can be used in individual cases to test the expected stresses in order to determine if linear compensation can be excluded.

Figure 5.3 Above ground pipe systems without linear compensation



Buried pipe systems are subject to other load characteristics than above ground pipe systems. In designing pipelines, emphasis is placed on determining the largest possible load capacity of the pipe under the effects of external forces and the testing of stability.

Figure 5.4 Buried pipe systems



Pipe systems can also be installed so that an encasement in concrete walls, decks, foundations, etc is possible after completion of the installation. The concrete surrounding the pipe impedes length changes resulting from temperature fluctuations (e.g. due to the temperature of the flow medium or the effects of external temperature). Since no friction-type connection exists between the plastic pipe and the concrete, measures must be taken to protect individual pipe elements.

Figure 5.5 Concrete-encased pipe systems

6 Planning and construction guidelines and stress types

In principle, several internal and/or external stresses can affect a pipe system. This especially applies to buried pipe systems. Potential types of stress will be discussed below.

6.1 Internal and external pressure loads

In a pressure pipe system, principal stresses occur in various directions under the effects of compressive loads (internal and external overpressure, or internal underpressure). In principle, the below-listed types of stress can be distinguished:

- Radial stress (σ_r)
- Axial stress, longitudinal stress (σ_a)
- Tangential stress, circumferential stress (σ_t)

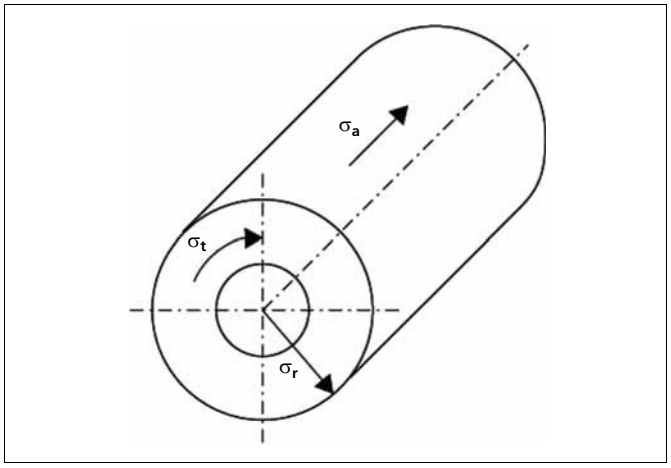


Figure 6.1 Stresses as function of the direction of their effects

The size of the respective stress can be calculated using the equations in chapter 7. The diagrams in appendix B are also aids for determining pressure load capacity.

6.1.1 Internal overpressure

An overload of a pressure pipe system due to internal overpressure results, especially in association with additional heat effects, to a continuous expansion of the pipe until it breaks.
The danger of an expansion arises as a result of too small wall thicknesses, in which an indiscriminate wall thickness increase is not justifiable. In the presence of heat expansion, a wall thickness enlargement also increases the reactive forces on the pipe fixed points. The engineer must ensure that the wall thickness is designed to meet requirements while the pipe remains elastic in response to any length changes that might arise. A sudden change in structural operating conditions due to internal pressure leads to pressure surges. The distinctive elasticity of the plastic pipe has the advantage that the extreme values of pressure waves are significantly lower than in steel pipes. Despite this fact, pipe systems operated by pumps or containing rapidly closing shut-off valves must be tested for any foreseeable effects of pressure surges.

6.1.2 Internal underpressure and/or external overpressure

Thin-walled pipes can dent as a result of internal underpressure or external overpressure, which is to say that they can lose their circular shape. To guard against possible instability, the critical dent pressure of a pipe must be calculated in relation to the standard dimension ratio. The critical dent pressure (ρ_{crit}) must display a safety factor SF = 2.0 against underpressure (according to ATV A 127, a safety factor of 2.0 to 2.5 is to be incorporated). In professional literature, the denotation "N" is used to designate the safety factor (SF).

6.2 Stress due to pipe deflection

Usually, deflection occurs in a pipe length as a result of the filled pipe's dead weight, including the weights of valves. The flexural stress resulting from a bend depends on the weight and span of the pipe between two support points.
In establishing support distances (LD) in compliance with appendix B4, the flexural stresses are so small that no overload or strain on the outer surface can occur. It must be noted that support distances have to be reduced when other components (e.g. valves) are present, or else additional support has to be provided. Especially notable are the significantly higher flexural stresses created by deformation of pipe branches and bends in connection with changes in direction.
Experienced has shown that, depending on the installation temperature and the standard dimension ratio, the bending of pipe strings that might predominantly occur in buried installations does not have any effect on the service life and operational reliability of the pipe. Temperature loads in a plastic pipe system affect strength values. Varying temperature loads can produce heat stresses if pipe expansion is restricted or prevented. Heat stresses are also created by temperature differences between the inner and outer wall of the pipe.

The stresses created by constricted conditions (e.g. impeded thermal expansion between two fixed points) are absorbed by the visco-elastic behaviour of the plastic pipe until a tension/expansion equilibrium is created. This process is also termed relaxation. Critical operating conditions arise when varying loads are involved, and the periods of high temperature grow longer than the periods of low temperature. In particular, tensile stresses with long-term effects can, after frequent load changes, result in fatigue fractures. Stress peaks occur when an initial temperature variation affects an installation condition. If the temperature level remains nearly constant over a longer period, the heat stresses are reduced by relaxation to level = 0.50% of the maximum value. Heat stress generated by a varying thermal load and tensile stress having a long-term relaxing effect can be calculated according to the equations in chapter 7.

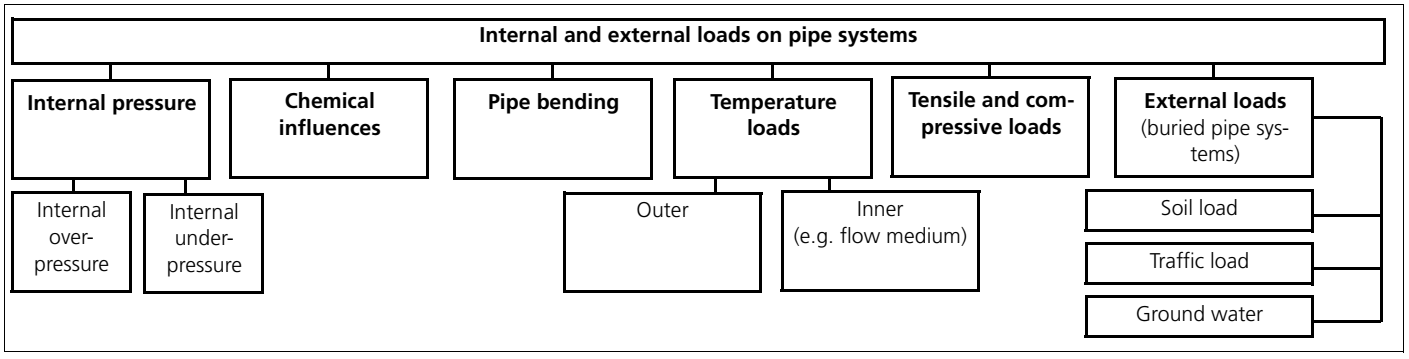


Figure 6.2 Internal and external loads on pipe systems

6.3 Tensile and compressive loads

As a result of differing thermal expansions in the inner and outer wall of a pipe, compressive stresses develop on the warmer side and tensile stresses on the colder side. At the same time, these stresses interact with the internal pressure. Stress values can be calculated using the equations in chapter 7. Compressive and tensile stresses do not only arise in connection with constricted thermal expansion but also due to the internal pressure itself. In particular, length changes related to short-term stress peaks can be observed in pressure tests involving increased internal pressure. It should also be noted that the effects of notches in the pipe wall are significantly strengthened by tensile loads.

6.4 Loads on buried pipe systems

6.4.1 Soil load

The bearing capacity of buried plastic pipes depends on the combined effects of pipe and soil. The top of the pipe is pressed down under soil load and the sides of the pipe are pushed out into the surrounding soil.
The reaction pressure that a lateral force exercises on the pipe causes a large cross-section deformation (support effect). The form of the trench, the nature of the pipe embedding and the backfill for the trench substantially determine the bearing capacity and stability of a buried plastic pipe system. The load must be evenly spread over the entire pipe length. It is also necessary to design pipe brackets that eliminate longitudinal bending and point loading. The acceptable installation depth (i.e. the bearable soil load (p_E)) is calculated using the following equation:

$$p_E = \gamma_B \cdot h$$

Equation 6.1

p_E = external soil pressure (kN/m^2)
γ_B = specific weight of the soil (kN/m^3)
(soil groups 1-3 -> γ_B = 20)
h = height of the soil layer above the top of the pipe

The acceptable installation depth (i.e. the bearable soil load) essentially depends on:
- pipe wall thickness
- pipe and soil stiffness
- form of the trench
- pipe embedding and trench backfill

6.4.2 Traffic load

Pressure dispersals resulting from traffic loads due to road and rail transport are assumed to be an evenly distributed surface load (p = surface load). The soil stress (p_{soil}) resulting from traffic loads is calculated in the following equation:

$$p_{soil} = a_F \cdot p_F$$

Equation 6.2

p_{soil} = soil stress (kN/m2) (acc. to ATV A 127, there designated "ρ")
a_F = correction factor for road-traffic loads (-)
p_F = soil stress resulting from traffic loads (kN/m^2)
(acc. to ATV A 127)

The stresses derived from the above-indicated equation are multiplied by a shock factor (φ), which takes the nature of traffic load into consideration.
Generally, the following shock factors are employed:
1.2 for SLW 60
1.4 for SLW 30 } road traffic
1.5 for SLW 12

Inserting the calculated stresses and corresponding shock factors in the following equation 6.3 yields the actual effective traffic load.

$$p_v = \varphi \cdot p_{soil}$$

Equation 6.3

p_{soil} = soil stress (kN/m^2) (acc. to ATV A 127)
φ = shock factor for road-traffic loads (-)
p_v = soil stress resulting from traffic loads (kN/m^2)
(acc. to ATV A 127)

For pipes under railways, the following applies:
$\varphi = 1.4 - (0.1 \cdot (H - 0.5)) \geq 1$
With burial depth ≥ 4.00 m, general experience indicates that all stress differences between dead soil load and percussive traffic load completely disappear. With diminishing burial depths, the influence of the traffic load above soil load grows larger. The minimum height of the soil layer H_{min} for railway traffic loads is:

$$H_{min} = 1{,}50\ m$$

Equation 6.4

Under certain conditions, a minimum soil layer $H_{min} \leq 1.50$ m make it necessary to invoke special measures (e.g. use of protective pipe). The guidelines from Bahn AG are to be observed when manufacturing railway crossings. The vertical aggregate stress on buried pipes is composed of both soil and traffic loads. The horizontal stresses produced by traffic load can be ignored.

6.4.3 Ground water

Buried pipes can be exposed to external overpressure (this especially applies to areas with high ground-water tables). Similarly, a pipe encased in concrete, if only for a short time, is subject to an external pressure. A dent resistance test is required for buried pipe systems that are burdened by additional external pressure.
The effects of the external pressure load correspond to the hydrostatic pressure on the pipe axis.

$$p_w = \gamma_W \cdot \left(h_W + \frac{d_e}{2}\right)$$

Equation 6.5

p_w = external water pressure (bar)
γ_w = specific weight of the fluid (for water = 1.00) (kN/m^3)
h_w = height of the water column above the top of the pipe

The critical dent pressure (p_K) of a circular PE pipe as a result of water pressure is:

$$p_k = \frac{2 \cdot E_{C_R}}{1 - \mu^2} \cdot \left(\frac{e}{d_e}\right)^3 \cdot 10$$

Equation 6.6

E_{CR} = creep modulus for the pipe material as a factor of temperature and load period (N/mm^2)
e = pipe wall thickness (mm)
d_e = outside diameter of the pipe (mm)
p_k = critical dent pressure (bar)
μ = transverse contraction value (for PE μ = 0.38-0.40) (-)

The safety factor (SF ≥ 2.0) usually used in the stability test (according to ATV A 127, a security factor designated there as "N" of 2.0 to 2.5 is to be taken into account) makes it necessary to undertake the following verification:

$$p_{W_{acc}} \leq \frac{p_k}{SF}$$

Equation 6.7

$p_{w\ acc}$ = acceptable external water pressure (bar)
p = critical dent pressure (bar)
SF = safety factor (-)

Note:
The soil surrounding a buried pipe has a supporting effect. It is therefore possible to derive support factors that enable the critical and, consequently, the acceptable external pressures to be increased. Technical literature provides the support factor values indicated in table 6.1.

Nominal pressure	Support factors fsup (-)	
(bar)	with compaction	without compaction
SDR 17	2.3	1
SDR 11	1.2	1

Table 6.1 Support factors for buried pipe systems

Appendix B11 can be consulted to roughly estimate the external pressure stability.

Example applying appendix B11
Invoking three examples, we can clarify the use of appendix B11 for potential pressure loads created by external overpressure or internal underpressure.

Case 1: External overpressure alone
Operating conditions:
Material: PE100, SDR 11
Operating temperature: 25°C
Internal underpressure (p_u) 0 bar (no underpressure)

Result:
Maximum pressure load ($p_{ex\ tot}$) from external overpressure (p_{ex}) (maximum height of the water column (h_w) above the top of the pipe) and no underpressure (p_u) in the pipe system:

Read from appendix B11:
$p_{ex\ tot}$ = 1.0 bar à 10 mWs
-> $p_{ex\ tot}$ = p_{ex} + p_u
-> p_{ex} = $p_{ex\ tot}$ - p_u = 1.0 bar - 0 bar = 1.0 bar
à p_{ex} = $p_{ex\ tot}$ = 1.0 bar

Case 2: Internal underpressure alone
Operating conditions:
Material: PE100, SDR 11
Operating temperature (T_{O1}): 25°C
Operating temperature (T_{O2}): 50°C
External over pressure (p_{ex}): 0 bar (no external overpressure)

Result:
Maximum pressure load (pex tot) from internal underpressure (pu) and no outside overpressure (pex):

Read from appendix B11:
for T_{O1} = $p_{ex\ tot1}$ = 1.0 bar
for T_{O2} = $p_{ex\ tot2}$ = 0.6 bar

For T_{O1}, the following holds:
-> $p_{ex\ tot1}$ = p_{ex} + p_u
-> p_u = $p_{ex\ tot1}$ - pex = 1.0 bar - 0 bar = 1.0 bar
-> p = $p_{ex\ tot1}$ = 1.0 bar
-> The selected pipe system is vacuum stable.

For T_{O2}, the following holds:
-> $p_{ex\ tot2}$ = p_{ex} + p_u
-> p = $\rho_{ex\ tot2}$ - p = 0.5 bar - 0 bar = 0.5 bar
-> p_u = p_{tot2} = 0.6 bar
-> p_{atm} = 1 bar ; p_{abs} = p_{atm} - p_u = 1 bar - 0.6 bar
= 0.4 bar absolute pressure
-> The selected pipe system is not vacuum stable under these operatingconditions, as $\rho_{u\ max}$ = 0.6 bar!

Case 3: Internal underpressure and external overpressure
Operating conditions:
Material: PE100, SDR 11
Operating temperature (T_{O1}): 25°C
Operating temperature (T_{O2}): 50°C
Maximum water column above the top of the pipe = p_{ex}: 7 m
Maximum underpressure (p_u) in pipe system: 0.2 bar

Result:
Maximum pressure load ($p_{ex\ tot}$) from external overpressure (p_{ex}) (maximum height of the water column (h_w) above the top of the pipe) and internal underpressure (p_u) in the pipe system:

Read from appendix B11:
for T_{O1} = p_{tot1}= 1.0 bar
for T_{O2} = p_{tot2}= 0.6 bar

For T_{O1}, the following holds:
-> p_{tot} = p_{ex} + p_u
-> $p_{ex\ tot}$ = p_{ex} + p_u = 0.7 bar + 0.2 bar = 0.9 bar
-> $p_{ex\ tot}$ = $p_{ex\ tot\ 1}$
-> selected pipe is suitable!

For T_{O2} , the following holds:
-> $p_{ex\ tot}$ = p_{ex} + p_u
-> $p_{ex\ tot}$ = p_{ex} + p_u = 0.7 bar + 0.2 bar = 0.9 bar
-> p_{ex} = $p_{ex\ tot2}$
-> Since $p_{ex\ tot}$ > $p_{ex\ tot2}$, the total pressure load for the pipe system selected in the example is too large, which means that the selected pipe is unsuitable for this load.

T_O = operating temperature (°C)
T_{O1}, T_{O2} = selected operating temperature (°C)
p_{ex} = external over pressure (bar)
p_{abs} = absolute pressure (bar)
p_{atm} = atmospheric pressure ≈ 1 bar (bar)
$p_{ex\ max}$ = maximum external overpressure (bar)
p_u = internal underpressure (bar)
$p_{u\ max}$ = maximum internal underpressure (bar)
$p_{ex\ tot}$ = pressure difference between external overpressure and internal underpressure (bar)
$p_{ex\ tot1}$ = pressure load read from appendix B11 for t_{O1} (bar)
$p_{ex\ tot2}$ = pressure load read from appendix B11 for t_{O2} (bar)
h_w = height of the water column above the top of the pipe (m)

6.4.4 Superposition of loads

According to appendix B11, the simultaneous effects of soil pressure and external water pressure can reduce additional load values.
In practice, the superposition of several internal and external influences can occur and have adverse effects on a pipe system. This means that, besides external loads, internal loads arising from internal pressure and/or impeded thermal expansion can affect the pipe system. In addition, buoyancy in ground water can cause flexural stress along the pipe axis.
The multiplicity of superposed loads requires careful and extensive planning of buried plastic pipe systems.

6.4.5 Structural analysis

Buried pipe systems must be regarded as special cases on account of their external loads.
They always require a differentiated analysis based on the installation guideline ATV A127. Most equations and data on the preceding pages

are established on the basis of this ATV guideline. A generalisation of the calculation methods is not possible due to the extent of the factors involved, making it necessary to abandon any simple overview of the equations.

6.5 Causes of length change

Plastic pipe systems are subject to discernible length changes even under small temperature variations on account of their high thermal length expansion coefficient (α_ϑ). As a result, the pipe system is constantly in motion in order to compensate for any temperature differences that arise. Length changes and associated linear expansions in pressure pipe systems mostly occur due to the superposition of several influential factors. The largest role in this regard is played by the additional occurrence of internal pressure loads.

6.5.1 Length change due to internal pressure load

Consideration must be given to pressure tests on pipe systems in which the test pressure can be 1.5 times larger than the nominal pressure. Test and/or operating pressures create axial stresses in the pipe that can result in longitudinal deformation on account of the low creep modulus of thermoplastics. The actual length change will often turn out to be smaller than the mathematically calculated one, since the expansion of the pipe system is impeded by friction. This difference is, however, irrelevant to the mathematical analysis of length changes and their effects.

6.5.2 Length change due to chemical effects

Besides the frequently mentioned good to very good resistance of polyolefin to a large number of chemicals, there are cases when chemical interaction is to be anticipated. In such cases, the appropriateness of the pipe material should be tested on the expected chemicals to be transported early in the planning stage. Various chemicals can cause length changes in pipe systems. Under certain circumstances, the chemicals being used can instigate swelling of the pipe or fitting. In such cases, the pipe wall absorbs more or less of the fluid contacting the pipe wall and consequently increases in volume. This expansion occurs both in a horizontal and in a radial direction to the pipe axis. The action of chemical compounds can, under certain conditions, result in reactions that have a detrimental effect on operating temperature. These temperature changes can subsequently produce thermal length changes that are unwanted and harmful to the pipe system.

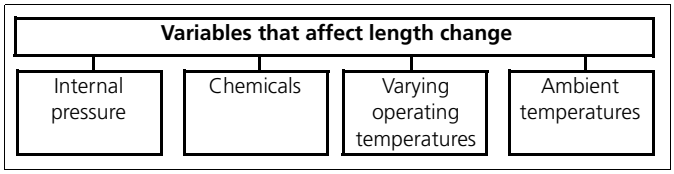


Figure 6.3 Variables that affect length change

6.5.3 Length change due to varying operating temperatures

In only considering the effects of operating temperature, it is possible to detect that the condition of the pipe changes after initial use in accordance with the operating temperature involved.
Decisive for the size of the length change is the temperature difference ($\Delta\vartheta$) that comes into effect. It is therefore advisable to test the effects of the length change at various operating temperatures at least once. After initial operation, a check should be made to see if the shifting of individual pipe lengths has damaged or might damage the pipe fixed points.

6.5.4 Length change due to ambient temperatures

Not only temperature differences of the medium but also outside temperature differences caused by changes between day and night as well as summer and winder periods are partly associated with large length changes. In particular, empty pipe systems exposed to solar radiation or the effects of frost must contain sufficiently designed compensation elements. The risk potential results from high flexural stresses in expansion bends and large forces on clamp positions (pipe fixed points).

6.6 Compensation for length changes

Plastic pipe systems are generally installed so that a compensation device absorbs any length change. There are also various design options, which will be dealt with in the following chapters.

6.6.1 Elbows

Usually, the site-specific pipe layout can be segmented by a given fixed-point design enabling length changes to be absorbed by pipe strings running at right angles to the direction of expansion.
This requires the smallest expenditure and the pipe system remains, in itself, closed.
The compensation pipe lengths created by this installation method have L, Z or U forms, or are geometrically interconnected with each other in the indicated forms.
Consideration has to be given to the fact that length changes in one pipe string lead to bends in others.
Since the resulting flexural stresses are transmitted to the expansion bend, it is recommended that these do not exceed the minimum length calculated in appendices B5 to B8.
The mathematical determination of expansion bends as compensation for length changes will be discussed in detail in chapters 7.2.10.

6.6.2 Compensators

If linear compensation by means of expansion bends is not or only partly possible, compensators must be incorporated in the system. These are also required at connection points with smaller load capacities, such as pump and tank supports.
In addition, compensators serve to reduce vibrations and their transmission to building structures. The design and construction of compensators is based on operating pressure and temperature.

- Axial compensators

Axial compensators are predominantly used to absorb length changes along the pipe axis. They can only absorb longitudinal forces by using tension bars, but not any transverse forces.

- Lateral compensators

Lateral compensators serve to absorb movement in both axial and transverse directions to the pipe axis. Since tension rods are involved in their construction, they constitute a force-locking element in the axial direction.

- Angular compensators

Angular compensators are also called lateral expansion joints. They provide suitable compensation for large length changes in both level and three-dimensional pipe systems. A length change is compensated in the expansion joint by bending pipe sections.

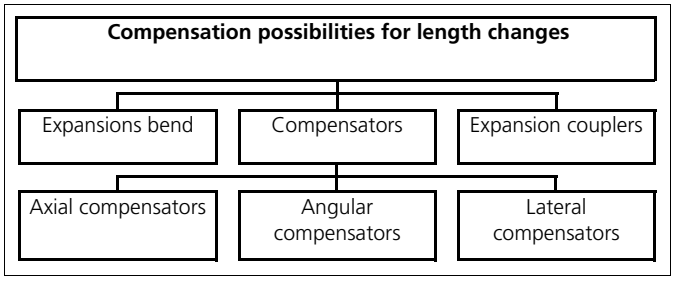


Figure 6.4 Length change compensation

- Forces in pipe lengths with compensators

Each length change in pipe systems generates a resistance of which the size is influenced by the nature of the compensation elements. The smaller that this resistance is, the smaller the reaction forces are and the larger the length change (Δl). The length change of the pipe causes the compensator to be pressed together or deformed and exercises, as a result, a reaction force.

The reaction force (= fixed point load) is composed of the deformation resistance of the compensator and the longitudinal force produced by the internal pressure, based on the effective cross-sectional area of the compensator.

The possibility cannot be excluded that the load on the fixed point is made larger by incorporating an compensator than it would be using expansion bends. In planning fixed point constructions, special attention should be paid to this fact.

- General remarks on compensators

The following rules need to be followed when making use of compensators:

- To function effectively, compensators must be mounted between two fixed points.
- The distance from one guide bracket (guide saddle) should not be any larger than 3x the pipe diameter.
- Only one compensator can be fitted between two fixed points.

6.6.3 Expansion couplers

Expansion couplers are suitable for absorbing axial length changes. Moreover, expansion couplers are only to be used in pipe systems in which no load produced by underpressure is to be expected (leakage in the sealing part of the coupler). If abrasive media are being transported (e.g. hydraulic transport of solids such as quartz sand water mixtures), FIP will certainly not be allowed to employ expansion couplers. Details on function, specifications and areas of application for expansion couplers can be found in chapter 8. By arranging guide brackets (guide saddles) in the immediate proximity of couplers, care needs to be taken to prevent the pipe from kinking on the side. The expansion coupler is not longitudinally force-locked and must also be installed between two fixed points. The resulting load on fixed points is smaller than the fixed-point that occur when compensators are used. A typical application for expansion couplers involves linear compensation in a rigid connecting piece between or more tanks.

6.7 Brackets

Brackets, also called pipe bearings, pipe saddles or pipe fixings, have the task of safely transferring all the loads arising in an pipe system to the building structure or infrastructure. Pre-requisite for the combined effects of pipes and brackets is the functional construction and design of the fixing elements. Examples of various arrangements of brackets in a pipe system are presented in figure 7.13.

6.7.1 Sliding and hanging brackets

Sliding and hanging brackets (sliding and hanging bracket saddles) can only absorb vertical forces and will only provide limited resistance to any operating movement. In incorporating sliding and hanging brackets, care must be taken that both longitudinal and a lateral movement of the pipe is given some play. The nature of this type of fixing is extremely susceptible to vibration, so their use in pipe systems powered by pumps is not recommended or only permissible along with guide brackets (guide saddles).

