



BSI Standards Publication

Plastics piping systems for water supply — Unplasticized poly(vinyl chloride)(PVC-U) and oriented PVC-U (PVC-O) — Guidance for installation

National foreword

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**Plastics piping systems for water
supply — Unplasticized poly(vinyl
chloride)(PVC-U) and oriented PVC-U
(PVC-O) — Guidance for installation**

*Systèmes de canalisations en plastique pour l'alimentation en eau —
Polychlorure de vinyle non plastifié (PVC-U) et orienté PVC-U (PVC-O)
— Pratique recommandée pour la pose*





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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 2, *Plastics pipes and fittings for water supplies*.

This second edition cancels and replaces the first edition (ISO/TR 4191:1989), which has been technically revised.

Introduction

This Technical Report is a guidance document and gives a recommended practice for the installation of unplasticized poly(vinyl chloride) (PVC-U) and oriented unplasticized poly(vinyl chloride) (PVC-O) piping systems conveying water under pressure for buried and above-ground drainage and sewerage systems.

Molecular orientation of PVC-U results in the improvement of physical and mechanical properties.

Unless specifically mentioned, the recommendations are valid for both PVC-U and PVC-O and expressed as PVC.

Plastics piping systems for water supply — Unplasticized poly(vinyl chloride)(PVC-U) and oriented PVC-U (PVC-O) — Guidance for installation

1 Scope

This ISO Technical Report gives recommended practices for installation of unplasticized poly(vinyl chloride) (PVC-U) and oriented unplasticized poly(vinyl chloride) (PVC-O) pipes, fittings, valves, and ancillaries when used in piping systems conveying water under pressure.

The recommendations are intended to give practical guidance of design and installation of piping systems incorporating pipes, fittings, valves, and ancillary equipment made from PVC materials and used for the following purposes:

- water mains and services buried in ground;
- waste water under pressure;
- conveyance of water above ground for both outside and inside buildings,

for the supply of water under pressure at approximately 20 °C (cold water) intended for human consumption and for general purposes.

This Technical report is also applicable to components for the conveyance of water up to and including 45 °C. For temperatures between 25 °C and 45 °C, Figure 1 of ISO 1452-2:2009 applies.

In addition, recommendations are given for the connection to fittings, valves, and ancillary equipment made from materials other than PVC.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3, *Preferred numbers — Series of preferred numbers*

ISO 161-1, *Thermoplastics pipes for the conveyance of fluids — Nominal outside diameters and nominal pressures — Part 1: Metric series*

ISO 1452-1:2009, *Plastics piping systems for water supply and for buried and above-ground drainage and sewerage under pressure — Unplasticized poly(vinyl chloride) (PVC-U) — Part 1: General*

ISO 1452-2:2009, *Plastics piping systems for water supply and for buried and above-ground drainage and sewerage under pressure — Unplasticized poly(vinyl chloride) (PVC-U) — Part 2: Pipes*

ISO 1452-3, *Plastics piping systems for water supply and for buried and above-ground drainage and sewerage under pressure — Unplasticized poly(vinyl chloride) (PVC-U) — Part 3: Fittings*

ISO 1452-4, *Plastics piping systems for water supply and for buried and above-ground drainage and sewerage under pressure — Unplasticized poly(vinyl chloride) (PVC-U) — Part 4: Valves*

ISO 1452-5, *Plastics piping systems for water supply and for buried and above-ground drainage and sewerage under pressure — Unplasticized poly(vinyl chloride) (PVC-U) — Part 5: Fitness for purpose of the system*

ISO 4065, *Thermoplastics pipes — Universal wall thickness table*

ISO 4633, *Rubber seals — Joint rings for water supply, drainage and sewerage pipelines — Specification for materials*

ISO 7387-1, *Adhesives with solvents for assembly of PVC-U pipe elements — Characterization — Part 1: Basic test methods*

ISO 9080, *Plastics piping and ducting systems — Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation*

ISO 9311-1, *Adhesives for thermoplastic piping systems — Part 1: Determination of film properties*

ISO 9969, *Thermoplastics pipes — Determination of ring stiffness*

ISO/DIS 16422:2013, *Pipes and joints made of oriented unplasticized poly(vinyl chloride) (PVC-O) for the conveyance of water under pressure — Specifications*

3 Terms and definitions, symbols, and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 1452-1:2009 and the following apply.

3.1.1

nominal outside diameter

d_n
numerical designation of size which is common to all components in a thermoplastics piping system other than flanges and components designated by thread size

Note 1 to entry: It is a convenient round number for reference purposes.

Note 2 to entry: For pipe conforming to ISO 161-1, the nominal outside diameter, expressed in millimetres, is the minimum mean outside diameter $d_{em, min}$.

3.1.2

nominal wall thickness

e_n
specified wall thickness, in millimetres

Note 1 to entry: It is identical to the specified minimum wall thickness at any point $e_{y, min}$.

3.1.3

nominal pressure (PN)

alphanumeric designation related to the mechanical characteristics of the components of a piping system and used for reference purposes

3.1.4

hydrostatic pressure

p
internal pressure applied to a piping system

3.1.5

working pressure (PFA)

maximum pressure which a piping system can sustain in continuous use under given service conditions without pressure surge

Note 1 to entry: For thermoplastics piping systems, the value of the nominal pressure is equal to the working pressure at a temperature of 20 °C expressed in bars.

3.1.6 hydrostatic stress

σ

stress induced in the wall of a pipe when it is subjected to internal water pressure

Note 1 to entry: The stress in megapascals is related to the internal pressure, p , in bars, the nominal wall thickness, e_n , in millimetres, and the nominal outside diameter of the pipe, d_n , in millimetres by the following formula:

$$\sigma = \frac{p \times (d_n - e_n)}{20e_n}$$

Note 2 to entry: If σ and p are given in the same units, the denominator becomes $2e_n$.

3.1.7 long-term hydrostatic strength at 20 °C

σ_{lhts}

quantity with the unit of stress, i.e. MPa, which can be considered to be a property of the material under consideration and which represents the 97,5 % lower confidence limit for the long-term hydrostatic strength and equals the predicted average strength at a temperature of 20 °C and a time of 50 years with internal water pressure

Note 1 to entry: ISO 9080 gives the possibility to extrapolate to 100 year lifetime.

3.1.8 lower confidence limit of the predicted hydrostatic strength

σ_{LPL}

quantity with the dimension of stress, which represents the 97,5 % lower confidence limit of the predicted hydrostatic strength for a single value at a temperature T and a time t

Note 1 to entry: It is denoted as $\sigma_{\text{LPL}} = \sigma_{(T,t,0,975)}$.

Note 2 to entry: The value of this quantity is determined by the method given in ISO 9080.

3.1.9 minimum required strength MRS

value of σ_{LPL} rounded to the next lower value of the R 10 series from ISO 3 when σ_{LPL} is below 10 MPa or to the next lower value of the R 20 series when σ_{LPL} is higher than 10 MPa

3.1.10 design coefficient

C

overall coefficient with a value greater than one, which takes into consideration service conditions, as well as properties of the components of a piping system other than those represented in σ_{LPL}

3.1.11 pipe series S

dimensionless number for pipe designation (see ISO 4065)

3.1.12 standard dimension ratio SDR

numerical designation of a pipe series which is a convenient round number approximately equal to the dimension ratio of the nominal outside diameter, d_n , and the nominal wall thickness, e_n

Note 1 to entry: According to ISO 4065, the standard dimension ratio, SDR, and the pipe series S are related as follows:

$$[\text{SDR}] = 2[\text{S}] + 1$$

3.2 Symbols

C	design coefficient
d_e	outside diameter (at any point)
d_{em}	mean outside diameter
d_i	inside diameter (at any point)
d_{im}	mean inside diameter of socket
d_n	nominal (outside or inside) diameter
DN	nominal size
E	wall thickness (at any point)
e_m	mean wall thickness
e_n	nominal wall thickness
f_A	derating (or uprating) factor for application
f_T	derating factor for temperatures
Δ	material density
Σ	hydrostatic stress
P	internal hydrostatic pressure
p_T	test pressure
σ_s	design stress
σ_{LPL}	stress at lower predicted confidence limit

3.3 Abbreviations

LPL	lower predicted confidence limit
MRS	minimum required strength
MOP	maximum operating pressure
PFA	allowable operating pressure
PEA	allowable site test pressure
PN	nominal pressure
DN	nominal diameter
PVC-U	unplasticized poly(vinyl chloride)
SDR	standard dimension ratio
PVC-O	oriented poly(vinyl chloride)

4 Parameters influencing design

4.1 Allowable operating pressure

4.1.1 Where pipe material temperatures do not exceed 25 °C, and where no extra safety considerations are applicable, nominal pressures are given in Table A.1 of ISO 1452-2:2009 and in Table 2 of ISO/DIS 16422:2013. These nominal pressures have been calculated on the basis of well-established data, taking into account a service life of at least 50 years of continuous operation. For common water supply systems up to 25 °C, the allowable operating pressure PFA in bars (1 bar = 105 N/m² = 0,1 MPa) is equal to the nominal pressure, PN.