6.7.2 Guide brackets

Guide brackets (guide saddles) have to prevent any lateral deflection of the pipe. Due to their construction, they are therefore able to absorb transverse forces. The incorporation of guide brackets ensures that a pipe string cannot kink as a result of axial restraint.

6.7.3 Criteria for using brackets

The most important criteria for the correct application of brackets in a plastic pipe system are:

- If possible, pipes should be equipped at the bracket points with saddles. If there is no provision for the sliding of pipes in the saddles, plastic or rubber inserts can be used. The pipe may, however, not be crimped at the fixed point.
- If the pipe is to have the possibility of moving freely and uninhibitedly in brackets (saddles), the inside diameter of the bracket must be larger than the outside diameter of the pipe.
- Brackets may not be sharp-edged or linear. Point supports are also not acceptable.
- Pipes with large diameters are frequently equipped with saddle shaped supports. The angle of contact of the pipe must be at least 90°. At the same time, it must ensure suitable lift protection.
- The expansion of the pipe string must not be impeded by the bracket construction. The structure of the sliding surfaces must be corrosion resistant and offer sufficient room for shifting. Under certain circumstances, a final limit is provided.
- In a pipe installation without linear compensation (axially constricted), the acceptable support intervals (L_S) is, according to appendix B4, comparable with the critical buckling length $L_K = L_F$ (guide distance) indicated in appendix B10.

The smallest value indicated in this comparison is to be used as the actual value, which is $L_{act} = L_x$ (with $L_x \leq f\ (L_s, L_K, L_F)$. The acceptable fixing distance is:

$$L_{act} \leq L_K \text{ by which } L_K \leq L_F < L_A$$

Equation 6.8

This especially applies to pipes of small diameter.

- At positions in which the bracket distances must have very large designs for structural reasons, additional or movable supports (e.g. installation rails) must be provided. A support also serves to stabilise small pipes and prevent larger flexural deflections in pipe systems under constantly high operating temperatures. The support is connected to the pipe by means of a strap. Care must also be taken to ensure that , despite the additional supports, unimpeded sliding in brackets and/or expansion couplings can occur.
- If heat expansion gives rise to the danger of the pipe being lifted off its supports, or if vertically hanging brackets are attached to vertically inclined pipe sections, the inclusion of additional spring elements can be required (constant support).
- Sliding and hanging brackets (sliding and hanging bracket saddles) are provided if movement might occur in any direction. The pipe supported in this manner is however very susceptible to damage from vibration and must have a few intermediate brackets for cushioning effect.
- Concrete applications for sliding and hanging brackets (sliding and hanging bracket saddles) occur as fixed points involving expansion bends. Their design ensures that the acceptable support distances are not exceeded even in cases of large expansion bends.
- Radial guide brackets (guide saddles) are predominantly used with inclined pipes. They should be constructed In such a way that movements along the pipe axis are possible while the pipe axis is prevented from kinking. In addition, reaction forces due to vibrations of the radial guide brackets can be dissipated.

6.7.4 Fixed points

Fixed points will prevent shifting or movement of the pipe in any direction. They also serve to absorb reaction forces (e.g. when compensators or expansion couplers are used).

If a pipe system is constructed so that linear compensation cannot occur (axially constricted), the fixed-point design must be given special attention. The mathematical calculation of loads on fixed points will be discussed in chapter 7.2.11.

6.7.5 Principles for the layout and construction of fixed points

- Fixed points are to be arranged so that direction changes in the pipe route can be used to absorb length changes.
- They are also to be designed in considering all the loads that might arise. In addition to reaction forces from friction at bracket contact points and deformation of bends, large forces are produced by fixed restraints of pipe lengths.
- The pipe must have the appropriate retainer rings to transfer the forces to the construction of the fixed point. Insufficient consideration of the restraint of the pipe in the bracket alone will, in many cases, cause deformation of the pipe cross section or damage to the pipe surface.
- Fixing pipe systems at fixed points should, if possible, be done at low ambient temperatures, giving rise to predominantly compressive stresses when heated (operating state).
- If flange connections occur in pipe lengths between fixed points, tensile stresses can cause the joint pre-tension forces to decrease, resulting in leakage at the flange connections.
- In inclining pipe segments, fixed points are employed to absorb dead weight and dynamic loads. The design has to ensure that vertical length changes do not produce any unacceptable tensile loads on the horizontal connections.

6.7.6 Valve mounting

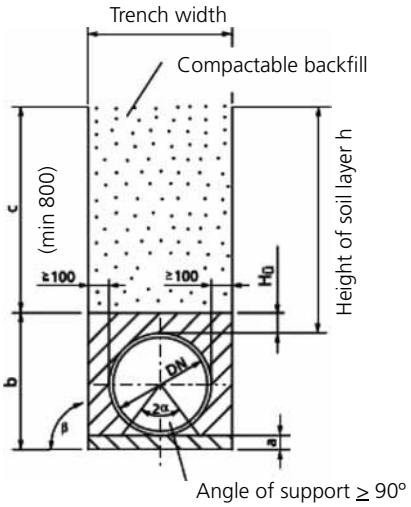
Locations in which valves or other heavy equipment encumber the pipe system have to be provided with an additional support structure. Supporting valves not only serves to bear weight but also prevents the transfer of large actuating forces to the pipe system.
The design features must be arranged to enable replacement of the valves without simultaneous disassembly of the entire fixing. If the valve mount corresponds to a fixed point, consideration must be given to the consequences of the restricted length change.

6.7.7 Protective measures

Protective measures for above ground pipe systems outside buildings (e.g. on pipe bridges) include insulation against loss of heat or cooling, concomitant heating and UV light blinding. Protected pipes are no longer exposed to extreme ambient temperatures that can result in such effects as a reduction in length change. In establishing the bracket distances in accordance with appendix A8 to A15, B4 and B10, it should be noted that the dead weight of the insulation will cause increased deflection. Protective measures can also be used to limit maximum pipe wall temperatures and therefore broaden the range of internal pressure loads for which the pipes are suitable. DVS 2210 Part 1 provides the following information on the UV stability of PE:
"Thermoplastic pipes treated with stabilising additives can be used in the open without any lasting effects from ultraviolet radiation (UV rays). Despite coating the thermoplastic with lightfast pigments, longer exposure to intensive UV light can cause discolouration (bleaching of the original colour). Reduced impact resistance is also not to be excluded."

6.8 Construction and installation of buried pipe systems (figure 6.5)

Following is based on German directions.



A = Pipe bed (in pipe zone)
100 mm for normal soil composition
150 mm on rocks or hard soils

B = Pipe zone with height of soil layer H_o

C= Backfill with a soil layer over the pipe zone that has a height of at least 800 mm

(stone-free sand, compacted)

Figure 6.5 Design of the trench

The height of the soil layer over the pipe is:
H_{min} (*) + H_{max} = mathematical calculation for the individual case in accordance with ATV guideline A 127.

(*) Note on H_{min}:
The KRV installation guideline for "pressure pipes" recommends that, in designing pipe trenches, all pipe elements are to be placed at a frost-free depth. Depending on the climate zone, the minimum height of the soil layer over the pipe must lie between 0.80 and 1.80 m. The standards for trench design are EN 1610, DIN 4124 and DIN 19630.

Trench bottom - Area a

The form and consistency of the trench bottom affects the mechanical properties of thermoplastic pipes. The already present or prepared bed must consist of stone-free sand and be easy to compact using appropriate equipment. The pipe must be laid so that a suitable supporting surface with an angle of at least 90° is formed. The depth of the trench can be calculated using equation 6.9, which is frequently employed in practice:

$$H_{Tr} = \text{minimum } 100 \text{ mm} + \frac{DN}{10}$$

Equation 6.9

H_{Tr} = depth of the trench (mm)
DN = Nominal diameter of the pipe (mm)

The above-cited equation 6.9 is given the same form in EN 1610. EN 1610 provides the following minimum values that, unless otherwise indicated, should not be exceeded:
- normal soil composition -> 100 mm
- rocks or hard soils -> 150 mm

Pipe embedding - Area b
The fill for the embedding of pipe systems must be stone-free soil, sand or similar material that must be capable of proper soil compaction. The embedding procedure significantly determines the soil pressure and soil-load distribution, as well as the formation of a stress-relieving, lateral soil pressure on the pipe.
The height of the embedding layer over the pipe (H_0) is:
H_0 = min. 150 mm over the top of the pipe and 100 mm over connecting elements (as stated in EN 1610)

Backfill - Area c
The backfilling and compacting of the trench occurs in layers. Soil types and materials that can result in settling at a later time may not be used to backfill the trench (e.g. ash, slag, stones). The compression ratio of backfill material is measure in %Proctor ($\%D_{pr}$). The use of heavy compacting or compression equipment for soil compaction is not permitted when the soil layer over the pipe is <1.0 m.

6.8.1 Construction principles
The design (i.e. the form of the trench), the backfill and the corresponding compaction of materials have important effects on the service life of plastic pipe systems.
The following construction principles should therefore be observed:
- The pipe trench is shaped so that all pipe parts are covered by the prescribed soil layer.
- In laying plastic pipes on the prepared trench bottom and in subsequently embedding them, stones must be prevented from contacting the plastic pipe (danger of notching that leads to cracking).
- In rocky or stony subsoil, the trench bottom is to be excavated 0.15 m deeper and the additional excavation filled by a stone-free support layer.
- Sand and fine gravel (grit size <20 mm) are the most suitable materials for embedding pipes and compacting the pipe zone.
- All soil types occurring in nature are classified in DIN 18196 "Soil classification for construction purposes and methods of recognising soil groups". Soils are divided into:
  Group 1: non-cohesive coarse soils (sandy, gritty soils)
  Group 2: cohesive, fine soils (coarse clay, clay)
  Group 3: cohesive, fine and coarse mixed soils (cohesive sandy soils, gritty soils, cohesive stony weathered soils).
- The compactability of individual soils and, consequently, the quality of the compaction depend on the granulometric composition, the grain shape and water content. The method of compaction with regard to the equipment used is shown in table 6.2.
- Concrete or clay bar must, in certain circumstances, be incorporated in slopes in order to prevent the sandy pipe bed from being washed away. In some cases, drainage must be provided.
- In the case of bearing capacity changes of the trench bottom due to differing soil layers, a sufficiently long fine-gravel or sand fill is applied at the transitions.

The following instructions sheets are important for pipe trench design:
- DIN 4124 "Excavations and trenches"
- DIN 19630 "Guidelines for the construction of water pipes: DVGW Technical Regulations"
- EN 1610 "Laying and testing drainage pipes and canals: Dutch Version EN 1610:1997"

Type of equipment		Service weight (kg)	Soil group I Coarse (non-cohesive) Appropriate	Layer height (cm)	Number Trans.	Soil group II Fine (cohesive) Appropriate	Layer height (cm)	Number Trans.	Soil group III Mixed grained (cohesive) Appropriate	Layer height (cm)	Number Trans.
1. Light compacting equipment (predominantly for the pipe zone)											
Tamper	**light**	≤ 25	+	≤ 15	2 - 4	+	≤ 10	2 - 4	+	≤ 15	2 - 4
Frogrammer	**medium**	25 - 60	+	20 - 40	2 - 4	+	10 - 30	2 - 4	+	15 - 30	3 - 4
	light	≤ 100	o	20 - 30	3 - 4	+	20 - 30	3 - 5	+	15 - 25	3 - 5
Vibrating plate	**light**	≤ 100	+	≤ 20	3 - 5	-	-	-	o	≤ 15	4 - 6
Vibrating roller	**medium**	100 - 300	+	20 - 30	3 - 5	-	-	-	o	15 - 25	4 - 6
	light	≤ 600	+	20 - 30	4 - 6	-	-	-	o	15 - 25	5 - 6
2. Medium and heavy compacting equipment (above the pipe zone)											
Tamper	**medium**	25 - 60	+	20 - 40	2 - 4	+	10 - 30	2 - 4	+	15 - 30	2 - 4
	heavy	60 - 200	+	40 - 50	2 - 4	+	20 - 30	2 - 4	+	20 - 40	2 - 4
Frogrammer	**medium**	100 - 500	o	20 - 40	3 - 4	+	20 - 30	3 - 5	+	25 - 35	3 - 4
Vibrating plate	**heavy**	500	o	30 - 50	3 - 4	+	30 - 40	3 - 5	+	30 - 50	3 - 4
	medium	300 - 750	+	30 - 50	3 - 5	-	-	-	o	20 - 40	3 - 5
Vibrating roller	**heavy**	750	+	40 - 70	3 - 5	-	-	-	o	30 - 50	3 - 5
		600 - 8000	+	20 - 50	4 - 6	-	-	-	+	20 - 40	5 - 6

+ = recommended o = most suitable

Table 6.2 Type of compaction

* The above-stated data represents average performance data. In unfavourable conditions (e.g. high water content, sheet lining, the indicated layer heights have to be decreased, while they can be increased in especially favourable conditions. Precise values are only ascertained by means of trial compaction. If no trial compaction is run (except in cases involving steel and ductile iron pipes), only use the highest values for the layer heights indicated in the table.

6.8.2 Bending radius

Route direction changes can be followed by bending the pipe.
To avoid the risk of buckling and overstraining the outside surface, it is recommended that the minimum bending radius not be exceeded (table 6.3).

Material	Bending radius at various installation temperatures				
	ISO-S	SDR	0°C	10°C	20°C
PE100	8	17	50 x d_e	35 x d_e	20 x d_e
	5	11	50 x d_e	35 x d_e	20 x d_e

Table 6.3 Bending radius

Note to table 6.3:
The safety factor (SF) for the indicated SDR and ISO-S values of PE is 1.6. The bending radius at an installation temperature of 20°C were mathematically calculated. To calculate the bending radius at an installation temperature of 0°C, the mathematically calculated values for an installation temperature of 20°C were multiplied by a factor of 2.5. The bending radius at an installation temperature of 10°C were interpolated (mean values).

6.8.3 Building connections

When buried pipes connect to buildings, the possibility of settling has to be taken into account. The elastic plastic pipe, due to the deformation capacity zone (figure 6.6) over the length DZ (elbow length) ensures that no overload can occur in the area of settlement.

6.9 Principles of constructing and installing concrete-encased pipe systems

Plastic pipes encased in concrete after installation represent a special case. Their handling in connection with the technical application guidelines in for pressure pipes in this manual is therefore limited to important or critical details. The instructions may be applied to other similar circumstances.

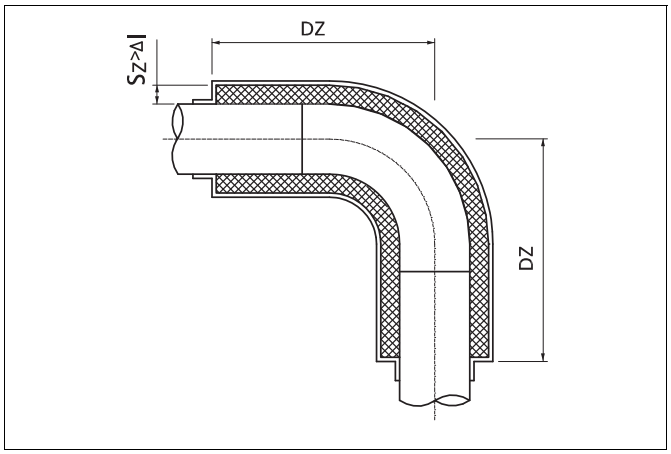


Figure 6.6 Expansion zones in pipe bends

6.9.1 Behaviour of pipe systems under temperature loads

Once a pipe system is encased in concrete, no movement can any longer occur. A pipe system without linear compensation is created, meaning that increased heat stresses have to be taken into account. Since no friction-lock connection is formed between the straight pipe and surrounding concrete, the fittings constitute fixed points and are correspondingly subjected to stress. In installing pipe systems, measures need to be taken to limit the load on the fittings. Examples of such practices are described below.

6.9.2 Load on pipe bend

If extreme temperature differences can arise, pipe bends have to be protected against overstress. For this purpose, an expansion zone using deformable material is incorporated. The chosen thickness of the expansion cushions must be at least as large as Δl. The length of the expansion zone corresponds to the dimensions of the expansion bends in appendices B5 to B8.

6.9.3 Load on tee

Due to varying temperatures, fittings are subject to surface pressure. This adverse load concentrates on tee sections, as additional shear forces are created at outgoing connections.

If a load limiting element is placed directly beside the fitting, an electrofusion coupler is the most suitable connection piece. The longitudinal force (force on a fixed point) (F_{Fp}) remains equally large, but the deformation due to the significantly smaller Δl is clearly less. Another option for protection against overloading is the incorporation of an expansion zone (expansion cushion).

6.9.4 Fixing pipe systems

In comparison with brackets, the installation of a concrete-encased pipe system does not require any special measures. The fixing during installation only serves as float protection and is to be regarded as provisional attachment prior to encasement with concrete.

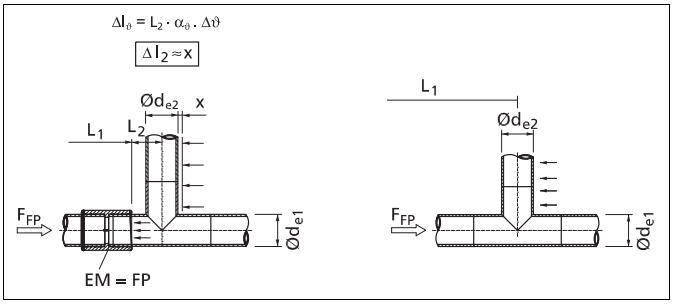


Figure 6.7 Shear and fixed-point forces on tees and 45° branches

6.10 Chapter summary

Internal pressure loads	Internal pressure loads create stresses in various directions. Radial stresses, axial stresses and tangential stresses can occur.
Internal overpressure	Internal overpressure can result in pipe expansion, especially under the effects of heat. Sudden changes in operation conditions can cause pressure surges.
Internal underpressure / external overpressure	Exposed to internal underpressure or external overpressure, a pipe will tend to buckle, which means it deviates for its ideal form (circular cross section). The critical buckle pressure should be calculated with regard to stability.
Pipe bending	Pipe bending is usually caused by the dead weight of the pipe and/or additionally incorporated valves and pipe fill. The relevant bracket distances (support distances) must therefore be determined and the suitable pipe brackets incorporated.
Temperature loads	Temperature loads have a very large effect on the mechanical properties of plastic pipe. Attention is first of all to be paid to the relatively large thermal length change.
Tensile and compressive stresses on the pipe wall	They are created during pipe manufacture due to differing cooling conditions. Compressive stresses arise in the outer wall of the pie (usually the first surface to cool) and tensile stresses on the warmer inner wall of the pipe.
Soil load	The soil layer on top of the pipe loads weight on the pipe and can cause it to deform. This load therefore has a significant effect on the pipe structure and the service life of the pipe.
Trench form, pipe embedding and backfill	Pipe trench design substantially influences the bearing capacity and stability of a pipe system, and therefore has a large influence on the service life of the system.
Traffic loads	Traffic loads are additional external loads that can affect the pipe system. They require special protective measures. If the prescribed minimum soil layer over the pipe is not maintained, protective pipes may have to be installed.
Railway traffic loads (railway crossings)	The installation guidelines from ProRAil are important for installation under railways and railway facilities as well as for railway crossings.
Ground water	Areas having a high ground water table can load external overpressure on the pipe system. The same holds true for concrete-encased pipe systems, which are exposed to short-term heightened overpressures. Both cases require the calculation of dent resistance.
Length change	The length change of a pipe system is caused by varying operating temperatures, varying ambient temperatures or internal pressure loads. Frequently, several of these influences are superposed.
Compensation for length changes	The inclusion of elbows, expansion couplers or compensators can compensate for length changes.
Elbow	Elbows (expansion bends) absorb length changes by moving laterally perpendicular to the expansion direction. Depending on structural and spatial conditions, they can be U, L or Z shaped.
Compensators	Compensators are used if other compensation options cannot or can only be partially applied. The design depends on operating pressure and temperature. Axial, lateral and angular compensators are used.
Expansion couplers	Expansion couplers are predominantly employed in pressureless systems as connection elements and compensation for length changes.
Brackets	Brackets have the task of transferring the effective loads on the pipe system to the building structure or infrastructure.
Sliding and hanging brackets (sliding and hanging bracket sleeves)	They are only able to absorb vertical forces.
Guide brackets (Guide saddles)	They serve to absorb both vertical and horizontal forces.
Fixed points	Fixed points in association with suitable bracket concepts prevent shifting or movement of pipe systems.
Valve fixing	Valve fixings not only serve as support for valves but prevent the transfer of reaction forces.
Protective measures for above ground pipe systems	They are used to improve the insulation properties of pipe systems. The use of concomitant heating is necessary in many cases. Protective measure may also be taken against UV radiation.
Bending radius	In bending pipe, certain bending radius should not be exceeded (table 6.3).
Building connections	Connections of building can be exposed to settling, which can be compensated by creating deformable zones.
Concrete-encased pipe systems	Concrete-encased pipe systems function as a fixed restraint. Fittings behave in concrete as fixed points and are therefore also subject to the same stresses, which means that any heat stresses must be absorbed and compensated for in the pipe system.

7 Basic calculations

7.1 Factors influencing pipe system design

Type of influence	Short symbol	Unit
Outside diameter	d_e	mm
Inside diameter	d_i	mm
Internal pressure	p_i	bar
External pressure	p_{ex}	bar
Underpressure	p_u	bar
Reference stress	σ_{ref}	N/mm^2
Creep modulus	E_{cR}	N/mm^2
Operating temperatures		
Lowest operating temperature	$T_{i\,min}$	°C
Highest operating temperature	$T_{i\,max}$	°C
Highest ambient temperature	$T_{a\,max}$	°C
Average installation temperature	T_{ins}	°C
Safety factor		
for load class I = 1.3	S	
for load class II = 1.8	S	
for load class III = 2.0	S	
for stability N = 2.0	S	
Calculated pipe wall temperature		
$T_W = 0{,}9 \cdot T_{Flow\ medium}$	$T_{W\,min}$ $T_{W\,max}$	°C
Maximum occurring temperature difference		
max $\Delta\vartheta = T_u - T_i$ T_0 = upper maximum value T_u = lower maximum value	$\Delta\vartheta$	K
Load period:		
Load h/a (= hours per annum)		
for min T_w	-	h/a
for max T_w	-	h/a
for ρ_i	-	h/a
for ρ_a	-	h/a
Calculated service life for calculation of creep strength	t_{SL} t_{SL}	h a
Reduction factors		
Time dependence (if applying appendix A1, this factor has already been taken into account)	A_1	-
Reduction factor (influence of ambient medium) according to DVS 2205 - Part 1	A_2	-
Reduction factor Temperature dependence (if applying appendix A1, this factor has already been taken into account!)	A_3	-
Reduction factor (influence of specific resilience) DVS 2205 - Part 1 (*See table 7.12)*	A_4	-
Flow medium		
Pressure loss per m pipe	Δp	bar/m
Flow velocity	w	m/s
Flow volume	$\dot{V}$	m^3/h
Pressure Surge	p_{surge}	
Welding factors		
Short-term welding factor	f_s	-
Long-term welding factor	f_l	-
(The abbreviations f_s and f_l indicated here have been freely chosen by FIP. In the DVS 2205 Part 1 guideline they are shown as f_z (short-term welding factor) and f_l (long-term welding factor)!		
Connection method		
- *detachable connection*		
- unions		
- couplings		
- plug-in connections		
- flange connections		
- compression connections		
- *permanently attached connections*		
- welding		
o electrofusion	EF	
o butt-welding	BW	
o hot gas extrusion welding	HE	
o hot gas hand welding	HW	
o hot gas speed welding	HR	
Types of installation		
- above ground with linear compensation	☐	
- above ground without linear compensation	☐	
- concrete encased	☐	
- buried	☐	
- installation in the open	☐	
- installation in buildings	☐	
Additional influences		

Table 7.1

The listed data is meant to guide compilation of important data and variables important for the construction of a pipe installation.

Note:
The listed mathematical operations and relations have been simplified as much as possible. Plastic-specific parameters and generally valid factors are partly already integrated into calculation formulae. We have abstained from detailing the derivation or reproduction of single values to abbreviate this section.

7.2 Calculating pipe parameters

7.2.1 Explanation

The calculation of thermoplastic pipe systems is especially important for the engineer undertaking a project. This chapter presents the basic principles required for designing plastic pipe systems. However, the practitioner (user) should also be able to acquire the necessary data and standard variables for internally pressure-loaded pipe in a relatively simple manner without spending a lot of time. The mathematical operations are supported by diagrams in the appendices from which most values and data can be read off. Thermoplastic pipe calculations basically occur on the basis of long-term values. The reference stress (σ_{ref}) and mechanical (creep) strength (i.e. creep modulus (E_{cR})) of a pipe system in relation to temperature can be derived from the creep diagram in appendix A1 and the creep modulus curve diagram in appendix A2. The creep rupture curves are based on internal pressure tests on pipe samples filled with water and represent minimum values. If pipe systems are not intended for water but for other flow media, their effects on creep strength properties must be given special consideration.

7.2.2 Hydraulic principles

- Calculating flow velocity

$$w = 354 \frac{\dot{V}'}{d_i^2} \quad resp. \quad w = 1275 \cdot \frac{\dot{V}''}{d_i^2}$$

Equation 7.1

d_i = inside diameter -> $d_s = d_e - 2 \cdot e$ (mm)
$\dot{V}'$ = flow volume (flow rate) (m^3/h)
$\dot{V}''$ = flow volume (flow rate) (l/s)
w = flow velocity (m/s)
Standard values for fluids:
w ≈ 0.5 - 1.0 m/s -> intake side
w ≈ 1.0 - 3.0 m/s -> pressure side

- Calculating the flow volume

The required pipe size is derived from the flow velocity of the medium and the clear cross-section of the pipe. The flow rate of fluids is calculated as follows:

$$\dot{V} = A \cdot w = const.$$
$$A = \frac{d_i^2 \cdot \pi}{4} \qquad d_i = d_e - 2 \cdot e$$

Equation 7.2

d_i = inside diameter of the pipe (mm)
d_e = outside diameter of the pipe (mm)
e = pipe wall thickness (mm)
A = cross-sectional area of flow channel (mm^2)
w = flow velocity (m/s)
$\dot{V}$ = flow volume (m^3/h, l/s)

- Calculating the inside diameter of the pipe

If the flow rate (flow volume) is known and the constants in the above-stated equations have been compiled, this yields a conventionally-sued formula for calculating the inside diameter of the pipe:

$$d_i = 18{,}8 \cdot \sqrt{\frac{\dot{V}'}{w}} \quad resp. \quad d_i = 35{,}7 \cdot \sqrt{\frac{\dot{V}''}{w}}$$

Equation 7.3

d_i = inside diameter of the pipe (mm)
w = flow velocity (m/s)
V' = flow volume (m^3/h)
V'' = flow volume (l/s)

The tomogram presented in the appendix A16 (along with the associated tables A16a, A16b and A16c) can be used to directly calculate the appropriate dimensions.

- Calculating the Reynolds number (Re)

The Reynolds number (Re) indicates the relationship of the inert forces affecting the flow particles to the forces of viscosity. The Reynolds number is dimensionless and is calculated as follows:

$$Re = \frac{w \cdot d_i}{10^3 \cdot \nu}$$

Equation 7.4

Re = Reynolds number (-)
ν = kinematic viscosity (m^2/s)
w = flow velocity (m/s)
d_i = inside diameter of the pipe (mm)

- Determining the pipe friction number (λ_P)

The dimensionless pipe friction number (λ_P) is required to calculate the hydraulic loss in the pipe. For laminar flows (Re < 2320) in circular cross-sections, the following holds:

$$\lambda_P = \frac{64}{Re}$$

Equation 7.5

Re = Reynolds number (-)
λ_P = pipe friction number (-)

In most cases, turbulent flows are created in pipes (Re > 2320).
The pipe friction number (λ_P) for turbulent flows can be determined with the aid of appendix A3. The pipe roughness value (k), which is crucial for the calculation, can be considered to be 0.01. In practice, $\lambda_P = 0.02$ can be used to make rough estimates of hydraulic loss.

- Equivalent pipe length

$$L_{tot} = L_{Pipe} + L_{Fitting} + L_{Valve}$$

Equation 7.6

$$L_{Pipe} = \text{total pipe length (straight pipe)}$$
$$L_{Fitting} = \frac{d_i}{10^3} \cdot \Sigma \xi_F$$
$$L_{Valve} = \frac{d_i}{10^3 \cdot \lambda_P} \cdot \Sigma \xi_A$$

Equation 7.7

L_{tot} = total pipe length (m)
ΣL_{Pipe} = sum of all pipe lengths in the system (m)
$\Sigma L_{Fitting}$ = sum of all fitting lengths in the system (m)
ΣL_{Valve} = sum of all valve lengths in the system (m)
d_i = inside diameter of the pipe (mm)
λ_P = pipe friction number (-)
$\Sigma \zeta_F$ = sum of the individual resistances of fittings (-)
$\Sigma \zeta_A$ = sum of the individual resistances of valves (-)

An exact indication of pressure loss at connections (welding joints, flange connections, unions) is not possible because the nature and manner of the connections vary. An overall addition of 10% to the calculated total loss would appear to be appropriate.

- Calculating total pressure loss

In calculating the total pressure loss, the sum of the respective individual pressure losses must be computed. The sum of the individual pressure losses is calculated by:

$$\Delta p_{tot} = \Sigma \Delta p_{RP} + \Sigma \Delta p_{RF} + \Sigma \Delta p_{RV} + \Sigma \Delta p_{RC}$$

Equation 7.8

$\Sigma \Delta p_{tot}$ = sum of the individual losses (bar)
$\Sigma \Delta p_{RP}$ = sum of the pressure losses in straight pipe lengths (bar)
$\Sigma \Delta p_{RF}$ = sum of the pressure losses in fittings (bar)
$\Sigma \Delta p_{RV}$ = sum of the pressure losses in valves (bar)
$\Sigma \Delta p_{RC}$ = sum of the pressure losses in connections (bar)

- Pressure loss in straight pipe sections
The pressure loss in straight pipe sections is calculated using the following equation:

$$\Delta p_{RP} = \lambda_R \cdot \frac{L_P}{d_i} \cdot \frac{\rho_F}{2 \cdot 10^2} \cdot w^2$$

Equation 7.9

$\Delta\rho_{RP}$ = pressure loss in individual pipe sections (bar)
λ_R = pipe friction number (-)
L_P = length of the pipe sections (m)
d_i = inside diameter of the pipe (mm)
ρ_F = density of the flow (kg/m^3)
w = flow velocity (m/s)

- Pressure loss in pipe fittings
Given that substantial losses result from friction, changes of direction and transfer loss, these individual losses represent a significant portion of the total pressure loss in a pipe system. The pressure loss is calculated with the following formula:

$$\Delta\rho_{RF} = \zeta_{RF} \cdot \frac{\rho_F}{2 \cdot 10^5} \cdot w^2$$

Equation 7.10

$\Delta\rho_{RF}$ = pressure loss in individual pipe fittings (bar)
ρ_F = density of the flow (kg/m^3)
w = flow velocity (m/s)
ζ_{RF} = resistance factors for pipe fittings (-)

The resistance factors for fittings will be identified in tables 7.2 to 7.7.

- Pressure loss in pipe connections
Pressure loss also occurs in pipe connections, although it cannot be precisely characterised, as the geometric dimensions vary a great deal (e.g. welding beads). DVS 2210 Part 1 recommends basing pressure loss calculations for connections in plastic pipe systems (such as butt, sleeve and flange joints) on a resistance factor of ζ_{RF} = 0.1 (-) . For pressures losses in connections, this means:

$$\Delta\rho_{RC} = \zeta_{RC} \cdot \frac{\rho_F}{2 \cdot 10^5} \cdot w^2$$

Equation 7.11

$\Delta\rho_{RC}$ = pressure loss in connections (bar)
ρ_F = density of the flow (kg/m^3)
w = flow velocity (m/s)
ζ_{RC} = resistance factor for pipe connections = 0.1 (-)

To obtain a rough estimate of the pressure loss in connections, it is sufficient to consider an addition of 15% to the pressure loss in straight sections ζ_P and fittings ζ_{PF}.

- Pressure loss in valves
The pressure loss in valves can be determined using the following equation:

$$\Delta\rho_{RV} = \zeta_{RA} \cdot \frac{\rho_F}{2 \cdot 10^5} \cdot w^2$$

Equation 7.12

Δp_{RV} = pressure loss in valves (bar)
ρ_F = density of the flow (kg/m^3)
w = flow velocity (m/s)
ζ_{RA} = resistance factors for pipe valves (-)

The resistance factors for valves are shown in table 7.10.

- Resistance factors
The pressure loss in a pipe system is caused by friction, changes of direction and transfer loss. To determine the variables involving total pressure loss in a pipe system requires knowledge of the resistance factors (ζ_F) for fittings, pipe connections and valves. The most important resistance factors are indicated below.

- ζ_F - values for seamless pipe bends

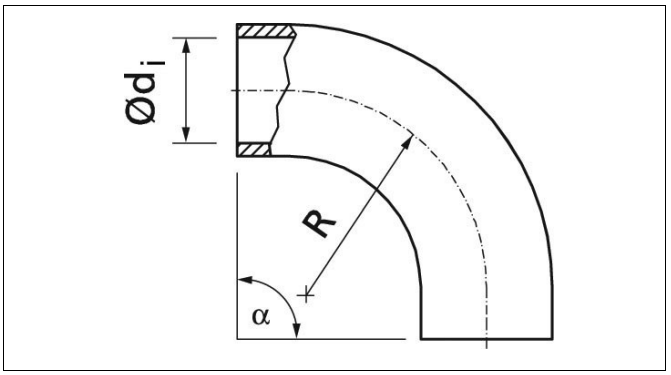


Figure 7.1 Seamless pipe bends

α \ R/d$_i$	1	1.5	2	4
30°	0.23	0.19	0.14	0.11
45°	0.34	0.27	0.20	0.15
60°	0.41	0.33	0.24	0.19
90°	0.51	0.41	0.34	0.23

Table 7.2 ζ_F value for seamless bends

- ζ_F values for segmented pipe bends

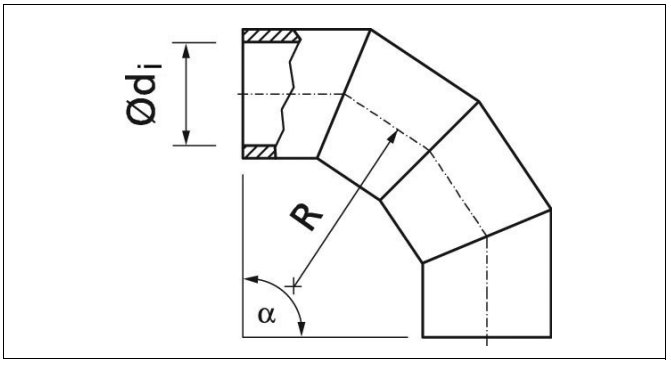


Figure 7.2 Segmented pipe bends

α \ R/d$_i$	1.5	3	4	6
30°	0.10	0.10	0.11	0.11
45°	0.14	0.15	0.16	0.17
60°	0.19	0.20	0.22	0.23
90°	0.24	0.26	0.28	0.29

Table 7.3 ζ_F values for segmented pipe bends

- ζ_F values for segmented pipe bends

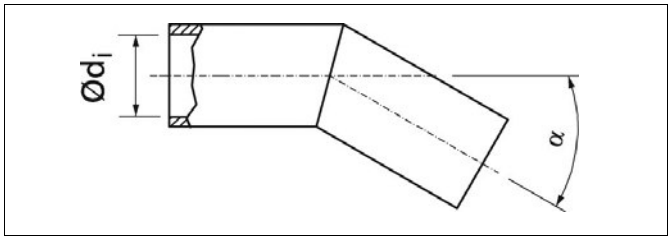


Figure 7.3 Elbows

α	10°	15°	20°	30°	45°
ζ_F	0.04	0.05	0.05	0.14	0.30

Table 7.4 ζ_F values for segmented pipe bends

- ζ_F values for tee sections

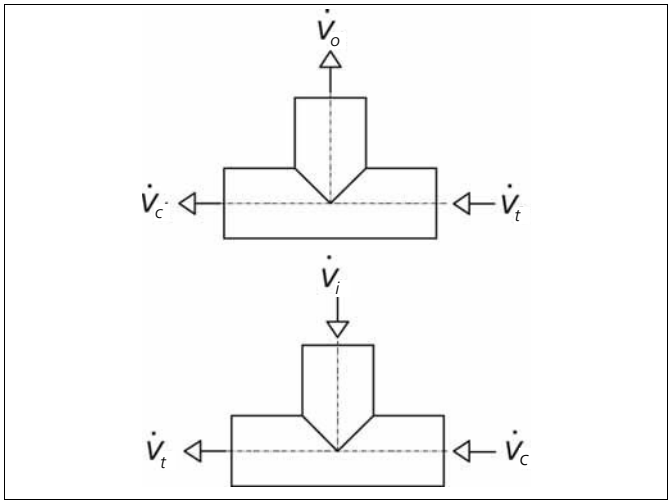


Figure 7.4 Tee for dividing and uniting flows

$\dot{V}_i/\dot{V}_t$	Uniting flows $\dot{V}_t=\dot{V}_o+\dot{V}_i$		$\dot{V}_o/\dot{V}_t$	Dividing flows $\dot{V}_t=\dot{V}_o+\dot{V}_c$	
	ζ_z	ζ_d		ζ_a	ζ_s
0.0	-1.20	0.06	0.0	0.97	0.10
0.2	-0.40	0.20	0.2	0.90	-0.10
0.4	0.10	0.30	0.4	0.90	-0.05
0.6	0.50	0.40	0.6	0.97	0.10
0.8	0.70	0.50	0.8	1.10	0.20
1.0	0.90	0.60	1.0	1.30	0.35

Table 7.5 ζ_F values for tees

$\dot{V}_t$ -> total flow volume (l/s - m^3/h)
$\dot{V}_c$ -> total continuous volume (l/s - m^3/h)
$\dot{V}_o$ -> outgoing volume (l/s - m^3/h)
$\dot{V}_i$ -> incoming volume (l/s - m^3/h)

Positive values indicate pressure loss, negative values pressure increases.

- ζ_F values for tanks and tank outlets

overlying -> ζ_F = 2.0
flush -> ζ_F = 0.3
rounded -> ζ_F = 0.05

- ζ_F values for cross-section changes

a) Pipe enlargement, perpendicular

d_{e1} / d_{e2}	1.2	1.4	1.6	1.8	2.0
ζ_F	0.07	0.15	0.24	0.46	0.56

Table 7.6 Pipe enlargement, perpendicular

b) Pipe constriction, perpendicular

d_{e1} / d_{e2}	1.2	1.4	1.6	1.8	2.0
ζ_F	0.10	0.22	0.29	0.33	0.35

Table 7.7 Pipe enlargement, perpendicular

c) Pipe enlargement, conical ζ value for λ_P = 0.025

	ζ_F values for angle of enlargement α_E		
d_{e2}/d_{e1}	4 - 8°	16°	24°
1.2	0.10	0.15	0.20
1.4	0.20	0.30	0.50
1.6	0.50	0.80	1.50
1.8	1.20	1.80	3.00
2.0	1.90	3.10	5.30

Table 7.8 Pipe enlargement, conical

α_E is the angle of enlargement. The ζ values are related to velocity (w_2). The conical length (l) is derived from the angle of enlargement (α_E) and the diameter ratio d_{e2}/d_{e1}. The best angle of enlargement in which the stream of the inflowing medium still does not lose contact with the pipe is about 7 to 8°.

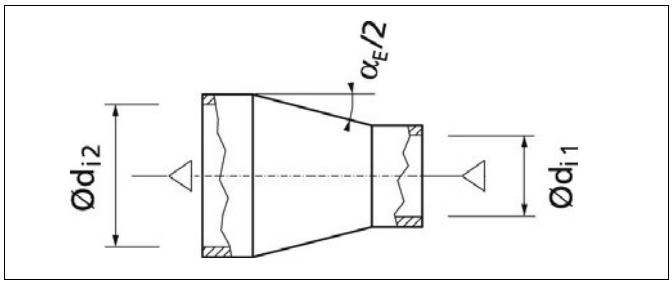


Figure 7.5 Conical enlargement of the flow cross section

d) Pipe enlargement, conical ζ value for λ_P = 0.025

	ζ_F values for angle of enlargement α_E		
d_{e2}/d_{e1}	4°	8°	24°
1.2	0.046	0.023	0.210
1.4	0.067	0.033	0.013
1.6	0.076	0.038	0.015
1.8	0.031	0.041	0.016
2.0	0.034	0.042	0.017

Table 7.9 Pipe enlargement, conical

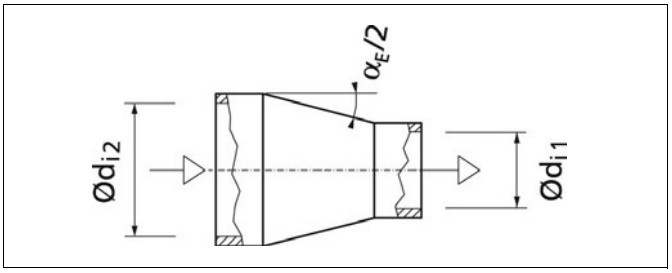


Figure 7.6 Conical enlargement of the flow cross section

- ζ_V values for valves

nominal diameter DN	diaphragm valve	flat-seat valve	ball valve	inclined seat valve valve without constriction	ball valve	butterfly valve	free-flow check valve	check valve
	Resistance factor (ζ)							
25	4.0	2.1	3.0	0.1...0.3	0.1...0.15	0.3...0.6	2,5	1,9
32	4.2	2.2	3.0	0.1...0.3	0.1...0.15	0.3...0.6	2.4	1.6
40	4.4	2.3	3.0	0.1...0.3	0.1...0.15	0.3...0.6	2.3	1.5
50	4.5	2.3	2.9	0.1...0.3	0.1...0.15	0.3...0.6	2.0	1.4
65	4.7	2.4	2.9	0.1...0.3	0.1...0.15	0.3...0.6	2.0	1.4
80	4.8	2.5	2.8	0.1...0.3	0.1...0.15	0.3...0.6	2.0	1.3
100	4.8	2.4	2.7	0.1...0.3	0.1...0.15	0.3...0.6	1.6	1.2
125	4.5	2.3	2.3	0.1...0.3	0.1...0.15	0.3...0.6	1.6	1.0
150	4.1	2.1	2.0	0.1...0.3	0.1...0.15	0.3...0.6	2.0	0.9
200	3.6	2.0	2.4	0.1...0.3	0.1...0.15	0.3...0.6	2.5	0.8

Table 7.10 ζ-values for valves

- ζ values for compensators
Surge suppressors : ζ = 2.0 per surge
Expansion joints : ζ = 3.0

- ζ values for welding seams
Electrofusion : ζ = 0.05
Butt-welding : ζ = 0.1

- ζ values for pipe bends in succession
180° bends : $\zeta = 2.0 \cdot \zeta\ 90°$
Stage of 2 x 90° bends : $\zeta = 2.5 \cdot \zeta\ 90°$
Expansion stage of 2 x 90° bends : $\zeta = 3.0 \cdot \zeta\ 90°$

7.2.3 Investigating pressure surges

The change in the stationary conditions of a pipe system (e.g. due to activation of a butterfly valve or the failure of a pump) creates a pressure wave producing superpositions due to reflections in bends, reducers, etc. that can amount to many times the operating pressure. The largest pressure increase occurs when the closure procedure or stop command following pump failure falls under the so-called reflection time. If a pipe system contains externally controlled valves or trip mechanisms, it must be ensured that their closure time is larger than the reflection time.
If a pressure surge occurs, its effects must be investigated by means of a short-term stress analysis and a stability test.

Note:
The pressure surge is not always sufficiently expressed by the following equations. In particular, more precise investigations must be employed in longer or complexly branched pipe systems in order to consider and evaluate all the significant factors.

Significant factors are:
Operating pressure, pump pressure = p_O (bar)
Flow velocity = w_o (m/s)
E modulus of the pipe material = E_{cR} (N/mm^2)
(short-term E modulus = creep modulus between 1 and 10 min)
E modulus of the flow medium = E_F (N/mm^2)
(for water at 20°C -> $E_F \approx 2100$ N/mm^2)
Density of the flow medium = ρ_F (g/cm^3)

- Calculating pressure wave velocity (a)

$$a = \frac{a_0}{\sqrt{1 + 2 \cdot \frac{E_F}{E_{C_R}} \cdot \frac{\eta^2 + 1}{\eta^2 - 1}}}$$

Equation 7.13

The indicated resistance factors are reference values and are used in rough pressure loss calculations. Object related calculations are based on the data of the respected valve manufacturers.

$$a_0 = 31{,}3 \cdot \sqrt{\frac{E_F}{\rho_F}}$$

Equation 7.14

$$\eta = \frac{d_e}{d_i}$$

Equation 7.15

a = pressure wave velocity (m/s)
a_0 = speed of sound (m/s)
d_e = outside diameter of the pipe (mm)
d_i = inside diameter of the pipe (mm)
η = correction factor (-)
E_{cR} = creep modulus of the pipe material (N/mm^2)
E_F = E modulus of the flow medium (N/mm^2)
ρ_F = density of the flow medium (kg/m^3)

- Maximum pressure surge for $\Delta w = w_0$

$$p_{Surge} = p_0 \pm \frac{a}{100} \cdot \Delta w$$

Equation 7.16

a = pressure wave velocity (m/s)
p_{Surge} = pressure surge (bar)
p_O = pump pressure, operating pressure (bar)
Δw = $w_0 - w_1$ (with w_1 = flow velocity at the reflection position) (m/s)

For short pipes of a single length can be assumed that a surge degradation occurs.

$$L_{Pipe} \leq \frac{a \cdot t_s}{2}$$

Equation 7.17

t_s = closing time of the butterfly valve or delay of the pump stop command after failure (c)
L_{Pipe} = pipe length (m)
a = pressure wave velocity (m/s)

The surge degradation factor is:

$$Z_s = \frac{2 \cdot L_{Pipe}}{a \cdot t_s} \geq 1$$

Equation 7.18

Z_s = surge degradation factor (-)
L_{Pipe} = pipe length between valve mechanism or pump and reflection position (m)
t_s = closing time of the butterfly valve or delay for the pump stop command after failure (c)
a = pressure wave velocity (m/s)

The complete pressure change ($\Delta\rho$) corresponding to the velocity change (Δ_w) velocity when the closing time (t_c) is smaller than the reflection time (t_R). The reflection time (t_R) is calculated by:

$$t_R = \frac{2 \cdot L_{Pipe}}{a}$$

Equation 7.19

t_R = reflection time (c)
L_{Pipe} = pipe length between valve mechanism or pump and reflection position (m)
a = pressure wave velocity (m/s)

The rough estimate of a pressure surge hazard can draw on the following rule of thumb:

$$K_s = \frac{L_{Pipe} \cdot w_0}{\sqrt{H_P}}$$

Equation 7.20

H_P = delivery height of the pump (m)
K_s = pressure wave size (-)
L_{Pipe} = pipe length between valve mechanism or pump and reflection position (m)
w_o = flow velocity (m/s)

For $K_s > 70$ and with simultaneous use of rapidly closing valves, a special pressure surge calculation is recommended.

- Calculating the pressure surge for the section involved
$L_{Pipe} \leq 500 \cdot de$

Equation 7.21 is an empirical calculation formula. It should therefore only be used when rough estimates are to be made for simple pipe systems without fittings.

$$p_{Surge} = p_0 \cdot \left[1 + \frac{100 \cdot w \cdot \rho_F}{\varphi \cdot p} \cdot \left(1 + 0{,}2 \cdot \sqrt{p_0} \right) \right]$$

Equation 7.21

p_{Surge} = pressure surge (bar)
p = pump pressure, operating pressure (bar)
w = flow velocity (m/s)
ρ_F = density of the flow medium (g/cm^3)
φ = surge factor (-)

In general, the following values can be selected for φ:
φ = 25 for rapidly closing valves
φ = 50 for normally closing valves
φ = 75 for slowly closing valves

The loads often arising along with pressure surges due to vacuums can, under certain conditions, cause buckling of the pipe in specific situations. The stability (i.e. buckling resistance) of the pipe series in question must be verified in every case.

$$p_{Crit} = 2{,}9 \cdot E_{C_R} \cdot \left(\frac{2 \cdot e}{d_i} \right)^3$$

Equation 7.22

p_{Crit} = critical underpressure (bar)
E_{cR} = elasticity modulus (between 1…10 min) (N/mm^2), see appendix A2.
e = pipe wall thickness (mm)
d_i = inside diameter of the pipe (mm)

From this, it follows:

$$SF = \frac{p_{Crit}}{p_u} \geq 2$$

Equation 7.23

p_u = under pressure from pressure surge calculation (bar)
p_{Crit} = critical underpressure (bar)
SF = safety factor (-)

Note:
Appendices B9 to B10 indicate the acceptable external pressure load (p_{ex}) or the underpressure load (p_u) in short-term observations (t = 100 h) and long-term observations (t = 25a) for PE at various SDR levels.

7.2.4 Calculating acceptable stress

Calculation of acceptable stress requires the inclusion of various reduction factors. The significance of individual reduction factors will be discussed in section 7.2.6. The acceptable stress is determined by the following formula.

$$\sigma_{acc} = \frac{\sigma_{ref} \cdot f_{s,l}}{R_2 \cdot R_4 \cdot SF}$$

Equation 7.24

σ_{acc} = acceptable stress (N/mm^2)
σ_{ref} = reference stress (N/mm^2), see appendix A2.
f_l = long-term welding factor (-)
f_s = short-term welding factor (max. 1h) (-)
R_2 = reduction factor for the influence of the flow medium (see table 2.3) (-)
R_4 = reduction factor for the influence of the specific resilience of the material (-)
SF = safety factor for the respective loads (see table 7.13) (-)

7.2.5 Welding factors

The size of the welding factors depends on the specific welding procedures. There is also a distinction made between short-term (f_s) and long-term welding factors (f_l). Only long-term factors may be used in component calculations. The calculation of welding factors is performed in DVS 2203 part 2.
Table 7.11 contains the relevant factors for PE butt-weld (DVS 2203 part 1) and electrofusion (DVS 2212 part 1).
The original abbreviations f_s and f_l have been freely chosen by FIP.

Material	Welding factor	PE
Butt-welding (BW)	f_s	0.9
	f_l	0.8
Electro-fusion (EF)	f_s	0.9
	f_l	0.8

Table 7.11 Welding factors f_s and f_l

7.2.6 Reduction factors

- Reduction factor R_1

The reduction factor R_1 (time dependent) accounts for the dependence of material strength on stress duration. This value is displayed in the creep rupture curves (appendix A1). Use of this diagram supplants direct observation.