4.1.2 Design coefficient, *C*, should comply with those specified in ISO 1452, for PVC-U, and ISO 16422, for PVC-O.

4.1.3 Where the water service temperature is between 25 °C and 45 °C, it is required that the maximum allowable pressure is reduced by applying a derating factor, *f_T*, as shown in Figure A.1 of ISO 1452-2:2009 and Annex C of ISO/DIS 16422:2013.

Figure A.1 of ISO 1452-2:2009 shows that for temperatures up to and including 25 °C, the derating factor to be applied is 1,0 and for temperatures above 25 °C, the derating factor reduces from 1,0 to 0,63 at 45 °C. The same is valid for PVC-O pipes.

Where water service temperatures are expected to exceed 45 °C, the manufacturer's advice should be obtained.

4.2 Ring stiffness of pipes

Where a calculation of the initial pipe deflection is applied, the initial ring stiffness of the pipe should be taken from [Table 1](#).

Table 1 — Initial ring stiffness of pipes

	Pipe series							
	S 20 (SDR 41)	S 16,7 (SDR 34,4)	S 16 (SDR 33)	S 12,5 (SDR 26)	S 10 (SDR 21)	S 8 (SDR 17)	S 6,3 (SDR 13,6)	S 5 (SDR 11)
Nominal pressure for $d_n \leq 90$ for $d_n > 90$	– PN 6	PN 6 PN 7,5	PN 6 PN 8	PN 8 PN 10	PN 10 PN 12,5	PN 12,5 PN 16	PN 16 PN 20	PN 20 PN 25
Calculated ring stiffness in kN/m ² (<i>S_{calc}</i>)	3,9	6,7	7,6	16	31,3	61	125	250
Nominal ring stiff- ness <i>SN</i>	4	8	–	16	32	–	–	–

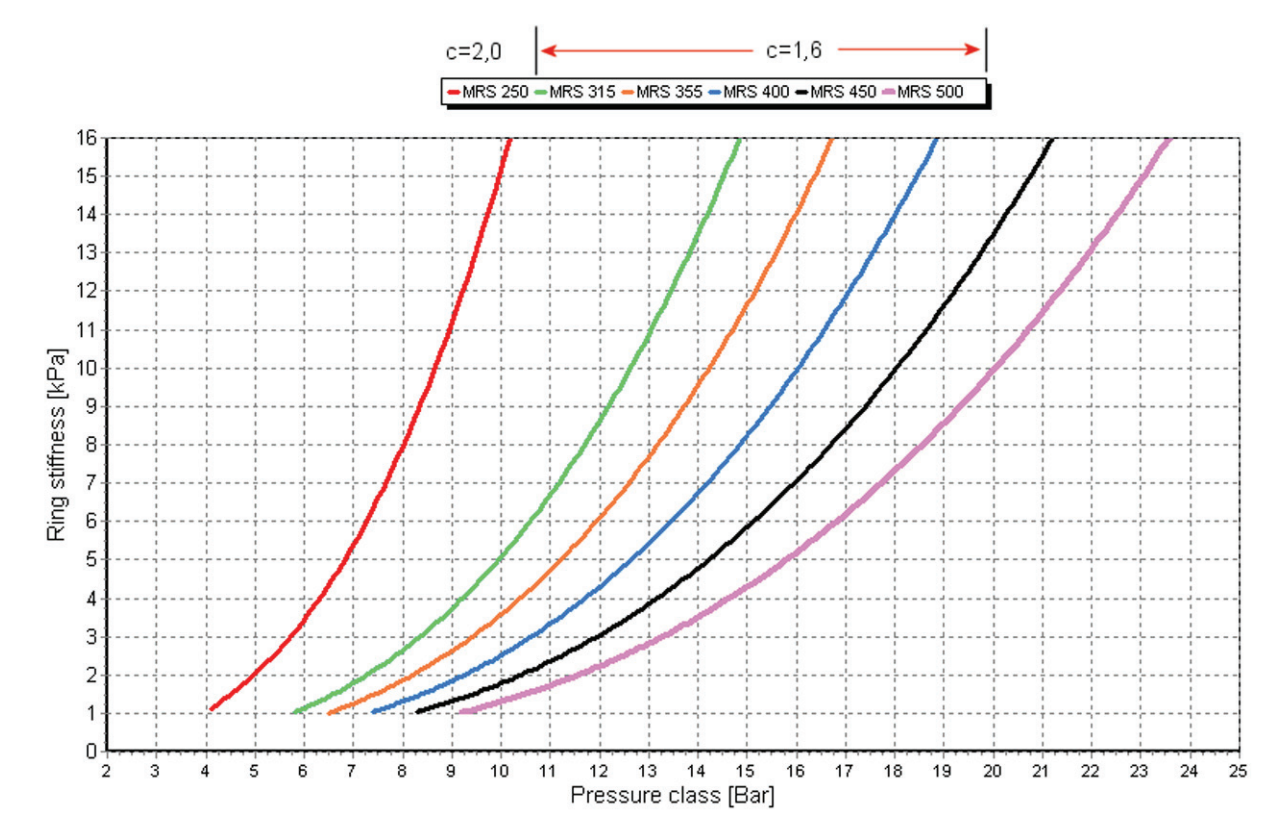
The initial ring stiffness S_{calc} in [Table 1](#) has been calculated using the following formula:

$$S_{\text{calc}} = \frac{E \times I}{(d_e - e_n)^3} = \frac{E}{96 [S]^3} \tag{1}$$

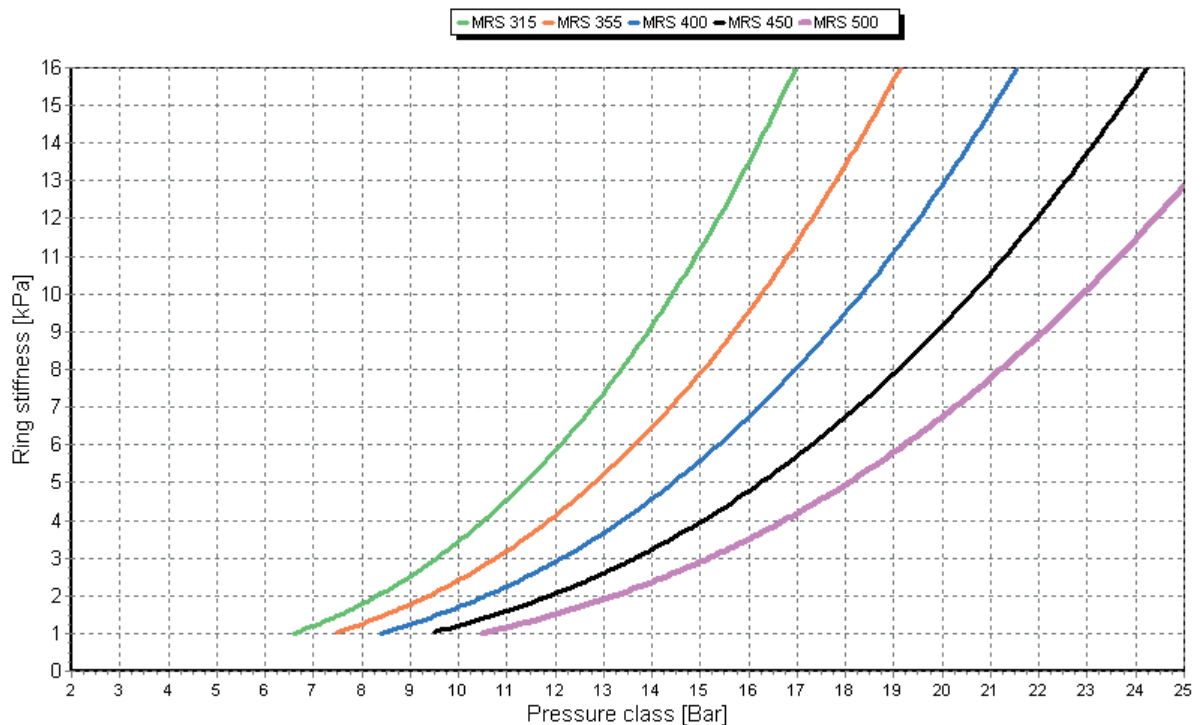
where

- S_{calc} is the calculated initial ring stiffness in kilonewtons per square metre;
- E is the modulus of elasticity in flexure, having the value of $3,2 \times 10^6$ kN/m² for PVC-U and having the value of 4×10^6 kN/m² for PVC-O;
- I is the moment of inertia in cubic millimetres with $\frac{1 \times e_n^3}{12}$ for 1 m pipe length;
- d_e is the nominal outside diameter in millimetres;
- e_n is the nominal wall thickness in millimetres;
- S is the pipe series.

The initial ring stiffness of PVC-O pipes with the different MRS values are given in the graphs of [Figure 1](#).
 E: PVC-O: 4×10^6 kN/m² (4 000 Mpa) E: PVC-U: $3,2 \times 10^6$ kN/m² (3 200 Mpa).



NOTE The following C factor has been used: MRS 250 (PVC-U): C = 2,0; PVC-O: C = 1,6.



NOTE The following C factor has been used: PVC-O: C = 1,4.

Figure 1 — Initial ring stiffness of pipes of PVC-O

In case the actual modulus measured or stated by the manufacturer or designer is known, then use the following correction formulae:

For PVC-U: $SN = SN1 \times E/3\ 200$

For PVC-O: $SN = SN1 \times E/4\ 000$

(SN1 = taken from the graph)

5 Hydraulic properties

5.1 Loss of head

For head losses through fittings, the manufacturer's advice should be obtained.

PVC pressure pipes are specified by nominal diameters, d_n . Internal diameters vary according to pipe series (see Table 2 of ISO 1452-2:2009 and ISO/DIS 16422:2013). This shall be taken into account when calculating the flow characteristics of pipes.

The flow is characterized by the Reynolds number as follows:

$$Re = v \times dh/\mu \quad (2)$$

where

Re is the Reynolds number [-];

v is the flow speed [m/s];

μ is the kinematic viscosity [m²/s].

The friction value f is then calculated by an iterative manner using Formula (3):

$$\frac{1}{\sqrt{f}} = -2 \log_{10} \left(\frac{\varepsilon/D_h}{3,7} + \frac{2,51}{Re \sqrt{f}} \right) \quad (3)$$

where

D_h is the hydraulic diameter (for a circular pipe, full flow = internal pipe diameter) [m];

Re is the Reynolds number [-];

ε is the roughness of the pipe [m].

And finally, the pressure loss is calculated by

$$\Delta p = f \times \frac{L}{D} \times \frac{\rho V^2}{2} \quad (4)$$

where

Δp is the pressure loss [m];

f friction value;

L is the length of the pipe [m];

D is the internal diameter of the pipe [m];

ρ is the density of the fluid [kg/m³];

V is the flow speed [m/s].

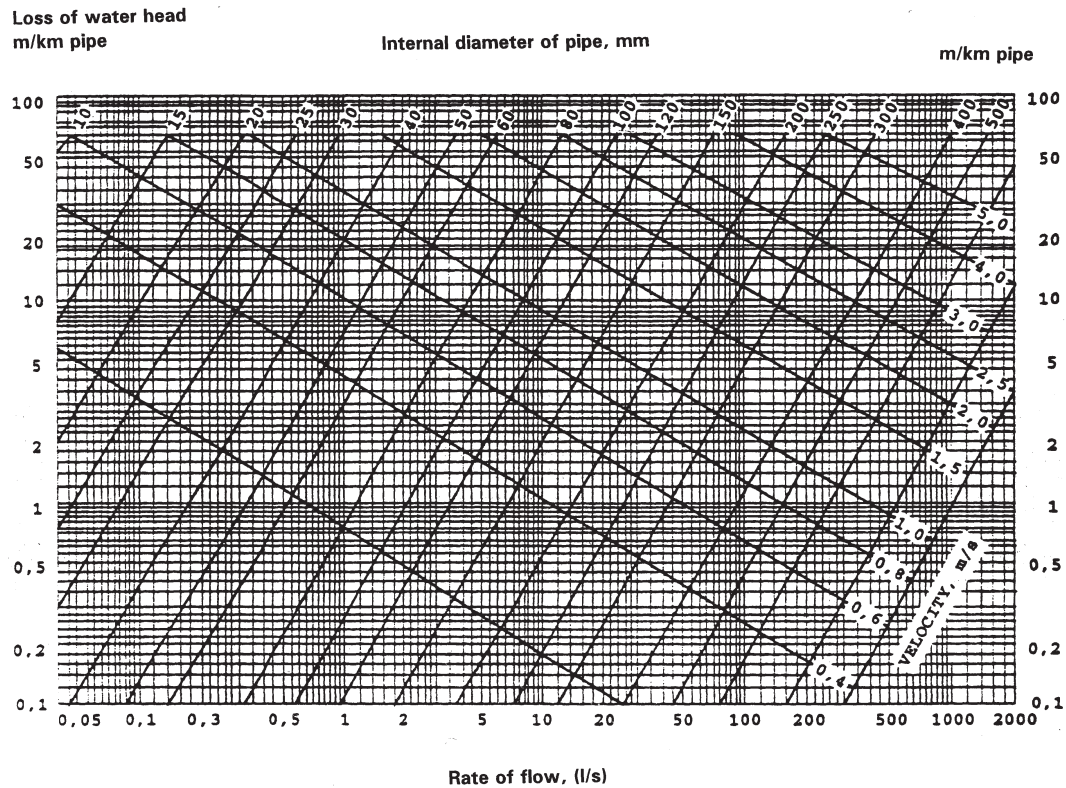


Figure 2 — Example of flow chart for head losses in pipes

[Figure 2](#) comprises the friction loss diagram for PVC-U pipes calculated by L-E Janson in accordance with Colebrook. For internal diameters up to 200 mm, $k = 0,02$ mm and for larger diameters, $k = 0,05$ mm. The temperature of the water is ± 10 °C.

6 Assembly methods

6.1 General

6.1.1 PVC pressure pipes conforming to ISO 1452-2:2009 are supplied in nominal lengths and with one of the following three end conditions:

- a) plain, for jointing by means of separate couplers;
- b) integral elastomeric ring socket (one end), for push-fit jointing;
- c) integral socket (one end), for solvent cement jointing.

6.1.2 Fittings of PVC for use with PVC pipes are specified in ISO 1452-3 and can either have socket-type joints for solvent cementing or elastomeric ring joints for push-fit jointing. Valves and ancillaries of PVC-U are specified in ISO 1452-4.

6.1.3 The principal types of joints and their characteristics are as follows:

a) Lastomeric ring seal joints (see Figure 3). An elastomeric sealing ring is compressed and forms a pressure-tight seal when a spigot is inserted into a socket. These joints do not sustain axial thrust (non-end-load-bearing).

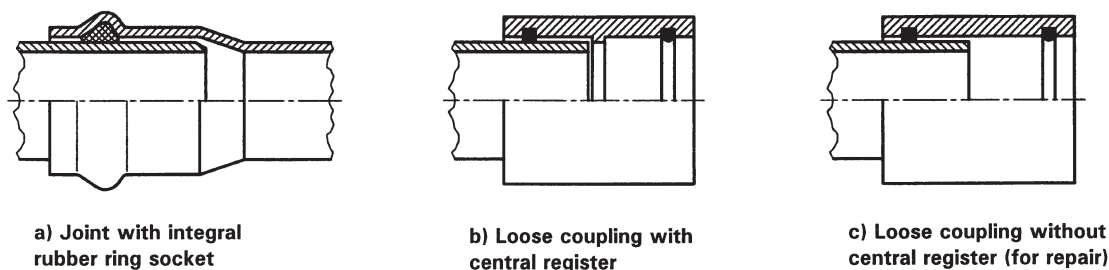


Figure 3 — Typical elastomeric ring seal joints

b) Solvent cement joints (see Figure 4). A solvent-based adhesive is applied to a spigot and to a socket and the two components are pushed together. Solvent-cemented joints sustain axial thrust (end-load-bearing).