- Reduction factor R_2

This reduction factor designates the influence of the flow medium (chemical resistance factor) on the creep strength of thermoplastic. Relevant values can be taken from table 2.3 in chapter 2.

- Reduction factor R_3
The dependence of strength on the operating temperature is accounted for in reduction factor (R_3). This value is also displayed in the creep rupture curves (appendix A1). Use of this diagram supplants direct observation.

- Reduction factor R_4
This factor accounts for the specific resilience of the material as a function of the operating temperature and is therefore derived from impact strength values. The corresponding values for reduction factor (R_4) are found in table 7.12.

Material	Pipe wall temperature			
	-10°C	20°C	40°C	60°C
PE100	1.2	1	1	1

Table 7.12 Reduction factor R_4

Factors can be interpolated for intermediary temperatures.

7.2.7 Safety factor (SF)

Load Class		
I	Even load on the pipe in installations in building. If damage occurs, no possible danger to people, property and the environment.	1.3
II	Load on the pipe under changing operating conditions in installations outside buildings. If damage occurs, no damage to people is expected. Effects on property and the environment limited. (*)	1.8
III	Load on the pipe under changing operating conditions in installations inside and outside buildings. If damage occurs, there are possible hazards for people, property and the environment. Applied for monitoring and inspection facilities.	≥2.0

Table 7.13 Safety factors (SF) for various loads

(*) In contrast to general references in the technical literature (e.g. DVS 2205 part 1) in which only two loads are distinguished, FIP has introduced this additional load class for larger loads that could affect a pipe system in an installation outside buildings.

7.2.8 Minimum wall thickness

- Straight pipes

$$e_0 = \frac{d_e \cdot p_i}{20 \cdot \sigma_{acc} + p_i}$$

Equation 7.25

e_0 = minimum wall thickness (mm)
d_e = outside diameter of the pipe (mm)
p_i = Internal pressure (bar)
σ_{acc} = acceptable stress (N/mm^2)

- Seamless and welded segmented pipe bends
For the inside of bends, the following holds:

$$e_i = \frac{d_e \cdot p_i}{20 \cdot \sigma_{acc} + p_i} \cdot f_{Bi}$$

Equation 7.26

e_i = wall thickness on the inside of the bend (mm)
f_{Bi} = factor for the inside of the bend from table 7.14 (-)
p_i = Internal pressure (bar)
d_e = outside diameter of the pipe (mm)
σ_{acc} = acceptable stress (N/mm^2)

For the outside of bends, the following holds:

$$e_o = \frac{d_e \cdot p_i}{20 \cdot \sigma_{acc} + p_i} \cdot f_{Bo}$$

Equation 7.27

e_o = wall thickness on the outside of the bend (mm)
f_{Bo} = factor for the outside of the bend from table 7.14 (-)
p_i = internal pressure (bar)
d_e = outside diameter of the pipe (mm)
σ_{acc} = acceptable stress (N/mm^2)

- Factors (f_{Bi}) and (f_{Bo}) for determining wall thicknesses of bends

		Radius R			
		1,0 · d_e	1,5 · d_e	2,0 · d_e	2,5 · d_e
Seamless pipe-bends	f_{Bi}	1,27	1,22	1,15	1,12
	f_{Bo}	0,92	0,93	0,95	0,96
Segmented bends	f_{Bi}	1,59	1,50	1,44	1,40
	f_{Bo}	1,15	1,16	1,19	1,20

Table 7.14 Factors for determining wall thicknesses for bends

- Welded branches (tees)
In principle, branches in pipes represent weaknesses.
This condition has the consequence that unreinforced welded tee sections do not correspond to the nominal pressure of the pipe. Welded tees can only be exposed to a reduced pressure load. An improvement of the internal load capacity is achieved by increasing the wall thickness of the connection or by a corresponding strengthening of welded joints.

- Wall thickness of branch pipes:

$$e_0 = \frac{d_e \cdot p_i}{\left(20 \cdot \sigma_{acc} + p_i\right) \cdot W_{RF}}$$

Equation 7.28

e_o = wall thickness (mm)
d_e = outside diameter of the pipe (mm)
p_i = internal pressure (bar)
σ_{acc} = acceptable stress (N/mm^2)
W_{RF} = weakening factor of the fitting (-)

Values for the weakening factor (WRF) can be interpreted from appendix B2.

The reduced internal loads for fittings welded on pipe segments is shown in appendix B2.

7.2.9 Internal pressure capacity of welded and injection-moulded fittings.

- Moulded fittings
Moulded fittings do not generally require any restrictions regarding a minimum internal pressure load capacity. They therefore withstand the same internal pressure load as a pipe of the same SDR level.

- Segment-welded tee sections
The inclusion of unreinforced welded tees in any pipe system reduces the tolerable operating pressure. The corresponding reduction factor is strongly temperature-dependent, which means that the internal pressure capacity is lowered by rising operating temperatures. Information about the internal pressure load capacity of segment-welded tees is provided by appendix B2.

- Segment-welded bends
Like the mentioned segment-welded tees, segment-welded bends (angle >30°) have a reduced internal pressure load capacity in comparison with a straight pipe. The weakening effect of butt-welded segmented bends is also dependent on the same temperature conditions affecting segment-welded tees. The actual internal pressure load capacities can be seen in appendix B2.

7.2.10 Length changes due to heating and internal pressure

- Thermal-conditioned length change
Exposing a pipe system to varying temperatures (e.g. ambient and operating temperatures) changes its status with regard to the expansion capacities of individual pipe sections. Pipe sections designate the distances between the system point in question to the relevant fixed point. The thermally conditioned length change (Δl_ϑ) of individual pipe sections is calculated as follows:

$$\Delta l_\vartheta = L_{Pipe} \cdot \alpha_\vartheta \cdot \Delta\vartheta_{max} \cdot 10^{3}$$

Equation 7.29

Δl_ϑ = thermal length change (mm)
L_{Pipe} = pipe length (m)
α_ϑ = thermal expansion coefficient (K-1)
$\Delta\vartheta_{max}$ = max. temperature difference (K)

Examples for the calculation of $\Delta\vartheta_{max}$:
$\Delta\vartheta_{max} = T_{W\,max} - T_{W\,min}$
or
$\Delta\vartheta_{max} = T_{W\,max} - T_M$
or
$\Delta\vartheta_{max} = T_{W\,max} - T_a$
$\Delta\vartheta_{max}$ = temperature difference (K)
$T_{W\,min}$ = minimum pipe wall temperature (°C)
T_M = average installation temperature (°C)
$T_{W\,max}$ = maximum pipe wall temperature (°C)
T_a = lowest ambient temperature (°C)

- Length change due to internal pressure loads
In any closed pipe string, a longitudinal expansion is produced by the occurrence of internal pressure loads as follows:

$$\Delta l_\rho = \frac{0{,}1 \cdot p_i}{E_{C_R}} \cdot \frac{(1\text{-}2 \cdot \mu)}{\left(\frac{d_e}{d_i}\right) - 1} \cdot L_{Pipe}$$

Equation 7.30

Δl_ρ = length change due to internal pressure (mm)
p_i = internal pressure (bar)
E_{cR} = creep modulus of the pipe material (N/mm^2)
d_e = outside diameter of the pipe (mm)
d_i = inside diameter of the pipe (mm)
L_{Pipe} = pipe length (L_1, L_2,···, L_x) (mm)
μ = transverse contraction number (-)

- Determining expansion bend dimensions
Length change (Δl_ϑ):

$$\Delta l_\vartheta = L_{Pipe} \cdot \alpha_\vartheta \cdot \Delta\vartheta \cdot 10^{3}$$

Equation 7.31

L_{Pipe} = pipe length (m)
α_ϑ = thermal expansion coefficient (K-^{1})
Δ_ϑ = temperature difference (K)
Δl_ϑ = thermal length change (mm)

In calculating temperature difference ($\Delta\vartheta$), care should be taken that the lowest and highest temperatures (installation, operating and stationary) are used in the calculation. Approximations usually take just flow medium and ambient temperatures into account. They simplest type of compensation for length changes in thermoplastic pipe installations involves using L-form expansion bends (90° changes of direction). L-bends are also referred to as elbows. The minimum dimensions of an elbow as illustrated in figure 7.7 is indicated by the following equation:

$$L_{B1,2} = \sqrt{\frac{3 \cdot d_e \cdot L_{1,2} \cdot \varepsilon \cdot E_{C_R}}{\sigma_{sf\,acc}}}$$

Equation 7.32

L_B = length of the expansion bend (mm)
$L_{1,2}$ = system lengths of expansion bends (mm)
d_e = outside diameter of the pipe (mm)
ε = expansion (-)
E_{cR} = (average) bending creep modulus of the pipe material for t = 25a (N/mm2)
$\sigma_{sf\,acc}$ = acceptable flexural stress share for t = 25a (N/mm^2)

Expansion bend lengths for L, Z and U bends are illustrated in appendices B5 to B8, and the corresponding values can be read from these diagrams.

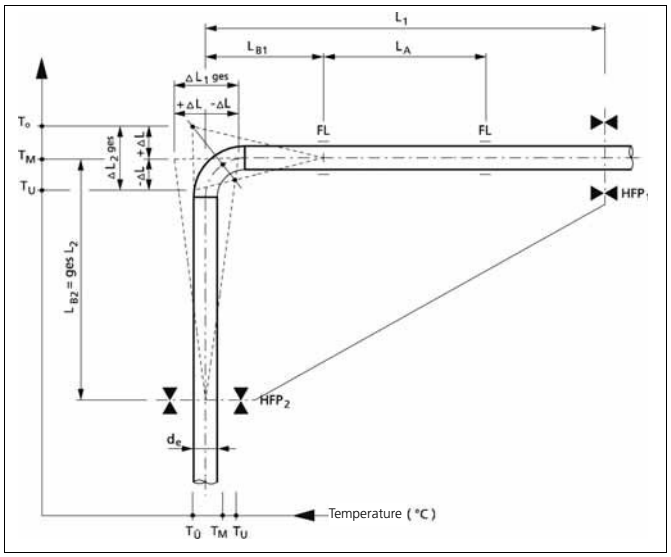


Figure 7.7 Elbow (L-bend)

- Pipe sections for absorbing length changes

As shown in figure 7.8, length changes subject pipe sections to bending. The dimensions of expansion bends (L_B) are established by the relationship:

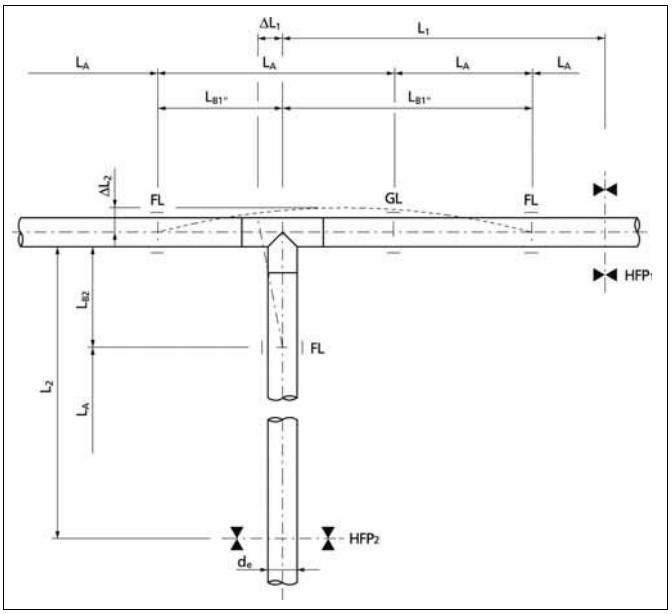


Figure 7.8 Pipe section for absorbing length changes

$$L_B = \sqrt{\frac{3 \cdot d_e \cdot L_{1,2} \cdot \varepsilon \cdot E_{c_R}}{\sigma_{f\,acc}}}$$

Equation 7.33

L_B = length of the expansion bend (mm)
d_e = outside diameter of the pipe (mm)
ε = expansion (-)
$L_{1,2}$ = system lengths of expansion bends (mm)
E_{cR} = (average) bending creep modulus of the pipe material for t = 25a (N/mm^2)
$\sigma_{f\,acc}$ = acceptable flexural stress (N/mm^2)

- Branch connections

In pipe sections subject to axial movement, it is also important to ensure that branching pipe strings are not exposed to high flexural tensions. The minimum distance between a tee section and the nearest guide bracket corresponds to the expansion bend length (L_B). With the aid of appendices B5 to B8, the required expansion bend lengths are visually illustrated.

7.2.11 Calculating forces at fixed points

Fixed points in pipe installations are brackets that fix the pipe in x, y and z directions. The forces at these points depend on the nature of individual pipe system. The "slacker" the pipe running between two fixed points is, the smaller the reaction forces generated by deformation effects. The exact calculation of the force components in any given pipe system is laborious. The calculation is made easier by employing the correspondingly suitable PC software for thermoplastic pipe systems.

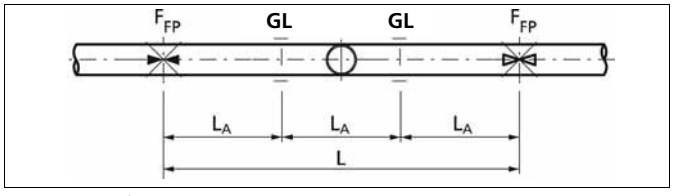


Figure 7.9 Firmly fastened pipe string

- Maximum force at fixed-points without compensation for length change

The largest fixed-point load occurs on a firmly fastened pipe string. It is calculated as follows:

$$F_{FP} = A_p \cdot \varepsilon \cdot E_{c_R}$$

Equation 7.34

Load from termal expansion: $\varepsilon = \alpha_\vartheta \cdot \Delta\vartheta$ *(35)*

Load from internal pressure: $\varepsilon = \dfrac{0{,}1 \cdot p_i \cdot (1\text{-}2 \cdot \mu)}{E_{c_R} \cdot \left(\dfrac{d_e^2}{d_i^2} - 1\right)}$ *(36)*

Load from swelling: $\varepsilon = 0{,}025 \ldots 0{,}040$ *(37)*

Equation 7.35-7.37

Explanation of symbols in equations 7.34 to 7.37
F_{FP} = force at fixed points in a firmly fastened pipe string (N)
A_P = area of pipe annular surface (mm^2)
ε = constricted length expansion (-)
α_ϑ = thermal expansion coefficient (K-1)
$\Delta\vartheta$ = maximum temperature difference between TL and TU (K)
p_i = internal pressure (bar)
E_{cR} = (average) creep modulus of the pipe material for t = 100 min (N/mm^2)
d_e = outside diameter of the pipe (mm)
d_i = inside diameter of the pipe (mm)
μ = transverse contraction number (-)

Since the creep modulus is dependent on time, temperature and stress, an average load period of 100 min is adopted for the calculations. The corresponding values can be derived from appendix A2. The forces at fixed points can also be interpolated from the appendix B9.

- System-dependent fixed-point force

Thermoplastic pipes are usually installed so that the compensation capacity of direction changes can be used to absorb length changes.
The resulting fixed-point forces are therefore system-specific. In most cases, they are smaller than the fixed-point load calculated in section 7.2.14. In practice however, the procedure is simplified by adopting the largest possible load to design the fixed-point structure. If, due to the load compensation parameters, the forces are prevented from being large enough (e.g. for pipe bridges, brickwork, containers, pump supports), a system-specific calculation is an essential part of a structural calculation. The PC calculation program can again serve this purpose.

Basic calculations

- Forms of compensation in level pipe systems

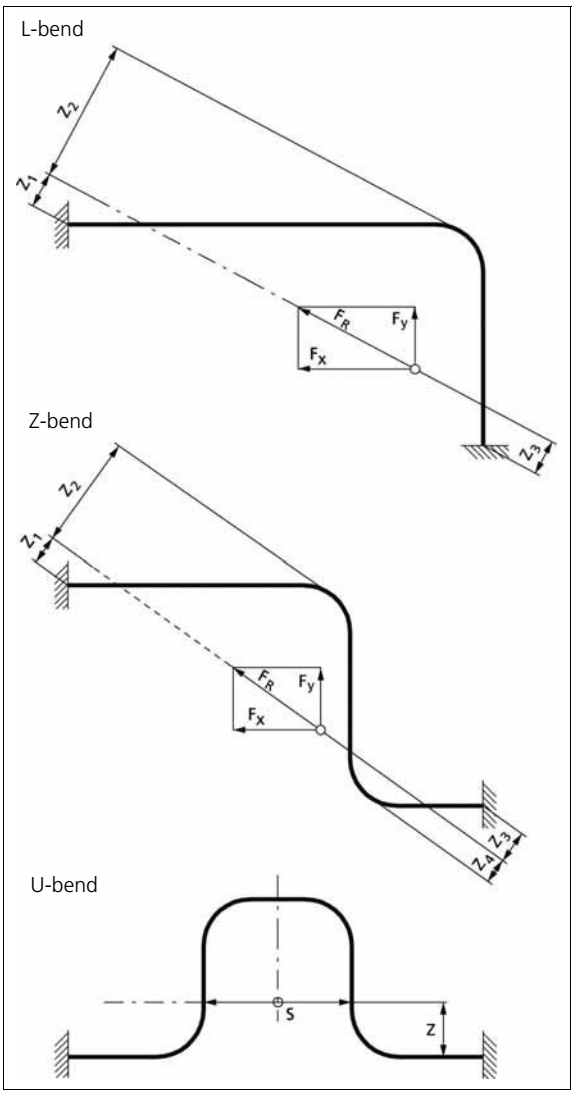


Figure 7.10 Forms of compensation in level pipe systems

Explanation of figure 7.10:

F_x , F_y , F_z = force components
F_y, F_x = F_T at fixed points "A" und "B"
F_T = transverse force
F_R = resulting total force
Z_1 , Z_2 , Z_3 = distances of the system points from the line of action
S = system centre of mass

The distance (Z) (lever) and the resulting total force (F_R) produces the moment (M)

$$M = F_R \cdot Z$$

Equation 7.38

at a given position of the individual pipe system

M = moment of torque (Nm)
F_R = resulting force (N)
Z = lever (m)

- Rough calculation of fixed-point forces in L-bends:

$$F_{LB} = \frac{12 \cdot \Delta l \cdot E_{c_R} \cdot J_P}{L_B^3}$$

Equation 7.39

F_{LB} = fixed-point load at (L, Z, U) bends -> F_y or F_x (N)
Δl = length change (mm)
E_{cR} = (average) creep modulus of the pipe material for t = 100 min (N/mm^2)
J_P = pipe moment of inertia (mm^4)
L_B = length of the expansion bend (mm)

$$J_P \approx \frac{d_e^4 - d_i^4}{20}$$

Equation 7.40

J_P = pipe moment of inertia (mm^4)
d_e = outside diameter of the pipe (mm)
d_i = inside diameter of the pipe (mm)

- Fixed-point force in cases of constricted length change due to internal pressure load

$$F_{FP} = A_P \cdot \sigma_a \quad with \quad A_P = \frac{\left(d_e^2 - d_i^2\right) \cdot \pi}{4}$$

Equation 7.41

σ_a = axial stress (N/mm^2)
A_P = area of pipe annular surface (mm^2)
F_{FP} = force at fixed point (N)
d_e = outside diameter of the pipe (mm)
d_i = inside diameter of the pipe (mm)

- Fixed-point force in cases involving compensators or expansion couplers

$$F_{FP} = 0{,}1 \cdot A_K \cdot p_i \quad with \quad A_K = \frac{d_i^2 \cdot \pi}{4}$$

Equation 7.42

A_K = surface subject to pressure (mm^2)
p_i = internal pressure (bar)
d_i = inside diameter of the pipe (mm)
F_{FP} = force at fixed point (N)

- Resulting force at fixed point

Brackets are subject to both horizontal and vertical loads. Simultaneous loads in both directions produce a resulting total force (F_R).

$$F_R = \sqrt{F_B^2 + F_V^2}$$

Equation 7.43

F_B = axial fixed-point force (F_{FP}) or friction force (F_μ) as a result of a length change in the pipe string
F_V = transverse force (F_{TV}) for fixed-point load and/or pipe weight (F_W) between two brackets with or without additional load.

7.2.12 Elasticity test

Elasticity tests on pipe systems serve predominantly to calculate force actions and stresses.
Stresses are created by:
- internal pressure loads
- constricted longitudinal movement under temperature change
- bending of bend sections when absorbing length changes

The forces affecting fixed points do not only cause bending moments in the bend sections but also in the firmly fastened pieces. In 3-D systems, the pipe string is also subject to torsion (twisting).
For facilities corresponding to load classes II and III (table 7.13) or requiring testing or monitoring in general, the elasticity calculation is not only a criterion for careful project planning but also partly prescribed.

7.2.13 Calculating the stresses arising in a pipe system

Pipe systems are usually exposed to a multi-axial state of stress. The mechanical stress measured in the internal pressure creep test (appendix A1) provides the basis for designing thermoplastic pipe systems. The layout of pipes is generally based on the internal pressure load, which corresponds to the load in the internal pressure creep test.

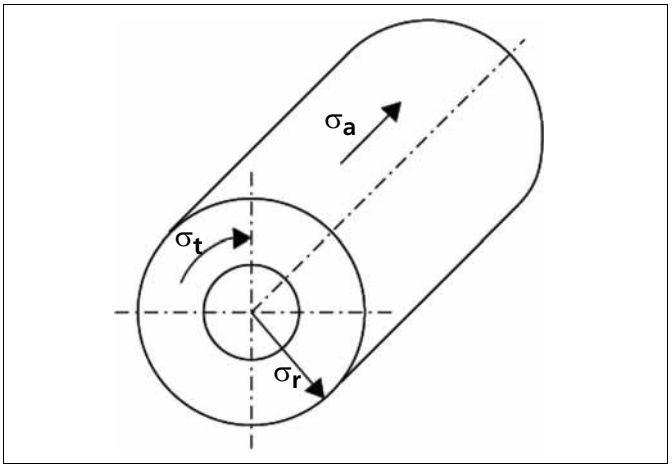


Figure 7.11 Radial (σ_r), Axial (σ_a) or Tangential (σ_t) stress

However, in addition to the mentioned stresses in axial, radial and tangential directions to the pipe axis, which are usually caused by heat or internal pressure loads, there are other stresses (e.g. flexural stresses) created in a pipe system, making it necessary to investigate all the stress components as part of a structural analysis. To establish the multi-axial state of stress requires calculation of the resulting stress (σ_{res}) and comparison with the value for (σ_{acc}). In particular, failure to account for flexural stresses around expansion bends and the tensile stresses resulting from impeded thermal expansion can result in failure of a pipe that is, otherwise, subject to a small internal pressure load.

- Axial stress (X axis) due to internal pressure

$$\sigma_a = \frac{p_i}{10} \cdot \frac{1}{\left(\frac{d_e}{d_i}\right)^2 - 1} \mathrel{\hat{=}} \sigma_1$$

Equation 7.44

- Tangential stress (Y axis) due to internal overpressure

$$\sigma_t = \frac{p_i}{10} \cdot \frac{\left(\frac{d_e}{d_i}\right)^2 + 1}{\left(\frac{d_e}{d_i}\right)^2 - 1} \mathrel{\hat{=}} \sigma_y$$

Equation 7.45

- Radial stress (Z axis due to inner over pressure)

$$\sigma_r = -\frac{p_i}{10} \mathrel{\hat{=}} \sigma_z$$

Equation 7.46

- Flexural axial stress (x axis) in a straight pipe between brackets

$$\sigma_f = \frac{q \cdot L_B^2}{8 \cdot W_R} \mathrel{\hat{=}} \sigma_x$$

Equation 7.47

- Flexural stress in bends

$$\sigma_f = \sigma_0 \cdot \frac{2}{1+12 \cdot \lambda_B^2} \cdot \left[9 \cdot \lambda_B + (1+6 \cdot \lambda_B^2) \cdot \frac{r_a}{R} \right]$$

Equation 7.48

M_b from the elasticy test

$$\sigma_0 = \frac{M_b \cdot d_e}{20 \cdot J_P}$$

Equation 7.49

$$\lambda_B = \frac{R \cdot e}{r_a^2}$$

Equation 7.50

$$r_m = \frac{d_e - e}{2}$$

Equation 7.51

- Stresses due to constricted thermal expansion

maximum stress value in a short-term perspective:

$$\sigma_{\vartheta\, max} = \pm\, \alpha_\vartheta \cdot \Delta\vartheta \cdot E_{C_R} \mathrel{\hat{=}} \sigma_x$$

Equation 7.52

in a long-term perspective:
Stress for temperature = constant

$$\sigma_\vartheta = 0{,}5 \cdot \sigma_{\vartheta\, max}$$

Equation 7.53

stress for temperature = variable

$$\sigma_{\vartheta} = 0{,}67 \cdot \sigma_{\vartheta\,max}$$

Equation 7.54

Tensile stress arises when the period of low operating temperature(t_{cold}) is shorter than the period of high operating temperature (t_{warm}) , i.e. $t_{cold} < t_{warm}$

$$\sigma_z = -0{,}33 \cdot \sigma_{\vartheta\,max}$$

Equation 7.55

- Residual stress due to temperature differences between inner pipe wall and outer pipe wall

$$\sigma_{\vartheta} = 0{,}81 \cdot E_{C_R} \cdot \alpha_{\vartheta} \cdot (T_{S_P} - T_{e_P})$$

Equation 7.56

- Calculating the resulting stress

$$\sigma_{res} = 0{,}71 \cdot \sqrt{(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2}$$

Equation 7.57

$$\sigma_x \leq \sigma_{acc} = \sigma_a + \sigma_f \pm \sigma_{\vartheta}$$

Equation 7.58

$$\sigma_y \leq \sigma_{acc} = \sigma_u$$

Equation 7.59

$$\sigma_y \leq \sigma_{acc} = \sigma_r$$

Equation 7.60

$$\sigma_{res} \leq \sigma_{acc}$$

Equation 7.61

Explanation of symbols in equations 7.44 - 7.61

R_p = moment of resistance of the pipe (cm^3)
M_b = bending moment due to the tensile or compressive forces affecting branch sections
L_B = bracket distance (m)
J_P = pipe moment of inertia (cm^4)
R = bending radius of bends (mm)
r_a = average pipe radius (mm)
q = weight of the full pipes (N/m)
e = pipe wall thickness (mm)
d_e = outside diameter of the pipe (mm)
d_i = inside diameter of the pipe
E_{cR} = average creep modulus of the pipe material (N/mm^2)
ρ_i = internal pressure (bar)
σ_0 = stress in straight pipe (N/mm^2)
σ_a = axial stress (N/mm^2)
σ_t = tangential stress (N/mm^2)
σ_r = radial stress (N/mm^2)
σ_f = flexural stress (N/mm^2)
σ_{ϑ} = axial stress due to constricted thermal expansion (N/mm^2)
$\sigma_{\vartheta max}$ = maximum axial stress due to constricted thermal expansion (N/mm^2)
σ_{res} = resulting stress (N/mm^2)
$\sigma_{x,\,y,\,z}$ = direction-dependent stress (N/mm^2)
σ_{acc} = acceptable stress (N/mm^2)
T_{sP} = inner pipe wall temperature (°C)
T_{eP} = outer pipe wall temperature (°C)
λ_B = bend factor (-)
a_{ϑ} = thermal expansion coefficient (K-1)

7.2.14 Expansions

If pipe deformation exceeds certain creep limits, flow zones and microscopic cracks are created across the direction of expansion. For usual applications, pipe deformation is calculated in the following manner.

$$\varepsilon_{\sigma x} = \frac{100}{E_{C_R}} \cdot \left[\sigma_x - \mu \cdot (\sigma_y - \sigma_z)\right]$$

Equation 7.62

$$\varepsilon_{\sigma y} = \frac{100}{E_{C_R}} \cdot \left[\sigma_y - \mu \cdot (\sigma_x + \sigma_z)\right]$$

Equation 7.63

$\varepsilon_{\sigma x}$, $\varepsilon_{\sigma y}$ = expansion along the x and y axes of stress in a multi-axial load (-)
σ_x, σ_y, σ_z = stress along the x, y and z axes (N/mm^2)
E_{cR} = average creep modulus of the pipe material (N/mm^2)
μ = transverse contraction number = 0.38 (-)

The largest expansion is calculated on each occasion and compared with the threshold value (ε_F) in table 7.15. The requirement reads:

$$\frac{\varepsilon_F}{\varepsilon_{max}} \geq 1{,}3$$

Equation 7.64

ε_F = expansion threshold value
ε_{max} = $\varepsilon_{\sigma x}$ or $\varepsilon_{\sigma y}$ (-)

Material	PE
expansion threshold value ε_F	3%

Table 7.15 Expansion threshold value for PE

Should the correlation between stress and expansion be expressed, it can also be included in the following relationship:

$$\sigma_0 = \varepsilon \cdot E_{C_R} \text{ resp. } \varepsilon = \frac{\sigma_0}{E_{C_R}} \cdot 100\%$$

Equation 7.65

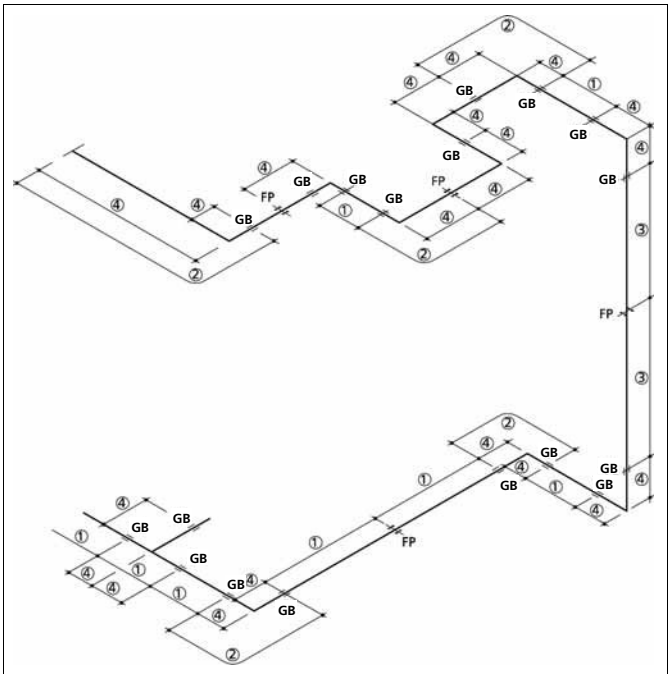
E_{cR} = average creep modulus of the pipe material (N/mm^2)
ε = expansion (-)
σ_0 = stress (N/mm^2)

7.2.15 Estimating service life

If the calculation variables, temperatures and their reaction time in relation to the assumed total load period are all available, the expected service life (life-span) can then be determined. The calculation of the service life however requires a large amount of mathematical complexity. For this reason, closer examination of the mathematical determination of a pipe system's service life will be set aside. In calculating service life, it should be noted that the life-span of the pipe system is also affected by chemical and/or physical conditions. A detailed treatment of the topic of service-life, complete with examples, is contained in the DVS 2205-1 guideline. The calculation of service lives involving varying loads requires firm knowledge about the handling of plastics. Valuable aids are PC calculating programmes, which can also provide support for less frequently used calculations.

7.2.16 Sample calculation

A number of values will be calculated for the isometric pipe system illustrated below.



GB = guide bracket (guide saddle), which is a fixing with an axial pipe guide
FP = fixed point, which is a fixing without any possibility for movement
① L_M = support distance for the middle of a continuous pipe
② L_E = support distance for a separate or end piece, as well as the self-supporting total pipe length of an L bend. If both bending lengths are, in total, longer than the acceptable support distance (L_F), an additional SB is to be placed between the pipe bend and the GB
③ L_V = guide bracket distance for an inclined pipe string. To absorb weight, a fixed point or bearing fixed point or support ring is to be provided for each string
④ L_B = bending lengths for absorbing length changes and operating conditions

Figure 7.12 Pipe isometrics

Explanation of terms ① ② ③ ④ for equations 7.66 to 7.73. The numbering and short symbols provide information about the variables being calculated and where their location in the isometric diagram. The illustration is therefore a guide and helps the user to obtain an overview of a pipe system and its calculations.

1. Load on brackets

Brackets are subject to both horizontal and vertical loads. Simultaneous loads produce a resulting total force (F_R), which can be calculated using the following equation 7.66. Figure 7.13 shows a bracket with the effective forces and the calculated bracket distance (B_d).

$$F_R = \sqrt{F_B^{\,2} + F_V^{\,2}}$$

Equation 7.66

FB = axial fixed-point force (F_{FP}) or friction force (F_μ) as a result of a length change in the pipe string
FV = transverse force (F_{TV}) for fixed-point load and/or pipe weight (F_W) between two brackets with or without additional load

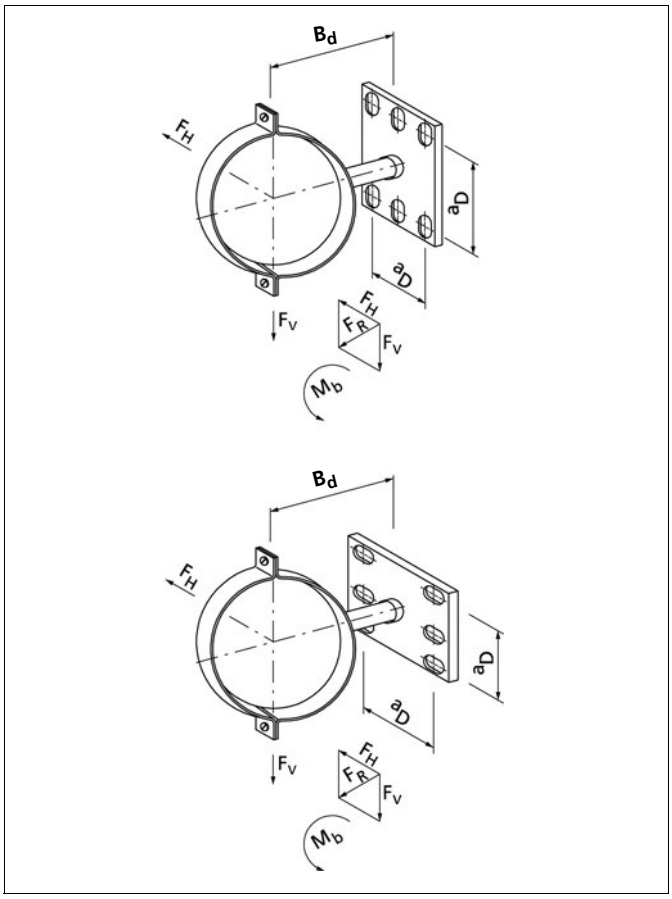


Figure 7.13 Pipe saddle load

Determination of the force components

F_{FP} = see equation 7.34

$F_\mu = F_W \cdot \mu$

F_{TV} = based on system calculation

$F_W = F_{W\,(Pipe)} + F_{W\,(Fill\ med)} + F_{W\,(Add\ load)}$

Equation 7.67

μ_F = friction coefficient usually between 0.3 and 0.5
F_{FP} = force at fixed point (N)
F_W = weight (N)
F_{TV} = transverse force (N)
$F_{w\,(Pipe)}$ = weight (pipe weight) (N)
$F_{W\,(Fill\ med)}$ = weight (weight of fill medium) (N)
$F_{W\,(Add\ load)}$ = weight (additional weight) (N)

2. Bracket distances (B_d)

The fixing distances of a plastic pipe are to be determined in such a way that no excessive stresses arise both under operating conditions and during testing. Similarly, consideration is also to be given to the deflection limits of the pipe. The arrangement of various brackets and their distances from each other can be seen in the illustrated example (figure 7.12) of pipe isometrics.

3. Calculating acceptable bracket distances

$$L_M = 1{,}86 \cdot \sqrt[4]{\frac{E_{C_R} \cdot f_{acc} \cdot \left(d_e^{\,4} - d_i^{\,4}\right) \cdot 10^5}{\left(d_e - d_i\right) \cdot e \cdot \rho_P + \frac{d_i^{\,2}}{2} \cdot \rho_F}}$$

Equation 7.68

L_M = support distance for the middle of a continuous pipe (mm)
E_{cR} = creep modulus of the pipe material for t = 25a (N/mm^2)
f_{acc} = acceptable pipe deflection according to the recommendations in table 7.16 (mm)
d_e = outside diameter of the pipe (mm)
d_i = inside diameter of the pipe (mm)
e = pipe wall thickness (mm)
ρ_P = density of the pipe medium (g/cm^3)
ρ_F = density of the flow medium (g/cm^3)

$$L_E = 0{,}67 \cdot L_M$$

Equation 7.69

$$L_V = Y \cdot L_M$$

Equation 7.70

Values for Y: ≤ Ø d_e 110 mm -> Y=1,1
Ø d_e125 - 200 mm -> Y=1,2
≤ Ø d_e 225 mm -> Y=1,3

L_B = mathematical definition in equation 7.28 respectively with appendices B3 to B7

Equation 7.71

Explanation of symbols in equations 7.69 to 7.71:
L_M = support distance for the middle of a continuous pipe (mm)
L_E = support distance for a separate and end piece, as well as the self-supporting total pipe length of an L bend.
L_V = guide distance for an inclined pipe string (mm)
L_B = length of the expansion bend (mm)
Y = factor (dependent on pipe dimensions) (-)

To calculate the support distances, the following deflections are recommended as acceptable values:

Ø d_e	20 - 110	125 - 200	225 - 355	400 - 600
f_{acc}	2 -3 mm	3 - 5 mm	5 - 7 mm	7 - 10 mm

Table 7.16 Deflection f_{acc} for pipes

If larger deflections are permitted, the pipe should not be axially constricted.

4. Verifying the acceptable buckling length

If pipes are installed so that axial expansion of all or individual strings is no longer possible (axial constriction), the calculated fixing distance must be tested for its buckling resistance. To avoid the risk of buckling due to constricted thermal expansion, the length of pipe between two brackets must be no more than L_K .

$$L_{K_{acc}} \leq 1{,}12 \cdot \sqrt{\frac{d_e^{\,2} - d_i^{\,2}}{\alpha_\vartheta \cdot \Delta\vartheta}}$$

Equation 7.72

See appendix B10.

$L_{K\,acc}$ = acceptable buckling length between two brackets (mm)
α_ϑ = thermal expansion coefficient (K^{-1})
Δ_ϑ = temperature difference (K)
d_e = outside diameter of the pipe (mm)
d_i = inside diameter of the pipe (mm)

The following applies to all pipe systems without linear compensation:

$$L_{B_{acc}} \leq L_{S_{acc}}$$

Equation 7.73

Values for LB are found in appendix B10:
$L_{B\,acc}$ = acceptable pipe length between two brackets (mm)
$L_{S\,acc}$ = available or calculated support distance according to equations ① ② ③ (equations 7.68 to 7.70)
d_e = outside diameter of the pipe (mm)
d_i = inside diameter of the pipe (mm)
α_ϑ = thermal expansion coefficient (K^{-1})
Δ_ϑ = temperature difference (K)

Note to equations 7.72 and 7.73:
Axially constricted pipe systems operated at raised temperatures or an expected reduction of the creep modulus (E_{cR}) as a result of chemical effects will both give rise to risks of buckling.
Raised operating temperatures are:
PE -> $T_{crit} \geq 45°C$
PP -> $T_{crit} \geq 60°C$
The buckling risk is strengthened due to bending along the pipe axis or insufficient pipe storage practices. Bending can result from too long support distances, improper storage of pipe and lasting pipe impacts during welding.
In such case, it is recommended that the buckling distances either calculated or interpolated from appendix B10 are reduced by a factor of 0.8. Pipe systems with $d_e \leq 50$ mm should be equipped with continuous support for economic reasons.

5. Determining pipe deflection for calculated support distances

Pipe deflection for the calculated support distance (L_M) (from equation 7.68) is determined by means of the following equation.

Pipe deflection for the calculated support distance (L_E) (from equation 7.69) is also determined by means of equation 7.74.

$$① \quad f_D = \frac{2{,}6 \cdot q \cdot L_M^{\,4}}{E_{C_R} \cdot J_P} \qquad ② \quad f_D = \frac{5{,}4 \cdot q \cdot L_E^{\,4}}{E_{C_R} \cdot J_P}$$

Equation 7.74

q = weight of the filled pipe along with any insulation (N/mm^2)
E_{cR} = creep modulus of the pipe material (N/mm^2)
L_M, L_E = bracket distance (m)
L_B = acceptable bracket distance (m)
J_P = pipe moment of inertia (mm^4)
f_D = deflection (mm)

At position 3, the pipe is not subject to deflection but to buckling.

8 Jointing

8.1 General

In planning and installing PE pipe systems, the planning and/or installation organisations can select a series of different jointing techniques. The nature of the load, the type of installation, the economics and the local conditions have large influences on the choice of appropriate connecting method. The nature of the pipe connection can have lasting positive and negative consequences for the manufacturing costs of a pipe system. Criteria for selecting the most appropriate jointing technique are:
- operational reliability
- accessibility
- level of sealing
- effects of the medium to which it will be exposed
- cost outlay
- internal pressure load of the pipe system

The planner and fitter of plastic pipe systems can choose between a detachable and non-detachable connecting technique. Various procedures are available for possible solutions. The detachable connection contains elements that generally enable non-destructive disassembly and reassembly without large additional expense.

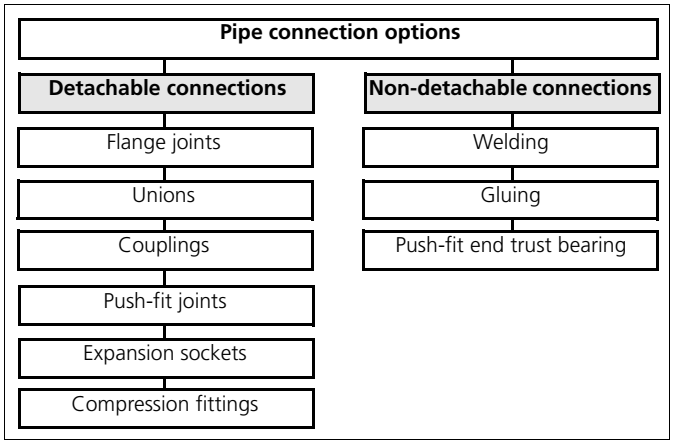


Figure 8.1 Detachable and non-detachable pipe connections

8.2 Detachable connections

8.2.1 General

In general, the group of detachable connecting elements for PE pipe systems consists of:
- flanges
- push-fit connections
- unions
- compression fittings

The individual jointing techniques in this group will be discussed below.

8.2.2 Flange joints

Connections to such components as pumps or valves are normally made by means of flange joints. The elements of the flange joint used in plastic pipe construction are the stub flange, backing ring, gasket and bolts with washers (possibly lock washers) and hex nuts. Flange joints can be either backing ring connections or blind flange joints. A blind flange joint is usually used to seal the end of a pipe. The fixed flange variant is generally ruled out due to higher costs. A backing ring connection is, in most cases, the substantially less expensive variant whenever a direct comparison is made, and therefore fixed flange joints are only of limited significance in the choice of flange joints.

The backing rings used as connecting elements in the plastic pipe construction are constructed from metal materials (e.g. steel, aluminium), fibre glass reinforced plastic or a combination of plastic and metal. The ease of assembly involved in their use and especially the higher operating reliability give backing ring connections definite advantages over fixed flange joints.

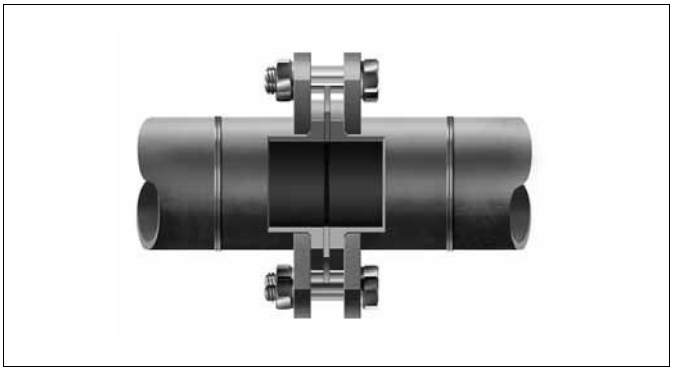


Figure 8.2 Flange joint

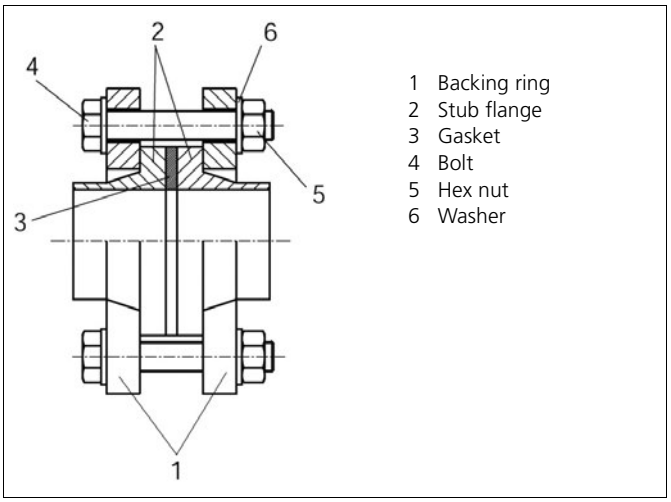


Figure 8.3 Cross-section of a flange joint

The gasket, nearly always in the form of a flat ring gasket, is available in various material and material qualities. Use is often made of gaskets composed of elastomers or elastomer compounds, such as neoprene, hypalon or viton. Hard gaskets have proven to be less suited or even unsuitable on account of their limited formability. The use of elastomer flat gaskets without steel inlays frequently results in leakage at higher internal pressures (e.g. during pressure testing). It is therefore recommended for use to be made of armoured gaskets with a convex cross-section. Their use is especially advisable when the internal pressure (operating pressure) comes close to the pipe's pressure rating. An additional improvement in the level of sealing is obtained when the inside of the gasket has the form of an O-ring. O-rings, double chamber gaskets, etc. are to be used in cases involving high internal pressures, especially when vacuums are involved as well. Gasket sizes are to be chosen so that the inside pipe diameter is not reduced by any excess gasket material, or that fissures can occur allowing fluid to penetrate the seal (with risk of sedimentation in the fissure!). During assembly, care must also be taken to ensure that the bolts are tightened evenly and the gasket and sealing surfaces are clean. Table 8.1 shows the standard values for the bolt torques in flange joints.

Standard bolt torques in flange joints of thermoplastic pipes (DVS 2210 Part 1)

d_e (mm)	DN (mm)	Bolt tightening torque (Nm)		
		Flat ring gasket ($p_{acc} \leq 10$ bar)	Profile gasket ($p_{acc} \leq 16$ bar)	O-ring gasket ($p_{acc} \leq 16$ bar)
20	15	15	10	10
25	20	15	15	15
32	25	15	15	15
40	32	20	15	15
50	40	30	15	15
63	50	35	20	20
75	65	40	20	20
90	80	40	20	20
110	100	40	20	20
125	100	40	20	20
140	125	50	30	30
160	150	60	40	35
180	150	60	40	35
200	200	70 (1)	50	40
225	200	70 (1)	50	40
250	250	80 (1)	55	50
280	250	80 (1)	55	50
315	300	100 (1)	60	55
355	350	100 (1)	70	60
400	400	120 (1)	80	65
450	500	190 (1)	90	70
500	500	190 (1)	90	70
560	600	220 (1)	100	80
630	600	220 (1)	100	80

(1) *for $P_{acc} \leq 6$ bar*

Table 8.1 Bolt tightening torques for flat, profile and O-ring gaskets

8.2.3 Push-fit connection

A push-fit connection is the general name given to all spigot and socket connections. The push-fit socket to be used will be explained in the following section.



Figure 8.4 Push-fit spigot

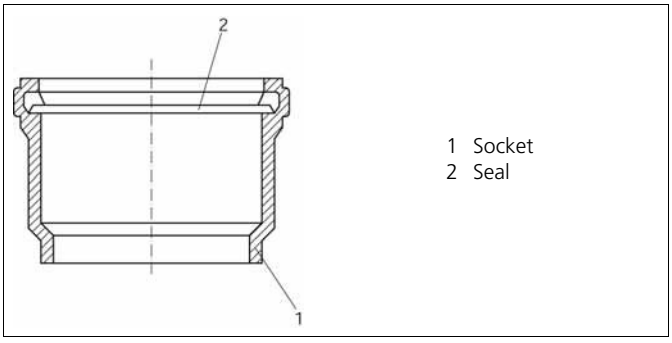


Figure 8.5 Cross-section of a connection with a push-fit socket

Push-fit and expansion sockets

The leak-tightness of a pipe connection with a push-fit and/or expansion socket is essentially achieved by applying the forces of a sealing element to the connecting pipe and/or fitting. In addition, the existing internal pressure helps to strengthen the radial sealing force. Small pipe deflections can be tolerated, as well as longitudinal movements corresponding to the distance that can be absorbed between the socket and seal seat.

Socket connections should only be used in pressure applications involving pipe systems that are free of underpressure. In principle, use is to be entirely avoided in pipe systems subject to internal pressure and another jointing technique chosen.

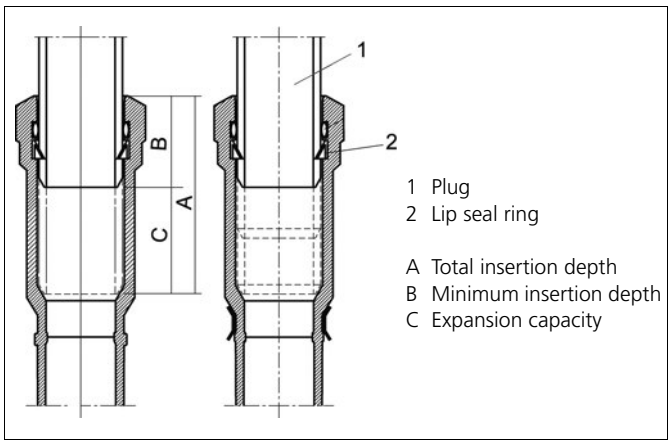


Figure 8.6 Functional principle of the expansion socket

8.2.4 Unions

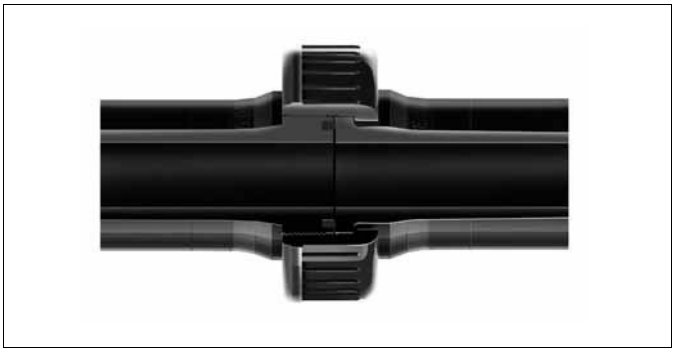


Figure 8.7 Screw-thread joint

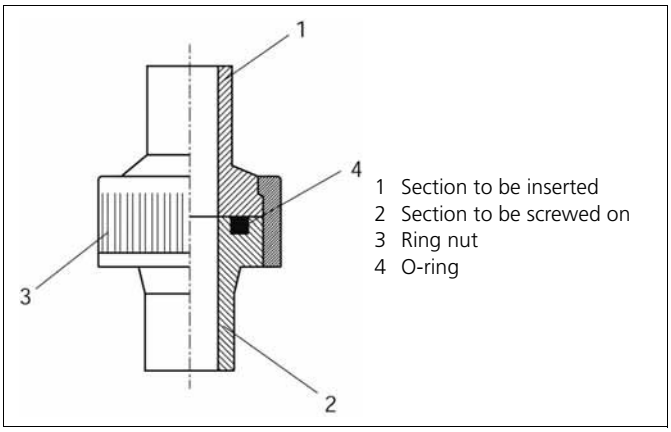


Figure 8.8 Cross-section of a union

These types of connecting elements are used in water lines as well as in transitions from plastic to other materials. The ease of assembly make them an especially valued connecting technique for small pipe sizes. Temperature effects can restrict application in pipe systems due to the flow behaviour of plastic. Each application must be carefully tested.