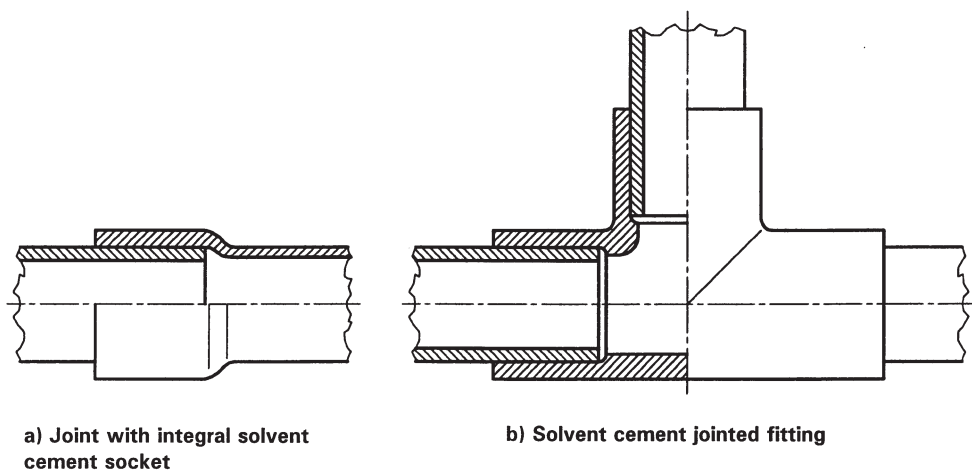


Figure 4 — Typical solvent cement joints

c) Mechanical joints (see Figure 5). These joints can be either end-load-bearing or non-end-load-bearing.

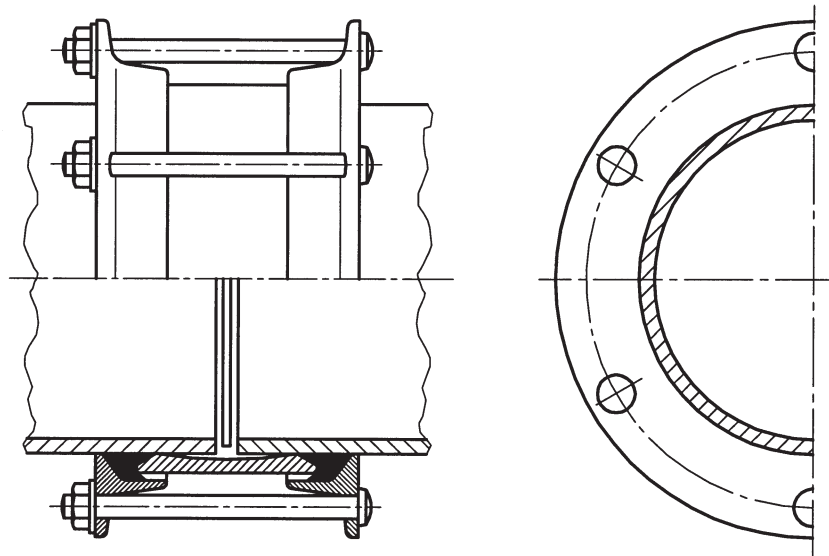


Figure 5 — Typical mechanical joint

These joints, also known as compression joints, use separate couplers made from PVC-U, reinforced plastics or metal, e.g. cast iron. A pressure-tight seal is achieved when an elastomeric sealing ring is compressed by tightening backing ring(s) of various designs. These joints may or may not sustain axial thrust (non-end-load-bearing). For the choice of specific mechanical couplers, advice shall be sought at the manufacturer of the PVC pipes.

d) Flanged joints (see Figure 6). A flange is incorporated onto the end of a pipe or fitting in a variety of ways. A pressure-tight seal is achieved by compressing a sealing gasket between the mating faces of flanges on adjacent pipes, fittings, or valves made from plastics or metals. These joints can be either end-load-bearing or non-end-load-bearing.

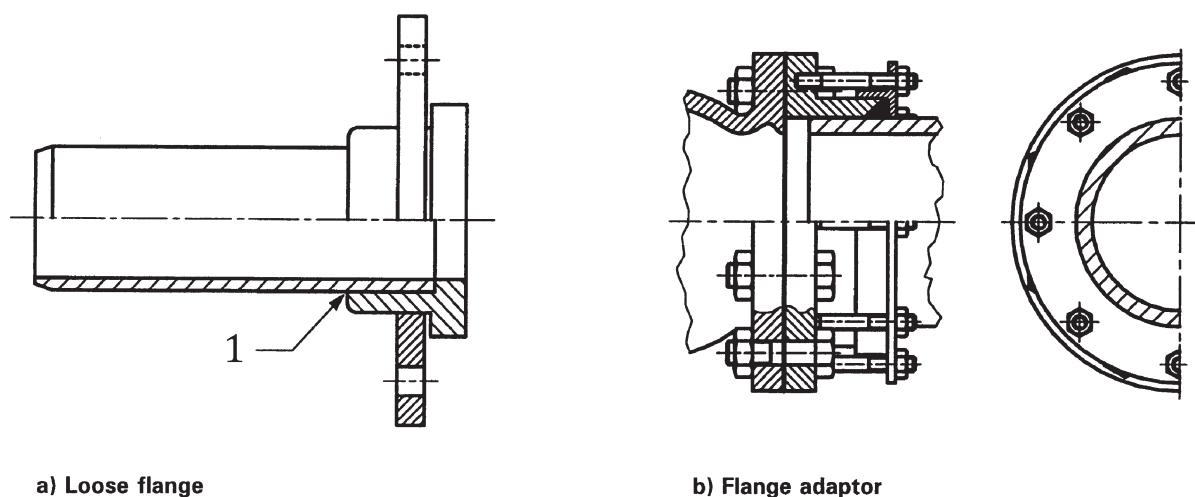


Figure 6 — Example of flanged joints

e) Union couplers and adaptors (see Figure 7). Union couplers and adaptors can be used for jointing PVC pipes to PVC pipes and PVC pipes to metal pipe threads. Union couplers and adaptors sustain axial thrust (end-load-bearing).

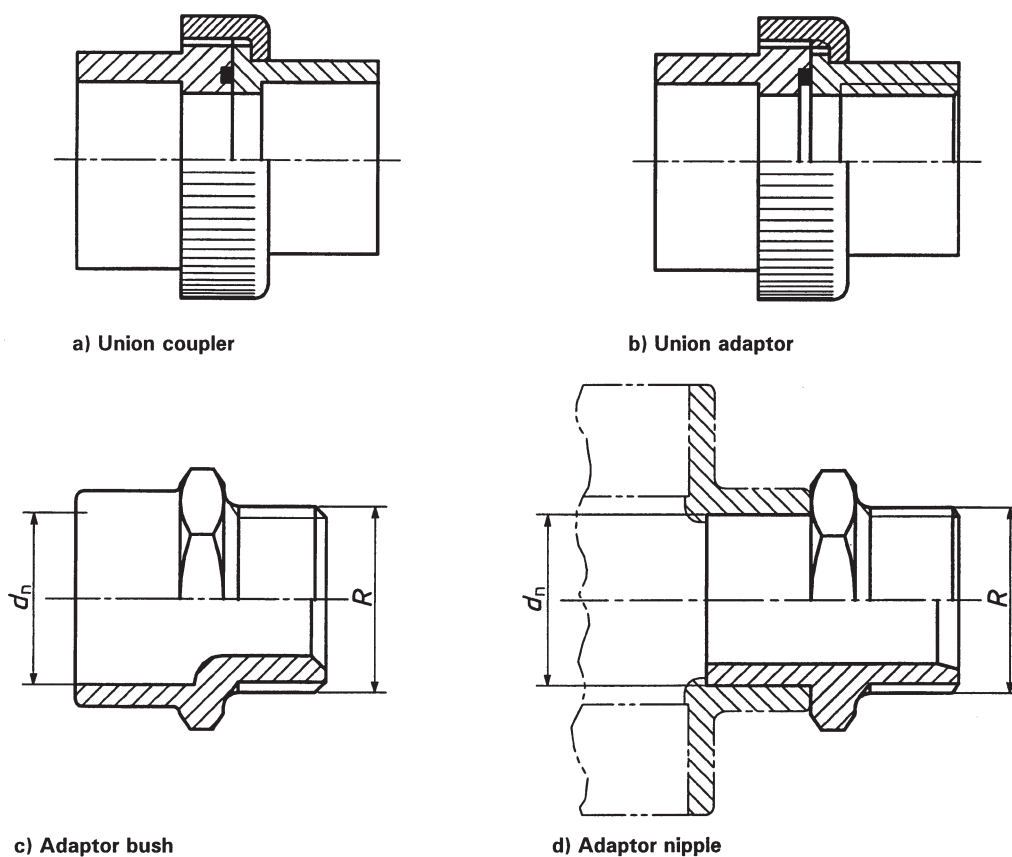


Figure 7 — Union couplers and adaptors

Where pipe installations include non-end-load-bearing jointing systems (above or below ground), it is essential to consider the probability of joint separation due to axial thrust.