8.2.5 Compression fitting

Compression fittings are used to connect pipes in a quick and easy manner. A pressure chamber contains a sealing ring. Screwing in the fitting causes the sealing ring to be clamped against the pipe. NBR O-rings are used to connect the PE pipes. Special compression rings can be adopted to connect PE pipes with other types of material, such as PVC-U, PVC-C, PP, PE-X copper, lead and steel. Compression fittings are used in swimming-pool systems, for (drinking) water distribution, irrigation and telecommunications as well as in the mining industry and horticulture.

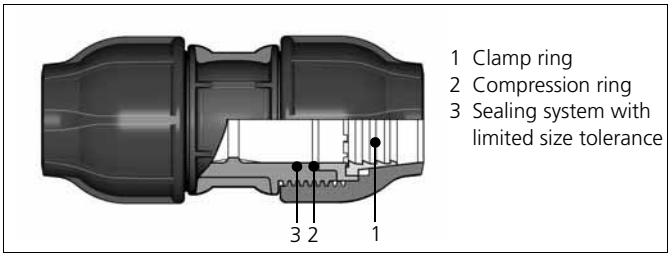


Figure 8.9 Compression fitting

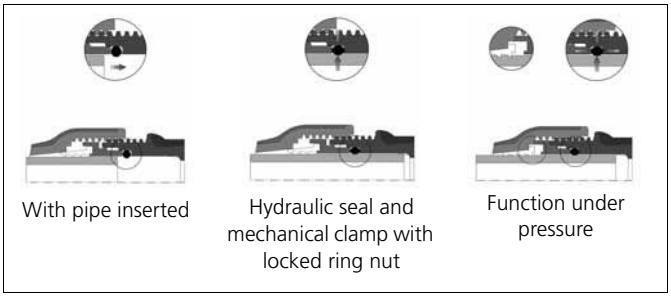


Figure 8.10 Compression principle

8.3 Non-detachable connections

8.3.1 General

Non-detachable jointing techniques are the most commonly used connection techniques in PE pipe construction. Welding is an extremely important form of connection used for PE fitting in plastic pipe construction. For this reason, welding has been made the focus of this Specification Manual and, on account of its importance, will be discussed in a separate chapter.

8.3.2 Welding

Welding has a special significance in pipe installation as well as in the production of PE shafts, tanks and special welded components. Many of the welding techniques described in chapter 9 are based on the principles in the DVS guidelines and have been adopted either directly or in analogous forms.

8.3.3 Gluing

Up to now, gluing has not been used in PE pipe construction. The characteristics of the plastics in question (polyolefin) make them unsuitable for glued connections (due to their "waxiness"), as their surfaces are not softened by adhesives. Special multi-component adhesives allow only limited connections to be formed that cannot be subject to mechanical loads and that are technically insignificant.

8.3.4 Push-fit socket end thrust bearing

Push-Fast is a unique spigot and socket type water jointing system, which combines the benefits of PE pipe with the ease of conventional push-fit joints. Unlike most spigot and socket type systems, Push-Fast has a specially designed and patented socket, which incorporates a tough thermoplastic 'grip' ring located in a tapered groove. This allows the joint to resist end-thrust generated by the internal pressure and eliminates the need for anchors or thrust blocks.



Figure 8.11 Section through assembled Push-Fast Joint showing grab ring and sealing

Push-Fast heads can easily be butt-welded to pipe lengths and coils. It is quick and easy to install. Suitable for underground pipe systems in subsidence areas and to limited space installation. The pipe system is immediately serviceable after assembly.

The performance of the Push-Fast joint depends on the efficiency of the seal between the elastromeric sealing ring, the pipe and the socket. Damage to the pipe or fittings or the presence of dirt or grit will adversely affect the performance of the joint.

8.4 Chapter summary

Connection method	In plastic pipe construction, there are two types of connecting techniques: detachable and non-detachable.
Detachable connection technique	Detachable connections can be easily disassembled and re-assembled without destroying the connection.
Non-detachable connection technique	Disassembly usually involves destruction of at least one of the connecting elements.
Flange connections	Can be fixed or backing ring connections. Backing ring connections consist of the components: stub flange, backing ring and gasket. A combination of stub flange, backing ring, blind flange and gasket can be used to seal pipes. At higher loads, backing ring connections are preferable to fixed flange connections.
Seals	Seals are needed to seal connections between two connecting elements. In the flange connections used in plastic pipe construction, flat gaskets (with and without steel inlays) and O-rings are mostly used. The material of the seal is adaptable to the flow medium.
Push-fit and expansion sockets	These are simple detachable connections. However, they should only be used in pressureless (under and overpressure free) pipe systems. They are therefore appropriate for pressureless drainage and/or sewerage systems.
Unions	Unions are quick connection devices. They are detachable connections and enable simple assembly, disassembly and re-assembly without special implements and tools.
Welding	Welding is one of the most commonly used jointing techniques in plastic pipe construction. Various plastic welding procedures are used to manufacture fittings from pipes and pipe segments, joints made of pieces of pipe, as well as plastic shafts, tanks and other special components. Welding processes non-detachable connection techniques.
Gluing	Gluing is only very conditionally meaningful and possible as an appropriate jointing technique for polyolefin materials. A bond is produced only with special multi-component adhesives. These glued connections are not at all capable of withstanding mechanical loads.
Push-fit socket end thrust bearing	Plug and socket type water jointing system with push fit joints. A tough thermoplastic 'grip' ring located in a tapered groove allows the joint to resist end-thrust. It is quick and easy to install. No anchors or thrust blocks required. Suitable for ground subsidence areas and to limited space installation. Immediately serviceable.

Aliaxis
UTILITIES & INDUSTRY

FIP

PRODUCT TABLES

Foreword catalogue

Technical data
All data complies with the actual technical data at time of print of this publication. All dimensions are in mm, unless otherwise stated. FIP cannot be held responsible for printing errors and temporary changes in this catalogue. For more information contact our Technical Support.

Approvals
The FIP product range has the following approvals and certificates:
- FIP spigot fittings: Kiwa and DVGW
- FIP S.p.A.: ISO 9001 and ISO 14001

Assembly instructions
The following guidelines are applicable for the jointing of the different product ranges:
- FIP spigot fittings according the appicable (inter)national standard
- Electrofusion fittings according FRIALEN assembly instruction or the applicable (inter)national standard.

Delivery conditions
Our general terms and conditions are applicable.

Inspection certificate
Inspection certificates can be issued and have to be requested at time of ordering. FIP will charge €25,- handling fee.

Distribution
The FIP pressure system is sold through a network of distributors. The contact details of the distributor in your country can be requested at the Customer Service department or can be found on our website: www.fipnet.it.

Storage
Fittings need to be stored in a dry environment. We recommand to keep the fittings as long as possible in the original packing to prevent corrosion and pollution.

Return goods
Products can only be returned after FIP has expressly given its consent in writing, an handling fee will be charged.

Service
Realising dureable and reliable joints request more than just good products. By giving training, supplying product information and site support we try to inform contractors, consultants, end-users and distributors about the properties, applications and assembly of PE pressure pipe systems. We do this with only one goal:
Safe and reliable jointings!

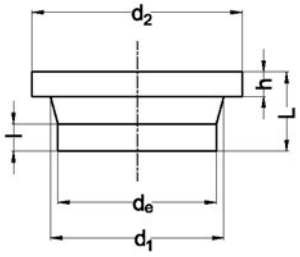
ABBREVIATONS	
AG	article group
Art. Nr.	article number
DN	nominal size
d_e	outside diameter
e	wall thickness of a pipe
G	cilindrical pipe threads where pressure-tight joints are not made on the threads ISO 228
L	length of fitting
l	length of spigot
q	package quantity
R	male pipe threads where pressure-tight joints are made on the threads ISO 7
R_p	cilindrical female pipe threads where pressure-tight joints are made on the threads ISO 7
R_c	conical female pipe threads where pressure-tight joints are made on the threads ISO 7
SDR	ratio between outer diameter / wall thickness
EN	European standard
ISO	international standard
DIN	national standard in Germany
ASTM	American standard
S	class indication ISO-S = (SDR-1)/2
o.r.	on request

Stub flange short QBE SDR 33

PE100
SDR 33
water 3,2 bar

for butt-welding





d_e	Art. Nr.		h	l	d_1	d_2	L
110	**QBE33110**		18	34	125	158	80
125	**QBE33125**		18	38	132	158	80
140	**QBE33140**		18	32	155	188	80
160	**QBE33160**		18	26	175	212	80
180	**QBE33180**		18	31	183	212	80
200	**QBE33200**		18	34	232	268	100
225	**QBE33225**		18	46	235	268	100
250	**QBE33250**		20	71	285	320	132
280	**QBE33280**		20	62	291	320	128
315	**QBE33315**		20	71	335	370	136
355	**QBE33355**		23	57	373	430	120
400	**QBE33400**		26	49	427	482	120
450	**QBE33450**		33	27	514	585	120
500	**QBE33500**		33	37	530	585	120
560	**QBE33560**		35	25	615	685	120
630	**QBE33630**		35	45	642	685	120
710	**QBE33710**	*	35	35	737	800	120
800	**QBE33800**	*	36	34	840	905	120
900	**QBE33900**	*	40	30	944	1005	120
1000	**QBE331000**	*	42	28	1047	1110	140
1200	**QBE331200**	*	50	20	1245	1330	140

* *fabrication on order, returning not possible*

With grooved jointing face.

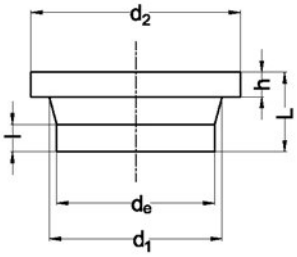
Short fittings for butt-welding

Stub flange short QBE SDR 17

for butt-welding

PE100
SDR 17
water 10 bar/gas 5 bar





d_e	Art. Nr.		h	l	d_1	d_2	L
50	**QBE17050**		12	21	61	88	50
63	**QBE17063**		14	16	75	102	50
75	**QBE17075**		16	14	89	122	50
90	**QBE17090**		17	33	105	138	80
110	**QBE17110**		18	27	125	158	80
125	**QBE17125**		18	42	132	158	80
140	**QBE17140**		18	34	155	188	80
160	**QBE17160**		18	34	175	212	80
180	**QBE17180**		20	60	182	212	80
200	**QBE17200**		24	36	232	268	100
225	**QBE17225**		24	46	235	268	100
250	**QBE17250**		25	35	285	320	100
280	**QBE17280**		25	45	291	320	100
315	**QBE17315**		25	35	335	370	100
355	**QBE17355**		30	30	373	430	120
400	**QBE17400**		33	42	427	482	120
450	**QBE17450**		46	14	514	585	120
500	**QBE17500**		46	24	530	585	120
560	**QBE17560**		50	10	615	685	120
630	**QBE17630**		50	30	642	685	120
710	**QBE17710**	*	50	20	737	800	120
800	**QBE17800**	*	52	18	840	905	120
900	**QBE17900**	*	55	15	944	1005	120
1000	**QBE171000**	*	60	10	1047	1110	140

* *fabrication on order, returning not possible*

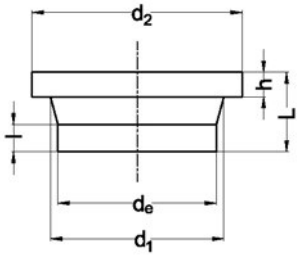
With grooved jointing face.

Stub flange short QBE SDR 11

for butt-welding

PE100
SDR 11
water 16 bar/gas 10 bar





d_e	Art. Nr.		h	l	d_1	d_2	L
20	**QBE11020**		7	30	27	45	50
25	**QBE11025**		9	26	33	58	50
32	**QBE11032**		10	25	40	68	50
40	**QBE11040**		11	24	50	78	50
50	**QBE11050**		12	21	61	88	50
63	**QBE11063**		14	16	75	102	50
75	**QBE11075**		16	14	89	122	50
90	**QBE11090**		17	33	105	138	80
110	**QBE11110**		18	27	125	158	80
125	**QBE11125**		25	25	132	158	80
140	**QBE11140**		25	27	155	188	80
160	**QBE11160**		25	34	175	212	80
180	**QBE11180**		30	60	182	212	80
200	**QBE11200**		32	36	232	268	100
225	**QBE11225**		32	46	235	268	100
250	**QBE11250**		35	35	285	320	100
280	**QBE11280**		35	45	291	320	100
315	**QBE11315**		35	35	335	370	100
355	**QBE11355**		40	30	373	430	120
400	**QBE11400**		46	29	427	482	120
450	**QBE11450**		60	20	514	585	120
500	**QBE11500**		60	20	530	585	120
560	**QBE11560**		60	30	615	685	120
630	**QBE11630**		60	20	642	685	120
710	**QBE11710**	*	67	20	737	800	120
800	**QBE11800**	*	74	20	840	905	120

* *fabrication on order, returning not possible*

With grooved jointing face.

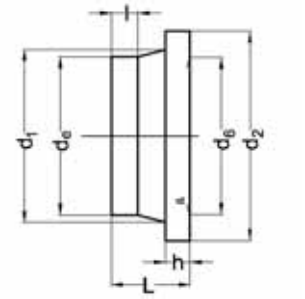
Short fittings for butt-welding

Stub flange short QBE/FK SDR 17 for FIP butterfly valve type FE and FK

PE100
SDR 17
water 10 bar

for butt-welding





d_e/DN	Art. Nr.		h	l	d_1	d_2	d_6/ß	L
50/40	**QPE17050**		12	21	61	88		50
63/50	**QPE17063**		14	16	75	102		50
75/65	**QPE17075**		16	14	89	122		50
90/80	**QPE17090**		17	33	105	138		80
110/100	**QPE17110**		18	27	125	158		80
125/100	**QPE17125**		18	42	132	158		80
140/125	**QPE17140**		18	34	155	188		80
160/150	**QPE17160**		18	34	175	212		80
180/150	**QPE17180**		20	60	182	212		80
200/200	**QBE17FK200**	*	24	36	232	268	179/20°	100
225/200	**QPE17225**		24	46	235	268		100
250/250	**QBE17FK250**	*	25	35	285	320	233/25°	100
280/250	**QPE17280**		25	45	291	320		100
315/300	**QBE17FK315**	*	25	35	335	370	288/25°	100

* *machined for free movement of disc*

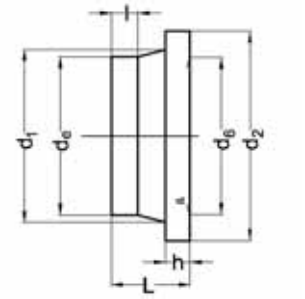
With flat jointing face.
Suitable for installation on both sides of the butterfly valve.
Dimensions are adapted to the profile backing ring for stub flange.

Stub flange short QBE/FK SDR 11 for FIP butterfly valve type FE and FK

PE100
SDR 11
water 16 bar

for butt-welding





d_e/DN	Art. Nr.		h	l	d_1	d_2	d_6/ß	L
50/40	**QPE11050**		12	21	61	88		50
63/50	**QPE11063**		14	16	75	102		50
75/65	**QPE11075**		16	14	89	122		50
90/80	**QPE11090**		17	33	105	138		80
110/100	**QPE11110**		18	27	125	158		80
125/100	**QPE11125**		25	25	132	158		80
140/125	**QPE11140**		25	27	155	188		80
160/150	**QBE11FK160**	*	25	34	175	212	148/20°	80
180/150	**QPE11180**		30	60	182	212		80
200/200	**QBE11FK200**	*	32	36	232	268	192/25°	100
225/200	**QBE11FK225**	*	32	46	235	268	201/15°	100
250/250	**QBE11FK250**	*	35	35	285	320	233/25°	100
280/250	**QBE11FK280**	*	35	45	291	320	257/25°	100
315/300	**QBE11FK315**	*	35	35	335	370	288/25°	100

* *machined for free movement of disc*

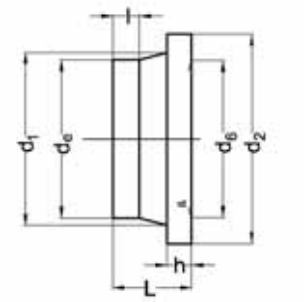
With flat jointing face.
Suitable for installation on both sides of the butterfly valve.
Dimensions are adapted to the profile backing ring for stub flange.

Stub flange short QPE SDR 17 for entrance side FIP check valve type CR and FR

PE100
SDR 17
water 10 bar

for butt-welding





d_e/DN	Art. Nr.	h	l	d_1	d_2	L
50/40	**QPE17050**	12	21	61	88	50
63/50	**QPE17063**	14	16	75	102	50
75/65	**QPE17075**	16	14	89	122	50
90/80	**QPE17090**	17	33	105	138	80
110/100	**QPE17110**	18	27	125	158	80
125/100	**QPE17125**	18	42	132	158	80
140/125	**QPE17140**	18	34	155	188	80
160/150	**QPE17160**	18	34	175	212	80
180/150	**QPE17180**	20	60	182	212	80
200/200	**QPE17200**	24	36	232	268	100
225/200	**QPE17225**	24	46	235	268	100
250/250	**QPE17250**	25	35	285	320	100
280/250	**QPE17280**	25	45	291	320	100
315/300	**QPE17315**	25	35	335	370	100

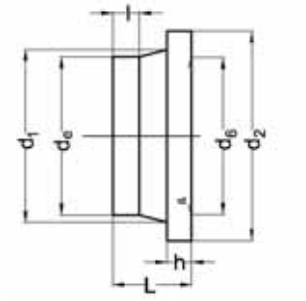
With flat jointing face.
Suitable for installation on entrance side. Install stub flange extended short CR/FR on exit side.
Dimensions are adapted to the profile backing ring for stub flange.

Stub flange short QPE SDR 11 for entrance side FIP check valve type CR and FR

PE100
SDR 11
water 16 bar

for butt-welding





d_e/DN	Art. Nr.	h	l	d_1	d_2	L
50/40	**QPE11050**	12	21	61	88	50
63/50	**QPE11063**	14	16	75	102	50
75/65	**QPE11075**	16	14	89	122	50
90/80	**QPE11090**	17	33	105	138	80
110/100	**QPE11110**	18	27	125	158	80
125/100	**QPE11125**	25	25	132	158	80
140/125	**QPE11140**	25	27	155	188	80
160/150	**QPE11160**	25	34	175	212	80
180/150	**QPE11180**	30	60	182	212	80
200/200	**QPE11200**	32	36	232	268	100
225/200	**QPE11225**	32	46	235	268	100
250/250	**QPE11250**	35	35	285	320	100
280/250	**QPE11280**	35	45	291	320	100
315/300	**QPE11315**	35	35	335	370	100

With flat jointing face.
Suitable for installation on entrance side. Install stub flange extended short CR/FR on exit side. Dimensions are adapted to the profile backing ring for stub flange.

Short fittings for butt-welding

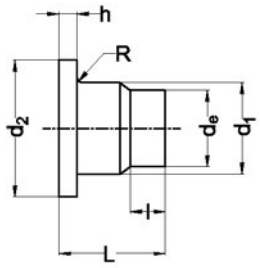
Stub flange extended short QBXE SDR 17 for exit side FIP check valve type CR and FR

PE100
SDR 17
water 10 bar

for butt-welding



d_e/DN	Art. Nr.	h	l	d_1	d_2	L	R
50/40	**QBXE17050**	12	20	61	90	50	3
63/50	**QBXE17063**	14	20	75	105	54	4
75/65	**QBXE17075**	16	20	89	125	58	4
90/80	**QBXE17090**	17	40	105	138	92	4
110/100	**QBXE17110**	18	40	125	160	92	4
140/125	**QBXE17140**	18	40	155	190	100	4
160/150	**QBXE17160**	18	40	175	215	120	4
225/200	**QBXE17225**	24	40	235	270	165	4
280/250	**QBXE17280**	25	40	291	325	195	6
315/300	**QBXE17315**	25	40	335	375	250	6



With flat jointing face. Extended for free movement of disc.
Suitable for installation on exit side. Install stub flange short CR/FR on entrance side.
Dimensions are adapted to the profile backing ring for stub flange.
Fabrication on order.

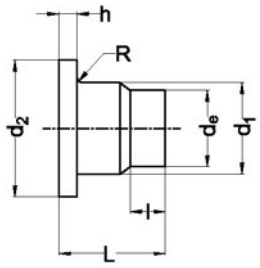
Stub flange extended short QBXE SDR 11 for exit side FIP check valve type CR and FR

PE100
SDR 11
water 16 bar

for butt-welding



d_e/DN	Art. Nr.	h	l	d_1	d_2	L	R
50/40	**QBXE11050**	12	20	61	90	50	3
63/50	**QBXE11063**	14	20	75	105	56	4
75/65	**QBXE11075**	16	20	89	125	65	4
90/80	**QBXE11090**	17	35	105	138	92	4
110/100	**QBXE11110**	18	35	125	160	92	4
140/125	**QBXE11140**	18	40	155	190	110	4
160/150	**QBXE11160**	18	40	175	215	120	4
225/200	**QBXE11225**	26	56	235	270	180	4
280/250	**QBXE11280**	35	40	291	325	220	6
315/300	**QBXE11315**	35	40	335	375	270	6



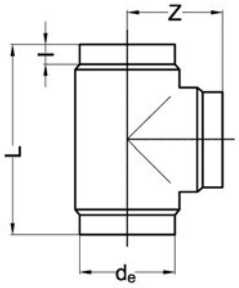
With flat jointing face. Extended for free movement of disc.
Suitable for installation on exit side. Install stub flange short CR/FR on entrance side.
Dimensions are adapted to the profile backing ring for stub flange.
Fabrication on order.