In below-ground applications, joint separation can be prevented by means of end-load-bearing joints or concrete anchor blocks (see Figure 8).

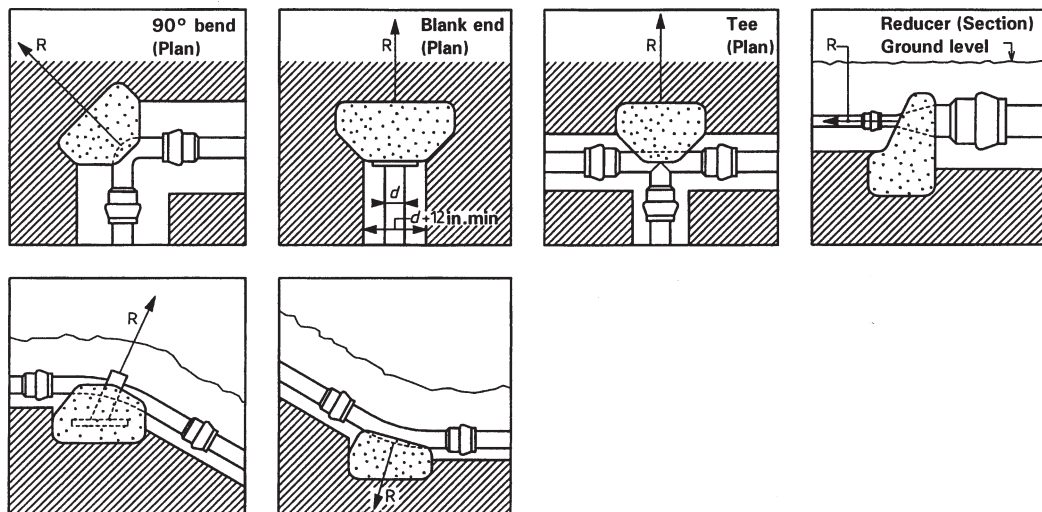


Figure 8 — Typical anchor block arrangements

Joint separation in above-ground applications can be prevented by properly designed anchor brackets or more easily by use of end-load-bearing jointing systems (see 7.5).

When evaluating the axial thrust, the test pressure shall be considered.

6.2 Integral rubber ring joints

6.2.1 Elastomeric sealing rings are usually made from synthetic materials, e.g. ethylene-propylene-diene (EPDM) copolymer, styrene-butadiene rubber (SBR), or a combination of synthetic and natural rubber. Profiles of the ring and of the socket depend on individual manufacturers' designs. The rings to be used should be those supplied by the manufacturer for his own assembly system. If the sealing ring is not in place at the time of delivery, the groove should be cleaned, any foreign bodies should be removed, and the ring should be located into the groove as directed by the manufacturer. Sealing ring materials shall fulfil the requirements as specified in EN 681-1 or ISO 4633.

6.2.2 Integral elastomeric ring joints do not normally sustain end thrust. Particular attention should be paid to the correct design of anchor blocks and to their location in the pipeline system (see 7.5).

In some countries, it is common practice to provide restraint against thrust by the inclusion of end-load-bearing joints at strategic points within the system. Where this practice is acceptable, the pipe and/or fittings manufacturer's advice should be sought to help identify the places where end-load-bearing joints should be applied (see 7.5).

6.2.3 Before assembling both, the elastomeric ring and spigot should be inspected and cleaned.

6.2.4 The correct assembly of an elastomeric ring seal joint requires that the spigot end of the pipe be chamfered and correctly lubricated prior to insertion into the socket. Lubricant should also be applied to the elastomeric ring once this is fitted into the ring groove.

The lubricant used should not have any detrimental effect on the pipe, fittings, ancillaries, or elastomeric sealing ring and shall not be toxic, shall not impart any taste or odour to the water, and shall not encourage the growth of bacteria.

In conformity to 4.2 of ISO 1452-1:2009, the lubricant should have no influence on water quality. Only lubricants recommended by the pipe or fittings supplier should be used.

As soon as the pipe spigot and elastomeric ring have been lubricated, the spigot should be introduced into the socket so as to avoid any risk of soiling or pollution.

After aligning the pipes in both horizontal and vertical planes, the spigot end should be inserted into the socket up to the reference mark on the spigot.

Pipes may be cut on site. If this is necessary, the cut should be square and the cut end deburred and/or chamfered to the angle and dimensions given in ISO 1452-2:2009.

6.3 Solvent cement joints

6.3.1 General

6.3.1.1 The dimensions of the sockets and spigots for solvent cement joints are given in ISO 1452.

6.3.1.2 The solvent cement adhesives identification characteristics should be specified by the manufacturer according to ISO 7387-1 and their properties shall conform to ISO 9311-1.

The adhesive(s) should have no detrimental effects on the pipe and shall not cause the test assembly to fail to conform to ISO 1452-5.

6.3.1.3 In conformity to ISO 1452, the solvent cements should have no influence on water quality.

6.3.2 Jointing operations

6.3.2.1 Solvent cement adhesives and cleaning fluids are flammable, therefore it is important that smoking or any other sources of ignition should be prohibited in the area in which these materials are being used. Solvent cement operations should be carried out in a well-ventilated area. Specific instructions can be found on the package of the Solvent cement.

6.3.2.2 The pipe end to be jointed should be cut square to its axis and free from irregularities such as burrs and swarf to prevent excessive amounts of adhesive being scraped off the socket. Chamfered pipes should not be used for solvent cementing. When the chamfer is applied on site, the angle and dimensions should conform to ISO 1452-2:2009.

6.3.2.3 The surfaces to be jointed should be clean, dry, and free from grease. It is recommended that a degreasing agent is used for this purpose in accordance with manufacturer's recommendations.

6.3.2.4 The solvent cement should be applied in an even layer and in a longitudinal direction to both spigot and socket mating surfaces.

6.3.2.5 The application of the solvent cement should be performed quickly. For diameters greater than 110 mm, two persons are necessary to apply the adhesive, one to the spigot end and one to the socket simultaneously. The size of the brush shall be in accordance with the manufacturer's instructions. It is recommended to take the brush size approximately 1/3 of the diameter of the pipe.

6.3.2.6 Immediately and without twisting, the spigot should be pushed into the socket to the required depth. Excessive amounts of adhesive around the socket mouth should be removed as soon as the joint has been made. Once the joint is made, leave to dry without disturbing for at least 5 min.

6.3.2.7 The joint becomes resistant to pressure only after an additional period. Allow the required minimum time given by the pipe manufacturers before applying the maximum recommended test pressure (see [Figure 11](#)).

NOTE 1 Solvent cements are slow to cure at low temperatures and cure fast at high temperatures. Solvent cementing is not recommended at temperatures of 0 °C and below.

NOTE 2 Solvent cements for joints >250 mm is not recommended on the installation site.

6.4 Mechanical joints

6.4.1 Compression joints

Compression joints are normally separate fittings made from PVC-U, reinforced plastics or metal and can be in the form of a coupler for connecting pipes and fittings of the same material and of the same dimensions or as an adaptor for connecting components of different materials and/or dimensions. Generally, compression fittings consist of the following four main elements:

- a) body;
- b) elastomeric sealing rings;
- c) backing (compression) rings;
- d) nuts or bolts.

Each element is positioned on the pipe separately and the sealing rings compressed between the body of the fitting and the pipe by tightening the backing rings. Nuts or bolts should be correctly tightened in accordance with the manufacturer's recommendations at all stages of assembly.

6.4.2 Threaded joints

There is a range of threaded joints for assembly to metallic pipes, including the following:

- a) PVC-U and metal union adaptor;
- b) PVC-U adaptor fittings.

PVC pipes conforming to ISO 1452-2:2009 and ISO 16422 are not recommended for threading in pressure application.

6.4.3 Flanged joints

PVC pipes, fittings, and ancillaries can be supplied with flanged ends. Although detailed flange designs vary considerably, all are suitable for connection to pipes, fittings, and valves made from other materials, e.g. metals. A pressure-tight joint is obtained by compressing a gasket or ring between the mating faces of adjacent flanges.