Tee 90° short TBE SDR 33

PE100
SDR 33
water 3,2 bar

for butt-welding





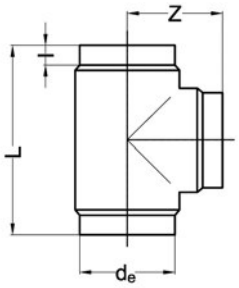
d_e	Art. Nr.	L	Z	l
110	**TBE33110**	249	121	50
140	**TBE33140**	293	145	48
160	**TBE33160**	318	160	55
180	**TBE33180**	356	175	59
200	**TBE33200**	385	194	55
225	**TBE33225**	442	212	59
250	**TBE33250**	465	232	70
280	**TBE33280**	536	268	80
315	**TBE33315**	530	263	75
355	**TBE33355**	658	330	95
400	**TBE33400**	690	345	104
450	**TBE33450**	890	450	130
500	**TBE33500**	895	450	130

Tee 90° short TBE SDR 17

PE100
SDR 17
water 10 bar/gas 5 bar

for butt-welding





d_e	Art. Nr.	L	Z	l
50	**TBE17050**	116	58	21
63	**TBE17063**	146	73	24
75	**TBE17075**	170	85	28
90	**TBE17090**	200	100	23
110	**TBE17110**	240	120	43
125	**TBE17125**	250	125	26
140	**TBE17140**	280	140	32
160	**TBE17160**	350	160	40
180	**TBE17180**	390	195	73
200	**TBE17200**	430	215	64
225	**TBE17225**	490	245	72
250	**TBE17250**	550	275	86
280	**TBE17280**	620	310	105
315	**TBE17315**	700	350	111
355	**TBE17355**	680	340	101
400	**TBE17400**	680	338	95
450	**TBE17450**	900	450	130
500	**TBE17500**	900	450	130

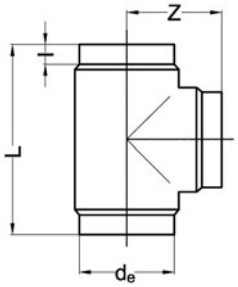
Short fittings for butt-welding

Tee 90° short TBE SDR 11

for butt-welding

PE100
SDR 11
water 16 bar/gas 10 bar





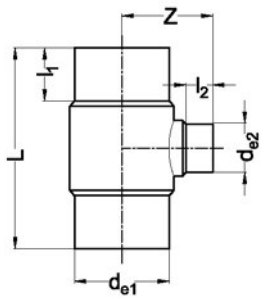
d_e	Art. Nr.	L	Z	l
20	**TBE11020**	50	25	8
25	**TBE11025**	60	30	10
32	**TBE11032**	80	40	12
40	**TBE11040**	88	44	16
50	**TBE11050**	116	58	21
63	**TBE11063**	146	73	24
75	**TBE11075**	170	85	28
90	**TBE11090**	200	100	23
110	**TBE11110**	240	120	43
125	**TBE11125**	250	125	26
140	**TBE11140**	280	140	32
160	**TBE11160**	350	160	40
180	**TBE11180**	390	195	73
200	**TBE11200**	430	215	64
225	**TBE11225**	490	245	72
250	**TBE11250**	550	275	86
280	**TBE11280**	620	310	105
315	**TBE11315**	700	350	111
355	**TBE11355**	680	340	101
400	**TBE11400**	680	338	95
450	**TBE11450**	900	450	130
500	**TBE11500**	900	450	130

Tee 90° reduced short TRBE SDR 17

with reduced branch
for butt-welding

PE100
SDR 17
water 10 bar/gas 5 bar



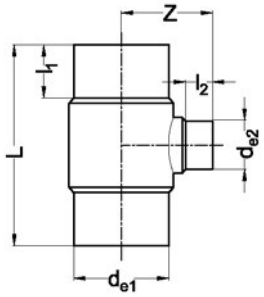


d_{e1}/d_{e2}	Art. Nr.	L	Z	l_1	l_2
110/90	**TRBE17110090**	240	115	48	38
140/63	**TRBE17140063**	300	120	83	32
140/75	**TRBE17140075**	300	130	81	35
140/90	**TRBE17140090**	300	130	81	41
140/110	**TRBE17140110**	300	137	50	47
160/110	**TRBE17160110**	320	145	56	38
160/125	**TRBE17160125**	315	150	58	47
180/63	**TRBE17180063**	358	134	125	30
180/75	**TRBE17180075**	360	140	112	30
180/125	**TRBE17180125**	358	160	92	50
225/110	**TRBE17225110**	440	264	89	89
225/125	**TRBE17225125**	445	180	135	40
225/160	**TRBE17225160**	470	200	89	60

Tee 90° reduced short TRBE SDR 11
with reduced branch
for butt-welding

PE100
SDR 11
water 16 bar/gas 10 bar





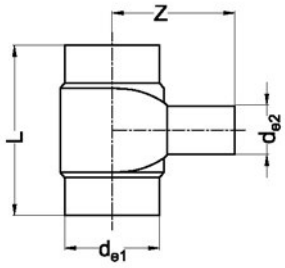
d_{e1}/d_{e2}	Art. Nr.	L	Z	l_1	l_2
90/50	**TRBE11090050**	213	90	53	28
110/32	**TRBE11110032**	244	94	66	22
110/50	**TRBE11110050**	244	103	66	27
125/63	**TRBE11125063**	278	112	70	31
140/63	**TRBE11140063**	305	120	83	32
140/75	**TRBE11140075**	305	130	81	35
140/90	**TRBE11140090**	305	130	81	41
140/110	**TRBE11140110**	305	140	50	47
160/110	**TRBE11160110**	320	145	56	38
160/125	**TRBE11160125**	325	150	58	47
180/63	**TRBE11180063**	358	134	125	30
180/75	**TRBE11180075**	352	140	112	30
180/110	**TRBE11180110**	365	158	106	48
180/125	**TRBE11180125**	366	166	92	50
225/110	**TRBE11225110**	440	264	89	88
225/125	**TRBE11225125**	456	178	135	40
225/160	**TRBE11225160**	470	200	89	60

Short fittings for butt-welding

Tee 90° reduced machined short TRCBE SDR17 - pressure class conform
with reduced branch
for butt-welding

PE100
SDR 17
water 10 bar/gas 5 bar





d_{e1}/d_{e2}	Art. Nr.	L	Z
280/63	**TRCBE17280063**	270	365
280/75	**TRCBE17280075**	280	365
280/90	**TRCBE17280090**	295	365
280/110	**TRCBE17280110**	315	365
280/125	**TRCBE17280125**	330	365
280/140	**TRCBE17280140**	345	365
280/160	**TRCBE17280160**	365	365
280/180	**TRCBE17280180**	385	365
280/200	**TRCBE17280200**	405	365
280/225	**TRCBE17280225**	430	365
315/75	**TRCBE17315075**	280	380
315/90	**TRCBE17315090**	295	380
315/110	**TRCBE17315110**	315	380
315/125	**TRCBE17315125**	330	380
315/140	**TRCBE17315140**	345	380
315/160	**TRCBE17315160**	365	380
315/180	**TRCBE17315180**	385	380
315/200	**TRCBE17315200**	405	380
315/225	**TRCBE17315225**	430	380
315/250	**TRCBE17315250**	455	380
355/90	**TRCBE17355090**	305	400
355/110	**TRCBE17355110**	325	400
355/125	**TRCBE17355125**	340	400
355/140	**TRCBE17355140**	355	400
355/160	**TRCBE17355160**	375	400
355/180	**TRCBE17355180**	395	400
355/200	**TRCBE17355200**	415	400
355/225	**TRCBE17355225**	440	400
355/250	**TRCBE17355250**	465	400
355/280	**TRCBE17355280**	500	400
400/110	**TRCBE17400110**	325	425
400/125	**TRCBE17400125**	340	425
400/140	**TRCBE17400140**	355	425
400/160	**TRCBE17400160**	375	425
400/180	**TRCBE17400180**	395	425
400/200	**TRCBE17400200**	415	425
400/225	**TRCBE17400225**	440	425
400/250	**TRCBE17400250**	465	425
400/280	**TRCBE17400280**	500	425
400/315	**TRCBE17400315**	535	425
450/125	**TRCBE17450125**	340	450
450/140	**TRCBE17450140**	355	450
450/160	**TRCBE17450160**	375	450
450/180	**TRCBE17450180**	395	450
450/200	**TRCBE17450200**	415	450
450/225	**TRCBE17450225**	440	450
450/250	**TRCBE17450250**	465	450
450/280	**TRCBE17450280**	500	450
450/315	**TRCBE17450315**	535	450
450/355	**TRCBE17450355**	575	450
500/140	**TRCBE17500140**	355	475
500/160	**TRCBE17500160**	375	475
500/180	**TRCBE17500180**	395	475
500/200	**TRCBE17500200**	415	475
500/225	**TRCBE17500225**	440	475
500/250	**TRCBE17500250**	465	475

-- to be continued --

Tee 90° reduced machined short TRCBE SDR17 - pressure class conform - continuation -

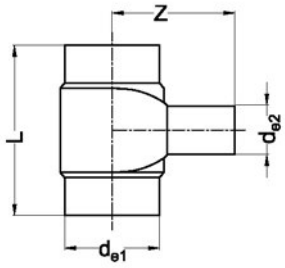
d_{e1}/d_{e2}	Art. Nr.	L	Z
500/280	**TRCBE17500280**	500	475
500/315	**TRCBE17500315**	535	475
500/355	**TRCBE17500355**	575	475
500/400	**TRCBE17500400**	620	475
560/160	**TRCBE17560160**	375	500
560/180	**TRCBE17560180**	395	500
560/200	**TRCBE17560200**	415	500
560/225	**TRCBE17560225**	440	500
560/250	**TRCBE17560250**	465	500
560/280	**TRCBE17560280**	500	500
560/315	**TRCBE17560315**	535	500
560/355	**TRCBE17560355**	575	500
560/400	**TRCBE17560400**	620	500
560/450	**TRCBE17560450**	670	500
560/560	**TRCBE17560560**	780	500
630/180	**TRCBE17630180**	395	540
630/200	**TRCBE17630200**	415	540
630/225	**TRCBE17630225**	440	540
630/250	**TRCBE17630250**	465	540
630/280	**TRCBE17630280**	500	540
630/315	**TRCBE17630315**	535	540
630/355	**TRCBE17630355**	575	540
630/400	**TRCBE17630400**	620	540
630/450	**TRCBE17630450**	670	540
630/500	**TRCBE17630500**	720	540
630/630	**TRCBE17630630**	850	540
710/180	**TRCBE17710180**	395	620
710/200	**TRCBE17710200**	415	620
710/225	**TRCBE17710225**	440	620
710/250	**TRCBE17710250**	465	620
710/280	**TRCBE17710280**	500	620
710/315	**TRCBE17710315**	535	620
710/355	**TRCBE17710355**	575	620
710/400	**TRCBE17710400**	620	620
710/450	**TRCBE17710450**	670	620
710/500	**TRCBE17710500**	720	620
710/560	**TRCBE17710560**	780	620
710/710	**TRCBE17710710**	950	650

Pressure rating guaranteed, branch extended with pipe.
Fabrication on order, returning not possible.

Short fittings for butt-welding

Tee 90° reduced machined short TRCBE SDR11 - pressure class conform PE100
with reduced branch SDR 11
for butt-welding water 16 bar/gas 10 bar





d_{e1}/d_{e2}	Art. Nr.	L	Z
280/63	**TRCBE11280063**	270	365
280/75	**TRCBE11280075**	280	365
280/90	**TRCBE11280090**	295	365
280/110	**TRCBE11280110**	315	365
280/125	**TRCBE11280125**	330	365
280/140	**TRCBE11280140**	345	365
280/160	**TRCBE11280160**	365	365
280/180	**TRCBE11280180**	385	365
280/200	**TRCBE11280200**	405	365
280/225	**TRCBE11280225**	430	365
315/75	**TRCBE11315075**	280	380
315/90	**TRCBE11315090**	295	380
315/110	**TRCBE11315110**	315	380
315/125	**TRCBE11315125**	330	380
315/140	**TRCBE11315140**	345	380
315/160	**TRCBE11315160**	365	380
315/180	**TRCBE11315180**	385	380
315/200	**TRCBE11315200**	405	380
315/225	**TRCBE11315225**	430	380
315/250	**TRCBE11315250**	455	380
355/90	**TRCBE11355090**	305	400
355/110	**TRCBE11355110**	325	400
355/125	**TRCBE11355125**	340	400
355/140	**TRCBE11355140**	355	400
355/160	**TRCBE11355160**	375	400
355/180	**TRCBE11355180**	395	400
355/200	**TRCBE11355200**	415	400
355/225	**TRCBE11355225**	440	400
355/250	**TRCBE11355250**	465	400
355/280	**TRCBE11355280**	500	400
400/110	**TRCBE11400110**	325	425
400/125	**TRCBE11400125**	340	425
400/140	**TRCBE11400140**	355	425
400/160	**TRCBE11400160**	375	425
400/180	**TRCBE11400180**	395	425
400/200	**TRCBE11400200**	415	425
400/225	**TRCBE11400225**	440	425
400/250	**TRCBE11400250**	465	425
400/280	**TRCBE11400280**	500	425
400/315	**TRCBE11400315**	535	425
450/125	**TRCBE11450125**	340	450
450/140	**TRCBE11450140**	355	450
450/160	**TRCBE11450160**	375	450
450/180	**TRCBE11450180**	395	450
450/200	**TRCBE11450200**	415	450
450/225	**TRCBE11450225**	440	450
450/250	**TRCBE11450250**	465	450
450/280	**TRCBE11450280**	500	450
450/315	**TRCBE11450315**	535	450
450/355	**TRCBE11450355**	575	450
500/140	**TRCBE11500140**	355	475
500/160	**TRCBE11500160**	375	475
500/180	**TRCBE11500180**	395	475
500/200	**TRCBE11500200**	415	475
500/225	**TRCBE11500225**	440	475
500/250	**TRCBE11500250**	465	475

-- to be continued --

Tee 90° reduced machined short TRCBE SDR11 - pressure class conform - continuation -

d_{e1}/d_{e2}	Art. Nr.	L	Z
500/280	**TRCBE11500280**	500	475
500/315	**TRCBE11500315**	535	475
500/355	**TRCBE11500355**	575	475
500/400	**TRCBE11500400**	620	475
560/160	**TRCBE11560160**	375	500
560/180	**TRCBE11560180**	395	500
560/200	**TRCBE11560200**	415	500
560/225	**TRCBE11560225**	440	500
560/250	**TRCBE11560250**	465	500
560/280	**TRCBE11560280**	500	500
560/315	**TRCBE11560315**	535	500
560/355	**TRCBE11560355**	575	500
560/400	**TRCBE11560400**	620	500
560/450	**TRCBE11560450**	670	500
560/560	**TRCBE11560560**	780	500
630/180	**TRCBE11630180**	395	540
630/200	**TRCBE11630200**	415	540
630/225	**TRCBE11630225**	440	540
630/250	**TRCBE11630250**	465	540
630/280	**TRCBE11630280**	500	540
630/315	**TRCBE11630315**	535	540
630/355	**TRCBE11630355**	575	540
630/400	**TRCBE11630400**	620	540
630/450	**TRCBE11630450**	670	540
630/500	**TRCBE11630500**	720	540
630/630	**TRCBE11630630**	850	540
710/180	**TRCBE11710180**	395	620
710/200	**TRCBE11710200**	415	620
710/225	**TRCBE11710225**	440	620
710/250	**TRCBE11710250**	465	620
710/280	**TRCBE11710280**	500	620
710/315	**TRCBE11710315**	535	620
710/355	**TRCBE11710355**	575	620
710/400	**TRCBE11710400**	620	620
710/450	**TRCBE11710450**	670	620
710/500	**TRCBE11710500**	720	620
710/560	**TRCBE11710560**	780	620
710/710	**TRCBE11710710**	950	650

Pressure rating guaranteed, branch extended with pipe.
Fabrication on order, returning not possible.

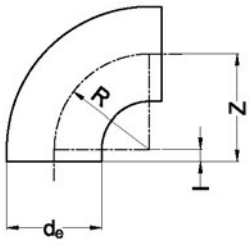
Short fittings for butt-welding

Bend 90° short GBE SDR 33

PE100
SDR 33
water 3,2 bar

for butt-welding





d_e	Art. Nr.	Z	l	R
110	**GBE33110**	120	10	110
125	**GBE33125**	140	15	125
140	**GBE33140**	150	10	140
160	**GBE33160**	180	25	155
180	**GBE33180**	200	25	175
200	**GBE33200**	220	23	197
225	**GBE33225**	250	20	230
250	**GBE33250**	290	25	265
280	**GBE33280**	290	10	280
315	**GBE33315**	340	40	300
355	**GBE33355**	340	40	300
400	**GBE33400**	345	45	300
450	**GBE33450**	450	50	400
500	**GBE33500**	450	50	400

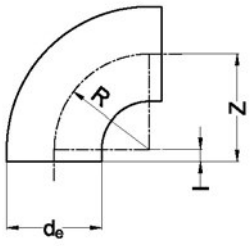
$R \approx 1 \times d_e$

Bend 90° short GBE SDR 17

PE100
SDR 17
water 10 bar/gas 5 bar

for butt-welding





d_e	Art. Nr.	Z	l	R
50	**GBE17050**	62	7	55
63	**GBE17063**	77	8	69
75	**GBE17075**	85	10	75
90	**GBE17090**	100	10	90
110	**GBE17110**	120	10	110
125	**GBE17125**	140	15	125
140	**GBE17140**	155	15	140
160	**GBE17160**	175	15	160
180	**GBE17180**	195	15	180
200	**GBE17200**	215	15	200
225	**GBE17225**	245	20	225
250	**GBE17250**	275	25	250
280	**GBE17280**	310	30	280
315	**GBE17315**	350	35	315
355	**GBE17355**	340	40	300
400	**GBE17400**	350	50	300
450	**GBE17450**	450	50	400
500	**GBE17500**	450	50	400

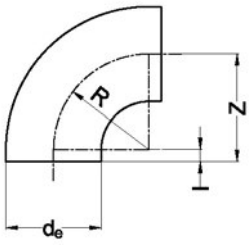
$R \approx 1 \times d_e$

Bend 90° short GBE SDR 11

for butt-welding

PE100
SDR 11
water 16 bar/gas 10 bar





d_e	Art. Nr.	Z	I	R
20	**GBE11020**	27	3	24
25	**GBE11025**	32	5	27
32	**GBE11032**	40	5	35
40	**GBE11040**	51	7	44
50	**GBE11050**	62	7	55
63	**GBE11063**	77	8	69
75	**GBE11075**	85	10	75
90	**GBE11090**	100	10	90
110	**GBE11110**	120	10	110
125	**GBE11125**	140	15	125
140	**GBE11140**	155	15	140
160	**GBE11160**	175	15	160
180	**GBE11180**	195	15	180
200	**GBE11200**	215	15	200
225	**GBE11225**	245	20	225
250	**GBE11250**	275	25	250
280	**GBE11280**	310	30	280
315	**GBE11315**	350	35	315
355	**GBE11355**	340	40	300
400	**GBE11400**	350	50	300
450	**GBE11450**	450	50	400
500	**GBE11500**	450	50	400

$R \approx 1 \times d_e$

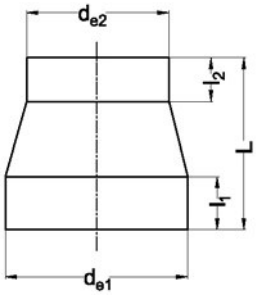
Short fittings for butt-welding

Reducer concentric DIN short RBE SDR 33

PE100
SDR 33
water 3,2 bar

for butt-welding





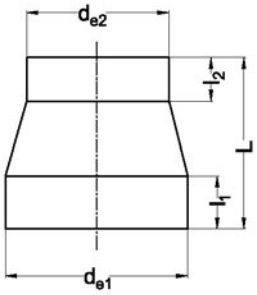
d_{e1}/d_{e2}	Art. Nr.	L	l_1	l_2
200/140	**RBE33200140**	154	50	35
200/160	**RBE33200160**	151	50	40
200/180	**RBE33200180**	151	50	45
225/140	**RBE33225140**	160	60	50
225/160	**RBE33225160**	171	55	40
225/180	**RBE33225180**	171	55	45
225/200	**RBE33225200**	171	55	50
250/160	**RBE33250160**	194	60	40
250/180	**RBE33250180**	182	60	45
250/200	**RBE33250200**	182	60	50
250/225	**RBE33250225**	182	60	55
280/200	**RBE33280200**	200	80	65
280/225	**RBE33280225**	200	80	75
280/250	**RBE33280250**	200	80	85
315/200	**RBE33315200**	230	95	85
315/225	**RBE33315225**	230	95	88
315/250	**RBE33315250**	230	95	95
315/280	**RBE33315280**	230	95	107

Reducer concentric DIN short RBE SDR 17

PE100
SDR 17
water 10 bar/gas 5 bar

for butt-welding





d_{e1}/d_{e2}	Art. Nr.	L	l_1	l_2
50/32	**RBE17050032**	55	12	12
50/40	**RBE17050040**	55	12	12
63/32	**RBE17063032**	65	16	12
63/40	**RBE17063040**	65	16	12
63/50	**RBE17063050**	65	16	12
75/32	**RBE17075032**	80	19	12
75/40	**RBE17075040**	71	19	12
75/50	**RBE17075050**	71	19	12
75/63	**RBE17075063**	71	19	16
90/50	**RBE17090050**	80	22	12
90/63	**RBE17090063**	80	22	16
90/75	**RBE17090075**	80	22	19
110/50	**RBE17110050**	105	28	12
110/63	**RBE17110063**	97	28	16
110/75	**RBE17110075**	97	28	19
110/90	**RBE17110090**	97	28	22
125/63	**RBE17125063**	112	30	16
125/75	**RBE17125075**	108	32	19
125/90	**RBE17125090**	108	32	22
125/110	**RBE17125110**	108	32	28
140/75	**RBE17140075**	123	35	19
140/90	**RBE17140090**	115	35	22
140/110	**RBE17140110**	115	35	28
140/125	**RBE17140125**	115	35	32
160/90	**RBE17160090**	135	40	22
160/110	**RBE17160110**	124	40	28
160/125	**RBE17160125**	124	40	32
160/140	**RBE17160140**	124	40	35

-- to be continued --

Reducer concentric DIN short RBE SDR 17 - continuation -

d_{e1}/d_{e2}	Art. Nr.		L	l_1	l_2
180/90	**RBE17180090**		157	45	22
180/110	**RBE17180110**		157	45	28
180/125	**RBE17180125**		136	45	32
180/140	**RBE17180140**		136	45	35
180/160	**RBE17180160**		136	45	40
200/140	**RBE17200140**		154	50	35
200/160	**RBE17200160**		151	50	40
200/180	**RBE17200180**		151	50	45
225/140	**RBE17225140**		160	60	50
225/160	**RBE17225160**		171	55	40
225/180	**RBE17225180**		171	55	45
225/200	**RBE17225200**		171	55	50
250/160	**RBE17250160**		194	60	40
250/180	**RBE17250180**		182	60	45
250/200	**RBE17250200**		182	60	50
250/225	**RBE17250225**		182	60	55
280/200	**RBE17280200**	*	200	85	70
280/225	**RBE17280225**	*	200	85	72
280/250	**RBE17280250**	*	200	85	80
315/200	**RBE17315200**	*	230	95	85
315/225	**RBE17315225**	*	230	95	88
315/250	**RBE17315250**	*	230	95	95
315/280	**RBE17315280**	*	230	95	107

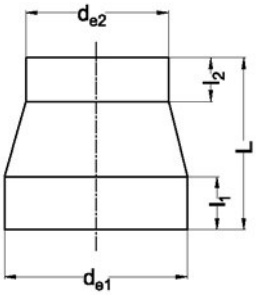
* *machined version*

Reducer concentric DIN short RBE SDR 11

for butt-welding

PE100
SDR 11
water 16 bar/gas 10 bar





d_{e1}/d_{e2}	Art. Nr.	L	l_1	l_2
25/20	**RBE11025020**	37	12	12
32/20	**RBE11032020**	43	12	12
32/25	**RBE11032025**	43	12	12
40/20	**RBE11040020**	50	12	12
40/25	**RBE11040025**	50	12	12
40/32	**RBE11040032**	50	12	12
50/25	**RBE11050025**	55	12	12
50/32	**RBE11050032**	55	12	12
50/40	**RBE11050040**	55	12	12
63/32	**RBE11063032**	65	16	12
63/40	**RBE11063040**	65	16	12
63/50	**RBE11063050**	65	16	12
75/32	**RBE11075032**	80	19	12
75/40	**RBE11075040**	71	19	12
75/50	**RBE11075050**	71	19	12
75/63	**RBE11075063**	71	19	16
90/50	**RBE11090050**	80	22	12
90/63	**RBE11090063**	80	22	16
90/75	**RBE11090075**	80	22	19
110/50	**RBE11110050**	105	28	12
110/63	**RBE11110063**	97	28	16
110/75	**RBE11110075**	97	28	19
110/90	**RBE11110090**	97	28	22
125/63	**RBE11125063**	112	30	16
125/75	**RBE11125075**	108	32	19
125/90	**RBE11125090**	108	32	22
125/110	**RBE11125110**	108	32	28
140/75	**RBE11140075**	123	35	19

-- to be continued --

Short fittings for butt-welding

Reducer concentric DIN short RBE SDR 11 - continuation -

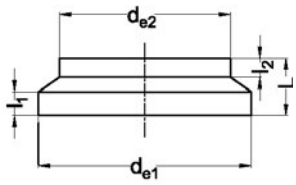
d_{e1}/d_{e2}	Art. Nr.		L	l_1	l_2
140/90	**RBE11140090**		115	35	22
140/110	**RBE11140110**		115	35	28
140/125	**RBE11140125**		115	35	32
160/90	**RBE11160090**		135	40	22
160/110	**RBE11160110**		124	40	28
160/125	**RBE11160125**		124	40	32
160/140	**RBE11160140**		124	40	35
180/90	**RBE11180090**		157	45	22
180/110	**RBE11180110**		157	45	28
180/125	**RBE11180125**		136	45	32
180/140	**RBE11180140**		136	45	35
180/160	**RBE11180160**		136	45	40
200/140	**RBE11200140**		154	50	35
200/160	**RBE11200160**		151	50	40
200/180	**RBE11200180**		151	50	45
225/140	**RBE11225140**		160	60	50
225/160	**RBE11225160**		171	55	40
225/180	**RBE11225180**		171	55	45
225/200	**RBE11225200**		171	55	50
250/160	**RBE11250160**		194	60	40
250/180	**RBE11250180**		182	60	45
250/200	**RBE11250200**		182	60	50
250/225	**RBE11250225**		182	60	55
280/200	**RBE11280200**	*	200	85	70
280/225	**RBE11280225**	*	200	85	72
280/250	**RBE11280250**	*	200	85	80
315/200	**RBE11315200**	*	230	95	85
315/225	**RBE11315225**	*	230	95	88
315/250	**RBE11315250**	*	230	95	95
315/280	**RBE11315280**	*	230	95	107

* *machined version*

Reducer concentric short RBE SDR 33 — PE100, SDR 33, water 3,2 bar

for butt-welding





d_{e1}/d_{e2}	Art. Nr.	L	l_1	l_2
355/200	**RBE33355200**	160	57	40
355/225	**RBE33355225**	140	57	40
355/250	**RBE33355250**	130	54	40
355/280	**RBE33355280**	120	53	40
355/315	**RBE33355315**	110	53	40
400/225	**RBE33400225**	160	64	40
400/250	**RBE33400250**	150	61	40
400/280	**RBE33400280**	140	60	40
400/315	**RBE33400315**	120	50	40
400/355	**RBE33400355**	110	51	40
450/280	**RBE33450280**	160	65	40
450/315	**RBE33450315**	140	55	40
450/355	**RBE33450355**	130	57	40
450/400	**RBE33450400**	120	60	40
500/280	**RBE33500280**	180	80	40
500/315	**RBE33500315**	170	71	40
500/355	**RBE33500355**	150	62	40
500/400	**RBE33500400**	140	65	40
500/450	**RBE33500450**	120	60	40
560/355	**RBE33560355**	170	75	40
560/400	**RBE33560400**	160	68	40