7 Storage, handling, and transport of pipes

7.1 Handling

When pipes are to be handled individually, they should be lowered, lifted, and carried in a controlled fashion and should never be thrown, dropped, or dragged. Single pipes up to nominal size 250 mm can be handled by two men without difficulty. Pipes of larger nominal size can require lifting apparatus, as with bundles.

7.2 Transport

When transporting pipes, flatbed vehicles should be used. The bed should be free from nails and other projections. When practicable, package of pipes should be transported in original package or scalp timbers if possible.

The vehicles should have side supports appropriately spaced approximately 2 m apart, and the pipes should be secured effectively during transport. All posts should be flat with no sharp edges.

When loading socketed pipes, the pipes should be stacked on the vehicle so that the sockets do not take excessive loads.

Where pipes overhang the vehicle, the amount of overhang should not exceed 1 m.

Unloading bundled pipes require the use of appropriate mechanical equipment. The chosen technique should not cause damage to the pipes, e.g. forklift truck with flat protected forks or suitable crane with spreader bars. PVC pipes should never be lifted using wire ropes and slings or metal hooks and chains. Slings should be non-metallic, e.g. rope or webbing.

Pipes should not be covered where temperatures may rise to unaccepted levels. Pipes having a ring stiffness lower than 4 should be stacked with intermediate scaffold wooden battens. Pipes should be arranged in a package in such a way that the socket and spigot ends are arranged in an alternate fashion.

7.3 Storage

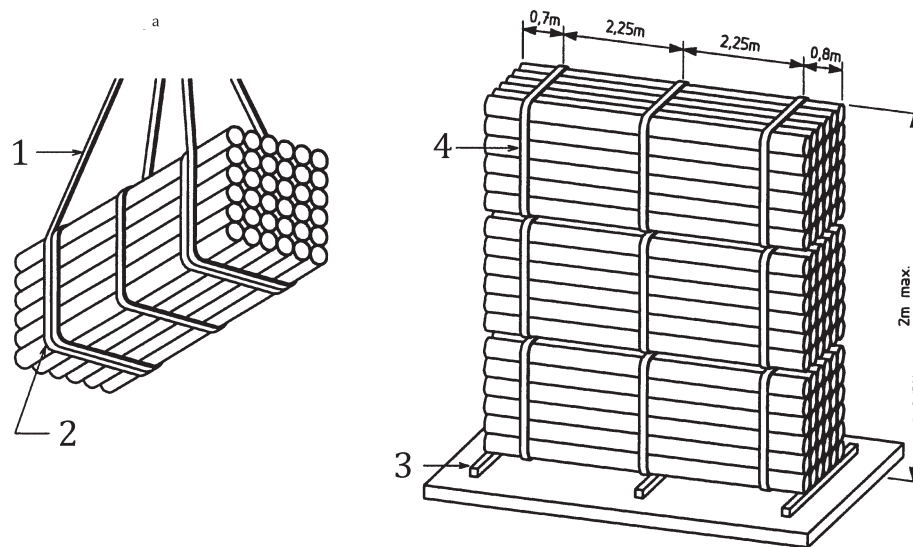
PVC pipes are light and easy to handle and consequently likely to be mistreated for that reason. Appropriate precautions should be taken during handling and storage to ensure that pipes are not damaged.

In depots or stores, bundled pipes should be stacked no more than three units or 2 m high, whichever is lower. At the construction site, bundles should be stacked no more than two units or 1 m high, whichever is lower. If the bundles are timber framed, they should be stacked timber to timber. Provision should be made for side supports, to prevent stack collapse, when banding or framing is removed. Side supports should be spaced at centres not greater than 3 m (see [Figure 9](#)).

Where pipes are supplied with end caps, plugs, or wrappings, these should not be removed before the pipes are put in place. Contact with fuels and solvents should be avoided during storage.

Prolonged exposure to strong ultraviolet light (sunlight) can slightly reduce the impact strength of PVC pipes and cause discoloration. Nevertheless, the resistance to internal water pressure is not reduced. Suitable protection by a free-venting opaque cover (canvas or polyethylene sheeting) is recommended if the total exposed storage time is likely to exceed 12 months.

In case sunlight results in very high surface temperatures, then also free-venting opaque cover should be applied. When pipes may become very hot (approximate more than 60 °C), then the integral sockets may change shape slightly, causing possible assembly problems.



Key

- 1 non-metallic wide band webbing
- 2 webbing positioned outside timber battans
- 3 additional support battans
- 4 strapped timber battans
- a Lifting bundlepacks by crane.

Figure 9 — Handling and storage

7.4 Cold bending on site

Cold bending on site is permitted for pipes to deviate from one continuous straight line by the following techniques:

- a) means of a slight deflection within an elastomeric ring joint;
- b) the gradual curvature of each pipe length.

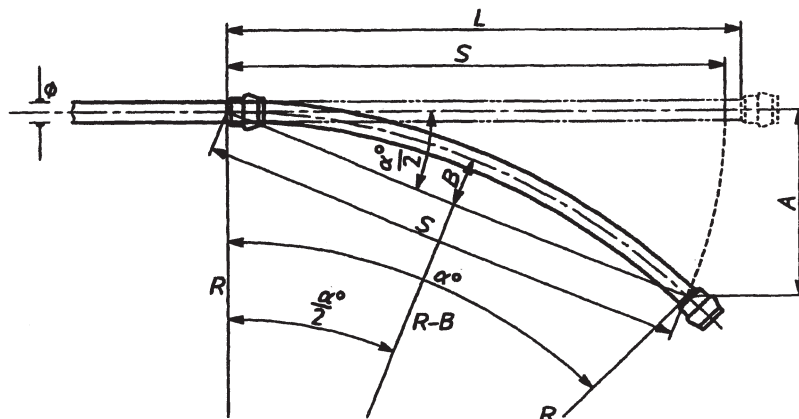
To ensure that the efficiency of the elastomeric ring seal is not impaired, deflection within the joint would normally be limited to a maximum of 1° . For greater deflections, special designs of joint should be used and the manufacturer's advice obtained.

The radius of curvature, R , of a cold-formed bend over the length of a 6 m pipe shall not be less than 300 times the external diameter of the pipe (see [Figure 10](#)).

[Table 2](#) gives useful dimensions for cold-bent PVC-U pipes up to and including DN 160 for PN 16 pipes. To avoid uncontrolled angle deflection, the pipe end in the socket should be fixed.

[Table 3](#) gives useful dimensions for cold-bent PVC-O pipes up to and including DN 160.

Ferrule straps or house connections should preferably not be applied to bend sections, unless otherwise recommended by the supplier.



ϕ = Max. OD pipe

$R = 200 \phi$

$\alpha = \frac{180L}{\pi R}$

$S = 2R \times \sin \frac{\alpha^\circ}{2}$

$A = S \times \sin \frac{\alpha^\circ}{2}$

$B = R - R \times \cos \frac{\alpha^\circ}{2}$

Figure 10 — Dimensions relating to pipe curvature

Table 2 — Allowable bending radii for PVC-U pipes
 (Effective bending length $L = 6,0$ m, $R = 200 \times d$)

DN [mm]	Minimum radius PVC-U [m]	Angle $\alpha/2$	Chord S [m]	Deflection A [m]
63	12,6	13,64	5,94	1,40
75	15,0	11,50	5,98	1,19
90	18,0	9,55	5,97	0,99
110	22,0	7,81	5,98	0,81
125	25,0	6,87	5,98	0,72
140	28,0	6,14	5,78	0,64
160	32,0	5,37	5,99	0,56
180	—	—	—	—

**Table 3 — Allowable bending radii for PVC-O pipes
 (Effective bending length $L = 6,0$ m, $R = 120 \times D$)**

DN [mm]	Minimum radius PVC-O [m]	Angle $\alpha/2$	Chord S [m]	Deflection A [m]
63	7,56	22,70	5,84	2,25
75	9,00	19,08	5,88	1,92
90	10,80	15,90	5,92	1,62
110	13,20	13,02	5,94	1,34
125	15,00	11,45	5,96	1,18
140	16,80	10,23	5,96	1,06
160	19,20	8,90	5,97	0,92
180	-	-	-	-

Other combination of bending radius and diameter can be calculated using the formulas in [Figure 10](#). For practical reasons, the bending moment should not become higher than 1000 kNm.

This bending moment can be calculated with $M = R / E_1$.

7.5 Anchoring and thrust blocks

Systems with non-tensile-resistant joints may require thrust support at fittings.

At any change in pipe direction or size or at any branch, valve, or end fitting, pressure thrusts arise which should be countered by the pipe system itself or by appropriate anchorages transferring the thrust back to the soil or supporting structure. A table of forces generated is given in [Table 4](#). In addition, external torque and bending loads on valves and hydrants can be significant, and design shall provide reaction that will guard against excessive loading on the pipe.

Table 4 — Thrust forces for blank ends and bends

Nominal diameter d_n mm	Thrust on blank end kN/bar ^a	Radial thrust on bends of various angles kN/bar ^a			
		90°	45°	22,5°	11,25°
63	0,31	0,44	0,24	0,12	0,06
75	0,44	0,62	0,34	0,17	0,09
90	0,64	0,90	0,49	0,25	0,12
110	0,95	1,34	0,73	0,37	0,19
125	1,23	1,74	0,94	0,48	0,24
140	1,54	2,18	1,18	0,60	0,30
160	2,01	2,84	1,54	0,78	0,39
180	2,54	3,60	1,95	0,99	0,50
200	3,14	4,44	2,40	1,23	0,62
225	3,98	5,62	3,04	1,55	0,78
250	4,91	6,94	3,76	1,92	0,96
280	6,16	8,71	4,71	2,40	1,21
315	7,79	11,02	5,96	3,04	1,53
355	9,90	14,00	7,58	3,86	1,94
400	12,57	17,77	9,62	4,90	2,46
450	15,90	22,49	12,71	6,21	3,12
500	19,63	27,77	15,03	7,66	3,85
560	24,63	34,83	18,85	9,61	4,83
630	31,17	44,08	23,86	12,16	6,11

^a The figures in the table are per bar of internal pressure.
1 bar = 105 N/m² = 0,1 MPa.

NOTE Thrust forces on reducers need only be considered where the reduction in diameter is large (e.g. 315 × 90). In such cases, the thrust is the product of test pressure and annulus area as given by Formula (5):

$$F = 0,2p \times \pi \frac{d_i^2 - d_e^2}{4} \quad (5)$$

where

F is the thrust force, in Newtons;

p is the test pressure, in bars;

d_i is the inside diameter of the larger pipe, in millimetres;

d_e is the outside diameter of the smaller pipe, in millimetres.

Pipe and fittings systems with fully end-load bearing joints, e.g. solvent cement joints, are self-supporting against pressure thrusts but can still require thrust support against external loads. It should be noted that repairs to systems relying on thrust resistant joints can result in loss of thrust support to fittings

Systems with non-end-load-bearing joints require thrust support at fittings where imbalanced thrusts occur. Bends, tees, and end fittings develop axial tensile thrusts at joints. Valves and reducers present a particular problem since these fittings can develop a compressive loading of downstream pipes. Such thrusts can cause additional hoop stress at the back of the joint, and in the case of thinner walled pipes, telescoping of the joint and consequent decoupling of an upstream joint. Further, the combination of tensile (hoop) and compressive (axial) stresses creates a biaxial stress state that can significantly lower the factor of safety against rupture.

Hybrid systems with elastomeric joints employ thrust-restraining joints or devices (see [Figure 11](#)) at and adjacent to fittings to transfer axial thrusts to the soil through friction. The soil friction varies with surround material type, the compaction, and the depth. Estimates of the available soil friction should be conservative since support can be lost through saturation or adjacent works. The frictional resistance is proportional to the diameter, whereas the thrust developed is proportional to the square of the diameter, so larger pipes will require more pipe length than smaller ones to develop the required frictional force. Reference to [Table 4](#) shows that the forces to be absorbed can be very large for larger pipes, and many lengths of adjacent pipes can require joint thrust restraint.

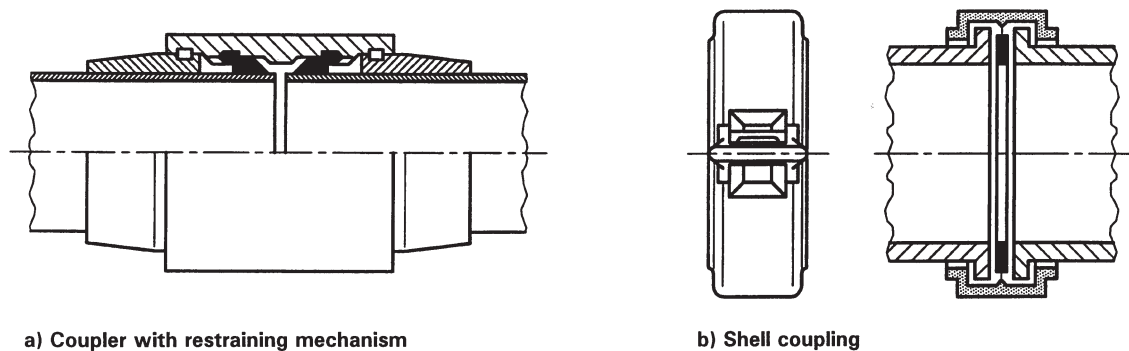


Figure 11 — Examples of special end-load-bearing couplings

Anchorage blocks should be designed to sustain the maximum thrust developed due to internal pressure when the test pressure is applied. Examples of anchor block design, location, and construction are shown in [Figure 8](#).

Typical bearing pressures of soil are shown in [Table 5](#). By using these pressures, one can calculate the size of the required thrust block.

Table 5 — Approximate safe bearing pressures for different soils

Soil type	Safe bearing pressure kN/m ²
Soft clay	24
Sand	48
Gravel, sand, stones mixtures	72
Sand and gravel bonded with clay	96

The values shown in [Table 5](#) for the safe bearing pressure are conservative; in case other values are available, those can apply.

8 Storage, handling, and transport of fittings, valves, and ancillaries

8.1 PVC-U fittings, valves, and ancillaries are light and easy to handle

Throughout all stages of storage, handling, and transport, they should be preserved from damage and contamination and be kept separate from and not temporarily jointed to the pipes until required for installation. When fittings are provided packaged, they should be retained in the individual package provided by the supplier, together with all associated rings, gaskets, nuts, bolts, and accessories.

8.2 The impact resistance of PVC-U fittings, valves, and ancillaries is reduced in cold weather and more care needs to be taken when handling these products at temperatures below 0 °C. If temperatures fall below –15 °C, special instructions from the manufacturer should be obtained.

Fittings, valves, and ancillaries should be used in the order of delivery to ensure the correct rotation of stock. Products are date marked at the time of manufacture and checks should be made to ensure the stock is being rotated on a “first in, first out” basis.

9 Installation

9.1 Installation below ground

The long-term performance of any pressure pipeline is directly affected by the quality of workmanship and materials used in installing the product. Competent supervision of all stages is recommended.

Reasonable care should be taken when handling and installing PVC pipes and components. Pipes and fittings with elastomeric ring seal joints are recommended for installations below ground.

Typical trench and backfill details for PVC pressure pipe installations are shown in [Figure 12](#).