-- to be continued --

Reducer concentric short RBE SDR 33 - continuation -

d_{e1}/d_{e2}	Art. Nr.		L	l_1	l_2
560/450	**RBE33560450**		140	62	40
560/500	**RBE33560500**		130	67	40
630/355	**RBE33630355**		200	80	40
630/400	**RBE33630400**		190	78	40
630/450	**RBE33630450**		170	72	40
630/500	**RBE33630500**		150	67	40
630/560	**RBE33630560**		130	64	40
710/500	**RBE33710500**	*	130	84	40
710/560	**RBE33710560**	*	170	81	40
710/630	**RBE33710630**	*	140	71	40
800/560	**RBE33800560**	*	200	85	40
800/630	**RBE33800630**	*	180	85	40
800/710	**RBE33800710**	*	150	78	40
900/630	**RBE33900630**	*	220	96	40
900/710	**RBE33900710**	*	190	89	40
900/800	**RBE33900800**	*	160	85	40
1000/710	**RBE331000710**	*	220	101	40
1000/800	**RBE331000800**	*	180	86	40
1000/900	**RBE331000900**	*	140	75	40
1200/1000	**RBE3312001000**	*	190	92	40

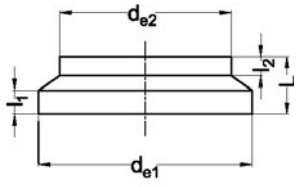
* *fabrication on order, returning not possible*

Reducer concentric short RBE SDR 17

PE100
SDR 17
water 10 bar/gas 5 bar

for butt-welding





d_{e1}/d_{e2}	Art. Nr.		L	l_1	l_2
355/200	**RBE17355200**		160	57	40
355/225	**RBE17355225**		140	57	40
355/250	**RBE17355250**		130	54	40
355/280	**RBE17355280**		120	53	40
355/315	**RBE17355315**		110	53	40
400/225	**RBE17400225**		160	64	40
400/250	**RBE17400250**		150	61	40
400/280	**RBE17400280**		140	60	40
400/315	**RBE17400315**		120	50	40
400/355	**RBE17400355**		110	51	40
450/280	**RBE17450280**		160	65	40
450/315	**RBE17450315**		140	55	40
450/355	**RBE17450355**		130	57	40
450/400	**RBE17450400**		120	60	40
500/280	**RBE17500280**		180	80	40
500/315	**RBE17500315**		170	71	40
500/355	**RBE17500355**		150	62	40
500/400	**RBE17500400**		140	65	40
500/450	**RBE17500450**		120	60	40
560/355	**RBE17560355**		170	75	40
560/400	**RBE17560400**		160	68	40
560/450	**RBE17560450**		140	62	40
560/500	**RBE17560500**		130	67	40
630/355	**RBE17630355**		200	80	40
630/400	**RBE17630400**		190	78	40
630/450	**RBE17630450**		170	72	40
630/500	**RBE17630500**		150	67	40
630/560	**RBE17630560**		130	64	40
710/500	**RBE17710500**	*	130	84	40
710/560	**RBE17710560**	*	170	81	40
710/630	**RBE17710630**	*	140	71	40

-- to be continued --

Short fittings for butt-welding

Reducer concentric short RBE SDR 17 - continuation -

d_{e1}/d_{e2}	Art. Nr.		L	l_1	l_2
800/560	**RBE17800560**	*	200	85	40
800/630	**RBE17800630**	*	180	85	40
800/710	**RBE17800710**	*	150	78	40
900/630	**RBE17900630**	*	220	96	40
900/710	**RBE17900710**	*	190	89	40
900/800	**RBE17900800**	*	160	85	40
1000/710	**RBE171000710**	*	220	101	40
1000/800	**RBE171000800**	*	180	86	40
1000/900	**RBE171000900**	*	140	75	40

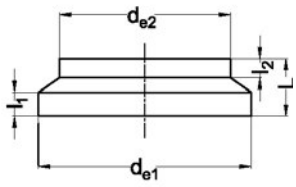
* *fabrication on order, returning not possible*

Reducer concentric short RBE SDR 11

PE100
SDR 11
water 16 bar/gas 10 bar

for butt-welding





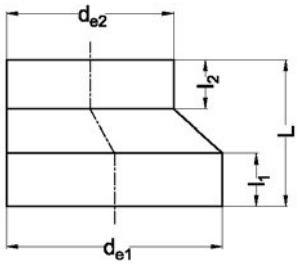
d_{e1}/d_{e2}	Art. Nr.	L	l_1	l_2
355/200	**RBE11355200**	160	57	40
355/225	**RBE11355225**	140	57	40
355/250	**RBE11355250**	130	54	40
355/280	**RBE11355280**	120	53	40
355/315	**RBE11355315**	110	53	40
400/225	**RBE11400225**	160	64	40
400/250	**RBE11400250**	150	61	40
400/280	**RBE11400280**	140	60	40
400/315	**RBE11400315**	120	50	40
400/355	**RBE11400355**	110	51	40
450/280	**RBE11450280**	160	65	40
450/315	**RBE11450315**	140	55	40
450/355	**RBE11450355**	130	57	40
450/400	**RBE11450400**	120	60	40
500/280	**RBE11500280**	180	80	40
500/315	**RBE11500315**	170	71	40
500/355	**RBE11500355**	150	62	40
500/400	**RBE11500400**	140	65	40
500/450	**RBE11500450**	120	60	40
560/355	**RBE11560355**	170	75	40
560/400	**RBE11560400**	160	68	40
560/450	**RBE11560450**	140	62	40
560/500	**RBE11560500**	130	67	40
630/355	**RBE11630355**	200	80	40
630/400	**RBE11630400**	190	78	40
630/450	**RBE11630450**	170	72	40
630/500	**RBE11630500**	150	67	40
630/560	**RBE11630560**	130	64	40

Reducer eccentric short REBE SDR 33

for butt-welding

PE100
SDR 33
water 3,2 bar





d_{e1}/d_{e2}	Art. Nr.	L	l_1	l_2
160/90	**REBE33160090**	140	54	40
160/110	**REBE33160110**	120	45	40
160/125	**REBE33160125**	110	44	40
160/140	**REBE33160140**	90	33	40
180/110	**REBE33180110**	140	54	40
180/125	**REBE33180125**	130	52	40
180/140	**REBE33180140**	110	41	40
180/160	**REBE33180160**	90	33	40
200/125	**REBE33200125**	150	61	40
200/140	**REBE33200140**	130	50	40
200/160	**REBE33200160**	110	41	40
200/180	**REBE33200180**	90	33	40
225/140	**REBE33225140**	160	65	40
225/160	**REBE33225160**	140	57	40
225/180	**REBE33225180**	120	48	40
225/200	**REBE33225200**	100	40	40
250/160	**REBE33250160**	160	62	40
250/180	**REBE33250180**	140	54	40
250/200	**REBE33250200**	120	45	40
250/225	**REBE33250225**	100	40	40
280/180	**REBE33280180**	170	66	40
280/200	**REBE33280200**	150	58	40
280/225	**REBE33280225**	130	52	40
280/250	**REBE33280250**	110	47	40
315/200	**REBE33315200**	190	78	40
315/225	**REBE33315225**	160	62	40
315/250	**REBE33315250**	140	57	40
315/280	**REBE33315280**	110	44	40

Larger diameters on request.

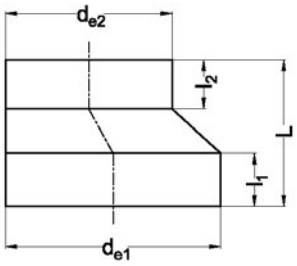
Short fittings for butt-welding

Reducer eccentric short REBE SDR 17

for butt-welding

PE100
SDR 17
water 10 bar/gas 5 bar





d_{e1}/d_{e2}	Art. Nr.	L	l_1	l_2
160/90	**REBE17160090**	140	54	40
160/110	**REBE17160110**	120	45	40
160/125	**REBE17160125**	110	44	40
160/140	**REBE17160140**	90	33	40
180/110	**REBE17180110**	140	54	40
180/125	**REBE17180125**	130	52	40
180/140	**REBE17180140**	110	41	40
180/160	**REBE17180160**	90	33	40
200/125	**REBE17200125**	150	61	40
200/140	**REBE17200140**	130	50	40
200/160	**REBE17200160**	110	41	40
200/180	**REBE17200180**	100	43	40
225/140	**REBE17225140**	160	65	40
225/160	**REBE17225160**	140	57	40
225/180	**REBE17225180**	120	48	40
225/200	**REBE17225200**	100	40	40
250/160	**REBE17250160**	160	62	40
250/180	**REBE17250180**	140	54	40
250/200	**REBE17250200**	130	55	40
250/225	**REBE17250225**	100	40	40
280/180	**REBE17280180**	170	66	40
280/200	**REBE17280200**	150	58	40
280/225	**REBE17280225**	130	52	40
280/250	**REBE17280250**	110	47	40
315/200	**REBE17315200**	190	78	40
315/225	**REBE17315225**	160	62	40
315/250	**REBE17315250**	140	57	40
315/280	**REBE17315280**	120	54	40

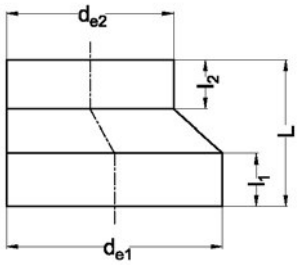
Larger diameters on request.

Reducer eccentric short REBE SDR 11

for butt-welding

PE100
SDR 11
water 16 bar/gas 10 bar





d_{e1}/d_{e2}	Art. Nr.	L	l_1	l_2
160/90	**REBE11160090**	140	54	40
160/110	**REBE11160110**	120	45	40
160/125	**REBE11160125**	110	44	40
160/140	**REBE11160140**	100	43	40
180/110	**REBE11180110**	140	54	40
180/125	**REBE11180125**	130	52	40
180/140	**REBE11180140**	120	51	40
180/160	**REBE11180160**	100	43	40
200/125	**REBE11200125**	150	61	40
200/140	**REBE11200140**	130	50	40
200/160	**REBE11200160**	120	51	40
200/180	**REBE11200180**	100	43	40
225/140	**REBE11225140**	160	65	40
225/160	**REBE11225160**	140	57	40
225/180	**REBE11225180**	120	48	40
225/200	**REBE11225200**	110	50	40
250/160	**REBE11250160**	170	72	40
250/180	**REBE11250180**	150	64	40
250/200	**REBE11250200**	130	55	40
250/225	**REBE11250225**	110	50	40
280/180	**REBE11280180**	180	76	40
280/200	**REBE11280200**	160	68	40
280/225	**REBE11280225**	140	62	40
280/250	**REBE11280250**	120	57	40
315/200	**REBE11315200**	190	78	40
315/225	**REBE11315225**	170	72	40
315/250	**REBE11315250**	150	67	40
315/280	**REBE11315280**	130	64	40

Larger diameters on request.

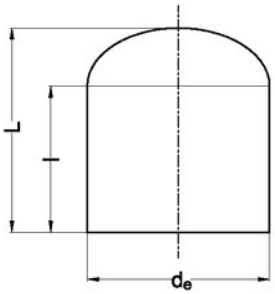
Short fittings for butt-welding

End cap long/short CBE SDR 17

PE100
SDR 17
water 10 bar/gas 5 bar

for butt-welding





d_e	Art. Nr.		L	l
63	**CDE17063**	*	85	62
75	**CDE17075**	*	95	63
90	**CDE17090**	*	110	79
110	**CDE17110**	*	127	88
125	**CDE17125**	*	124	95
140	**CDE17140**	*	140	110
160	**CDE17160**	*	152	121
180	**CDE17180**	*	169	134
200	**CDE17200**	*	184	140
225	**CDE17225**	*	200	160
250	**CDE17250**	*	230	152
280	**CDE17280**	*	257	162
315	**CDE17315**	*	262	167
355	**CDE17355**	*	270	250
400	**CDE17400**	*	275	250
450	**CBE17450**	**	85	-
500	**CBE17500**	**	90	-
560	**CBE17560**	**	100	-
630	**CBE17630**	**	110	-
710	**CBE17710**	**	110	-
800	**CBE17800**	**	120	-

* *long version*

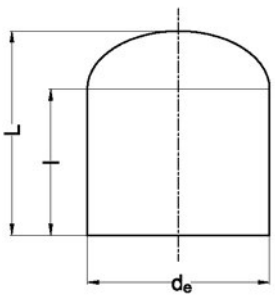
** *short version, machined*
fabrication on order, returning not possible

End cap long/short CBE SDR 11

PE100
SDR 11
water 16 bar/gas 10 bar

for butt-welding





d_e	Art. Nr.		L	l
20	**CDE11020**	*	45	35
25	**CDE11025**	*	52	40
32	**CDE11032**	*	58	44
40	**CDE11040**	*	67	50
50	**CDE11050**	*	75	55
63	**CDE11063**	*	85	62
75	**CDE11075**	*	95	63
90	**CDE11090**	*	110	79
110	**CDE11110**	*	127	88
125	**CDE11125**	*	124	95
140	**CDE11140**	*	140	110
160	**CDE11160**	*	152	121
180	**CDE11180**	*	169	134
200	**CDE11200**	*	184	140
225	**CDE11225**	*	200	160
250	**CDE11250**	*	230	152
280	**CDE11280**	*	257	162
315	**CDE11315**	*	262	167
355	**CDE11355**	*	280	250
400	**CDE11400**	*	285	250

-- to be continued --

End cap long/short CBE SDR 11 - continuation -

d_e	Art. Nr.		L	l
450	**CBE11450**	**	95	-
500	**CBE11500**	**	105	-
560	**CBE11560**	**	115	-
630	**CBE11630**	**	125	-

* *long version*

** *short version, machined*
fabrication on order, returning not possible

Short fittings for butt-welding

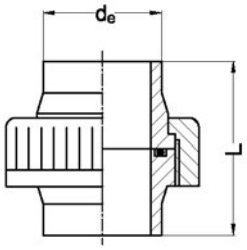
Union complete short BBE/C SDR 11 with EPDM O-ring

PE100
SDR 11
water 10 bar

for butt-welding



d_e	Art. Nr.	L
20	**BBEC11020E**	110
25	**BBEC11025E**	110
32	**BBEC11032E**	110
40	**BBEC11040E**	110
50	**BBEC11050E**	110
63	**BBEC11063E**	110
75	**BBEC11075E**	110
90	**BBEC11090E**	180
110	**BBEC11110E**	180



Unions complete consist of:
- PE union end and union bush
- PVC nut
- EPDM O-ring

Depending on temperature change the maximum operating pressure can be reduced strongly.

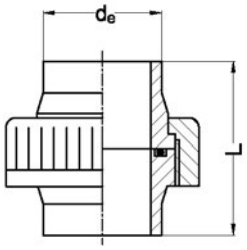
Union complete short BBE/C SDR 11 with FPM O-ring

PE100
SDR 11
water 10 bar

for butt-welding



d_e	Art. Nr.	L
20	**BBEC11020F**	110
25	**BBEC11025F**	110
32	**BBEC11032F**	110
40	**BBEC11040F**	110
50	**BBEC11050F**	110
63	**BBEC11063F**	110
75	**BBEC11075F**	110
90	**BBEC11090F**	180
110	**BBEC11110F**	180



Unions complete consist of:
- PE union end and union bush
- PVC nut
- FPM O-ring

Depending on temperature change the maximum operating pressure can be reduced strongly.
Collectioning on order.

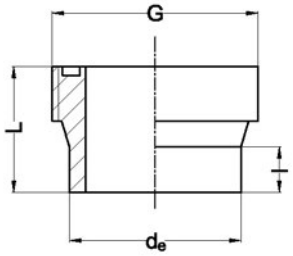
Union bush short F/BBE-C SDR 11

PE100
SDR 11

for butt-welding



d_e	Art. Nr.	L	l	G
20	**FBBEC11020**	55	13	1"
25	**FBBEC11025**	55	13	1¼"
32	**FBBEC11032**	55	14	1½"
40	**FBBEC11040**	55	16	2"
50	**FBBEC11050**	55	18	2¼"
63	**FBBEC11063**	55	20	2¾"
75	**FBBEC11075**	55	24	3½"
90	**FBBEC11090**	90	25	4"
110	**FBBEC11110**	90	28	5"



Thread according to EN-ISO 228.

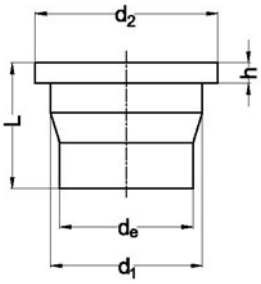
Union end short Q/BBE-C SDR 11

PE100
SDR 11

for butt-welding



d_e	Art. Nr.	L	h	d_1	d_2
20	**QBBEC11020**	55	5	27,4	30,0
25	**QBBEC11025**	55	6	35,9	38,5
32	**QBBEC11032**	55	6	41,4	44,5
40	**QBBEC11040**	55	7	52,8	56,2
50	**QBBEC11050**	55	7	58,8	62,2
63	**QBBEC11063**	55	8	73,8	78,3
75	**QBBEC11075**	55	9	82,5	96,5
90	**QBBEC11090**	90	10	97,5	109,5
110	**QBBEC11110**	90	11	117,5	134,5



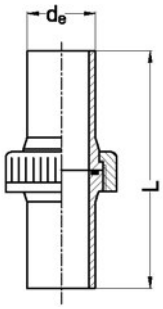
Short fittings for butt-welding

Union complete long BBE/L SDR 11 with EPDM O-ring

PE100
SDR 11
water 10 bar

for butt-welding and electrofusion





d_e	Art. Nr.	L
20	**BBEL11020E**	190
25	**BBEL11025E**	190
32	**BBEL11032E**	190
40	**BBEL11040E**	190
50	**BBEL11050E**	190
63	**BBEL11063E**	190
75	**BBEL11075E**	260
90	**BBEL11090E**	300
110	**BBEL11110E**	340

Unions complete consist of:
- PE union end and union bush
- PVC nut
- EPDM O-ring

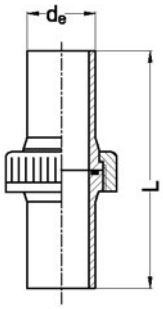
Depending on temperature change the maximum operating pressure can be reduced strongly.

Union complete long BBE/L SDR 11 with FPM O-ring

PE100
SDR 11
water 10 bar

for butt-welding and electrofusion





d_e	Art. Nr.	L
20	**BBEL11020F**	190
25	**BBEL11025F**	190
32	**BBEL11032F**	190
40	**BBEL11040F**	190
50	**BBEL11050F**	190
63	**BBEL11063F**	190
75	**BBEL11075F**	260
90	**BBEL11090F**	300
110	**BBEL11110F**	340

Unions complete consist of:
- PE union end and union bush
- PVC nut
- FPM O-ring

Depending on temperature change the maximum operating pressure can be reduced strongly.

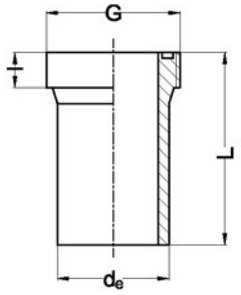
Collectioning on order.

Union bush long F/BBE-L SDR 11

PE100
SDR 11

for butt-welding and electrofusion





d_e	Art. Nr.	L	l	G
20	**FBBEL11020**	95	13	1"
25	**FBBEL11025**	95	13	1¼"
32	**FBBEL11032**	95	14	1½"
40	**FBBEL11040**	95	16	2"
50	**FBBEL11050**	95	18	2¼"
63	**FBBEL11063**	95	20	2¾"
75	**FBBEL11075**	130	24	3½"
90	**FBBEL11090**	150	25	4"
110	**FBBEL11110**	170	28	5"

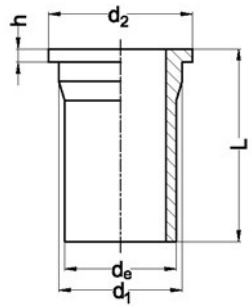
Thread according to EN-ISO 228.

Union end long Q/BBE-L SDR 11

PE100
SDR 11

for butt-welding and electrofusion





d_e	Art. Nr.	L	h	d_1	d_2
20	**QBBEL11020**	95	5	25,0	30,0
25	**QBBEL11025**	95	6	33,5	38,5
32	**QBBEL11032**	95	6	38,0	44,5
40	**QBBEL11040**	95	7	49,5	56,2
50	**QBBEL11050**	95	7	55,0	62,2
63	**QBBEL11063**	95	8	70,0	78,3
75	**QBBEL11075**	130	9	82,5	96,5
90	**QBBEL11090**	150	10	97,5	109,5
110	**QBBEL11110**	170	11	117,5	134,5

Short fittings for butt-welding

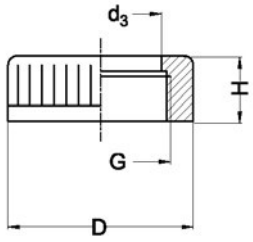
Union nut EFV for PE union end

PVC



d_e	Art. Nr.	D	G	d_3	H
20	**EFV100**	43	1"	27	24
25	**EFV114**	53	1¼"	36	27
32	**EFV112**	60	1½"	41	30
40	**EFV200**	74	2"	53	32
50	**EFV214**	80	2¼"	59	36
63	**EFV234**	103	2¾"	74	39
75	**EFV312**	122	3½"	83	43
90	**EFV400**	139	4"	98	49
110	**EFV500**	164	5"	118	55

Thread according to EN-ISO 228.

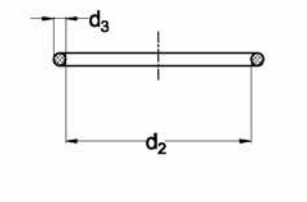


O-ring for PE union bush

EPDM



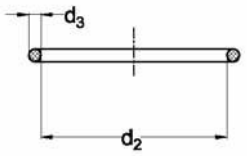
d_e	Art. Nr.	d_2	d_3
20	**OR4081E**	20,22	3,53
25	**OR4112E**	28,17	3,53
32	**OR4131E**	32,93	3,53
40	**OR6162E**	40,65	5,34
50	**OR6187E**	47,00	5,34
63	**OR6237E**	59,69	5,34
75	**OR6312E**	78,80	5,30
90	**OR6375E**	94,60	5,30
110	**Z481109000**	113,70	7,00



O-ring for PE union bush FPM



d_e	Art. Nr.	d_2	d_3
20	**OR4081F**	20,22	3,53
25	**OR4112F**	28,17	3,53
32	**OR4131F**	32,93	3,53
40	**OR6162F**	40,65	5,34
50	**OR6187F**	47,00	5,34
63	**OR6237F**	59,69	5,34
75	**OR6312F**	78,80	5,30
90	**OR6375F**	94,60	5,30
110	**Z481107000**	113,70	7,00



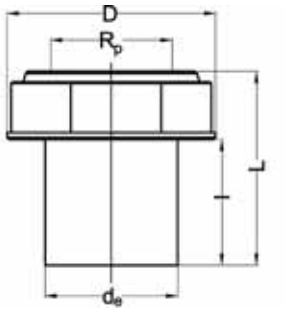
Short fittings for butt-welding

Adaptor long DBME SDR 11 with female thread

PE100
SDR 11
water 10 bar

for butt-welding and electrofusion





d_e/R_p	Art. Nr.	L	l	D	SW
20/½"	**DBME11020012**	65	40	39	32
25/½"	**DBME11025012**	65	40	39	32
25/¾"	**DBME11025034**	66	40	49	41
32/½"	**DBME11032012**	69	44	39	32
32/¾"	**DBME11032034**	70	44	49	41
32/1"	**DBME11032100**	72	44	55	46
40/¾"	**DBME11040034**	69	45	49	41
40/1"	**DBME11040100**	76	49	55	46
40/1¼"	**DBME11040114**	80	49	66	55
50/½"	**DBME11050012**	76	55	50	32
50/1"	**DBME11050100**	78	50	55	46
50/1¼"	**DBME11050114**	85	55	66	55
50/1½"	**DBME11050112**	86	55	83	70
63/2"	**DBME11063200**	100	63	94	85

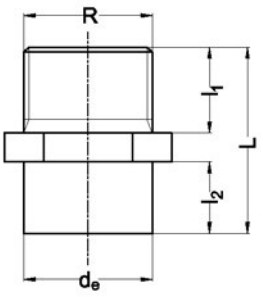
SW = size of the jaw.
Thread according to EN 10226 (ISO 7).
For sealing we advise PTFE tape.
Depending on assembly method and temperature change the maximum operating pressure can be reduced strongly.

Adaptor short SDR 11 with male thread

PE100
SDR 11
water 8 bar

for butt-welding





d_e/R	Art. Nr.	L	l_1	l_2	SW
20/½"	**KBFE11020012**	46	19	18	22
25/¾"	**KBFE11025034**	51	22	20	27
32/1"	**KBFE11032100**	61	28	24	36
40/1¼"	**KBFE11040114**	66	29	26	46
50/1½"	**KBFE11050112**	74	32	28	55
63/2"	**KBFE11063200**	80	35	31	65

SW = size of the jaw.
Thread according to EN 10226 (ISO 7).
For sealing we advise PTFE tape.
Depending on assembly method and temperature change the maximum operating pressure can be reduced strongly.
For specific applications please contact our Technical Support.