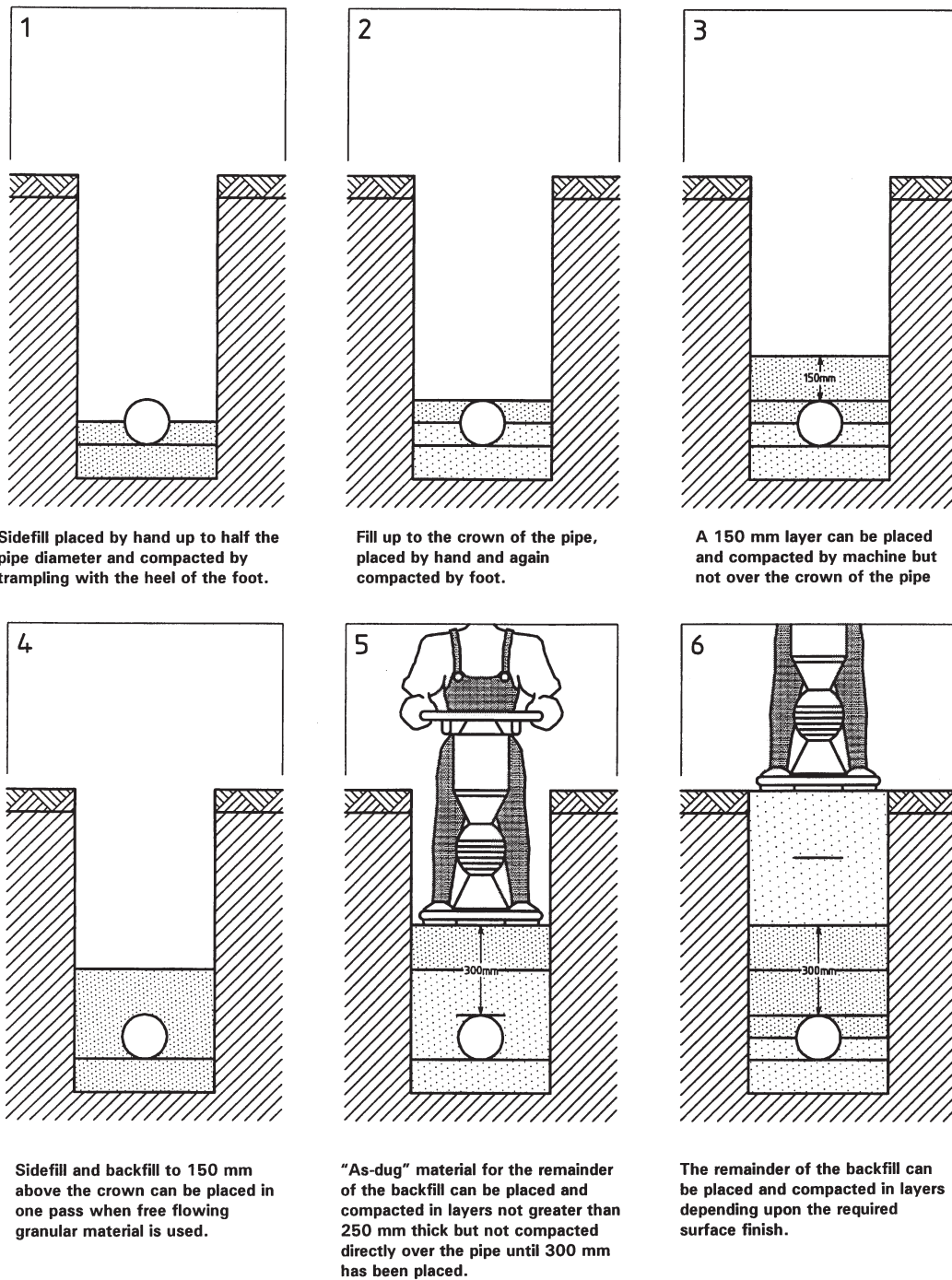


Figure 12 — Typical trench and backfill details

It is good practice to lay pipes with the spigot entered into the socket in the same direction as the intended flow of water. The internal surfaces of the pipe should be kept as clean as possible during the laying and jointing operation. To assist in this respect, the trench should be kept as dry as possible using appropriate de-watering techniques.

Suitable material for both bedding and side fill can be available by selection from the “as dug” excavated material. Such soils as free draining coarse sand, gravel, and soils of a friable nature are considered suitable (see [Annex A](#)).

When using as-dug material, the material shall be free from boulders, sharp stones, flints, lumps of clay, and chalk.

Thermoplastics pipes should never be encased in concrete.

In case PVC pipes have to be passed through a concrete structure, it has to be wrapped and there has to be a flexible joint within a prescribed distance of the point of exit from the concrete.

NOTE Encasing in concrete transforms a flexible pipe into a rigid structure, which can result in severe stresses at the entry point due to differential strain, settlement, or other earth movement.

The minimum depth of cover recommended for buried water pipes is 0,6 m. However, pipes should always be laid at a frost-free depth, therefore where local climatic conditions so dictate the minimum depth of cover can be in excess of 0,6 m.

The base of the trench should be carefully levelled and cleared of any sharp objects, edges, and stones. The trench bottom or bedding material should be excavated locally to accommodate the larger diameter of the joints.

Pipes should be laid along the centre-line of the trench with all joints laid in true alignment, unless deflected in accordance with [Clause 3](#).

The pipes are laid on the prepared bed. Where push-fit elastomeric sealing ring joints are used, the spigot should be introduced into the socket and the insertion completed up to the mark on the spigot pipe by use of a block of wood and a lever. Where mechanical means are used to push together large diameter pipes, care should be taken to avoid damaging the materials or displacing the elastomeric sealing ring.

Where end-load-bearing joints are used, the end-load-bearing joints should be provided at all connections to the components (e.g. tees, blank ends, bends, and valves) and additionally at the first joint in the straight pipes immediately adjacent to and on all sides of the fitting. This should be considered a minimum requirement. In some cases, it can be necessary to provide more than one end-load-bearing joint in the straight pipes. If in doubt, the pipe manufacturer’s advice should be obtained. Load-bearing joints can be both mechanical or chemical, like cement-jointed pipes. Cement-jointed pipes, however, should be made using a collar and socket. So in no way the solvent cement joint should be produced by socketing the pipe in the field. Also here, advice from the manufacture should be sought.

A recommended sequence for placing side fill and surround material is shown in [Figure 12](#).

Where selected material is returned to the trench, it should be placed in layers. The first side fill layer should be placed and compacted under the lower quadrants of the pipe and up to the spring level of the pipe. For pipes up to nominal outside diameter 315 mm, “trampling” or “heeling” is usually an effective means of achieving adequate compaction. Successive layers of 150 mm to 200 mm thickness can then be placed and compacted to a height above the crown of not less than 150 mm. Light vibrating machinery can be used but not directly above the pipe.

Where imported granular material is used, this should be able to flow around the pipe and be easily raked into position to form a complete, self-compacting, surround. With carefully controlled pouring, the whole surround up to 150 mm above the crown can be placed in one pass.

This method should be used when pipes of stiffness <4 kPa are used. This material does not require compaction.

The horizontal distance of the pipeline from foundations and similar underground installations should preferably not be less than 0,4 m in normal circumstances.

Where there is lateral proximity or where the pipeline runs parallel to other pipelines or cables, the distance in the horizontal projection between them should preferably not be less than 0,40 m.

Where cables and pipelines cross, a separation of 0,2 m should be adhered to or special measures should be taken to prevent contact. Transmission of forces through direct contact should be excluded.

Drinking water pipelines should preferably not be located below drainage or sewerage pipelines.

At the end of each working period, the pipeline should be temporarily capped to prevent the ingress of surface water, vermin, or debris. The site should be left tidy and safe against accident, vandalism, or flooding.

Installation of buried pressure pipes can be grouped in roughly three groups, based on the embedment material used and the treatment that it was given. In [Figure 13](#), these three groups are schematically presented. Depending on the way the installation is carried out, pipes will deflect during the installation. In [Figure 14](#), values are given for initial pipe deflection depending on the type of embedment and stiffness class of the pipe.

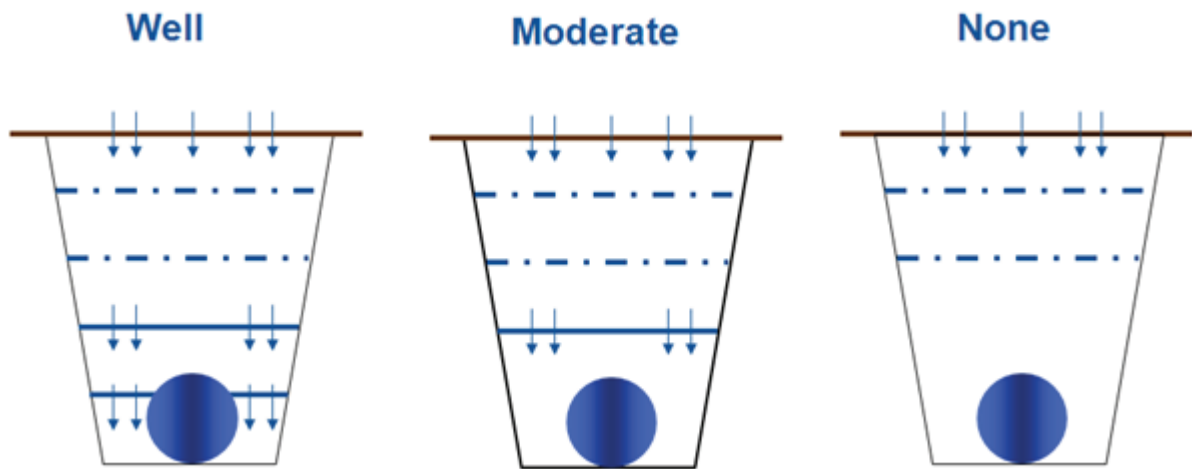


Figure 13 — Instructions for laying and embedment

9.2 Pipe deflection

Deflections occurring immediately after installation as a function of pipe ring stiffness (SN) and type of installation.

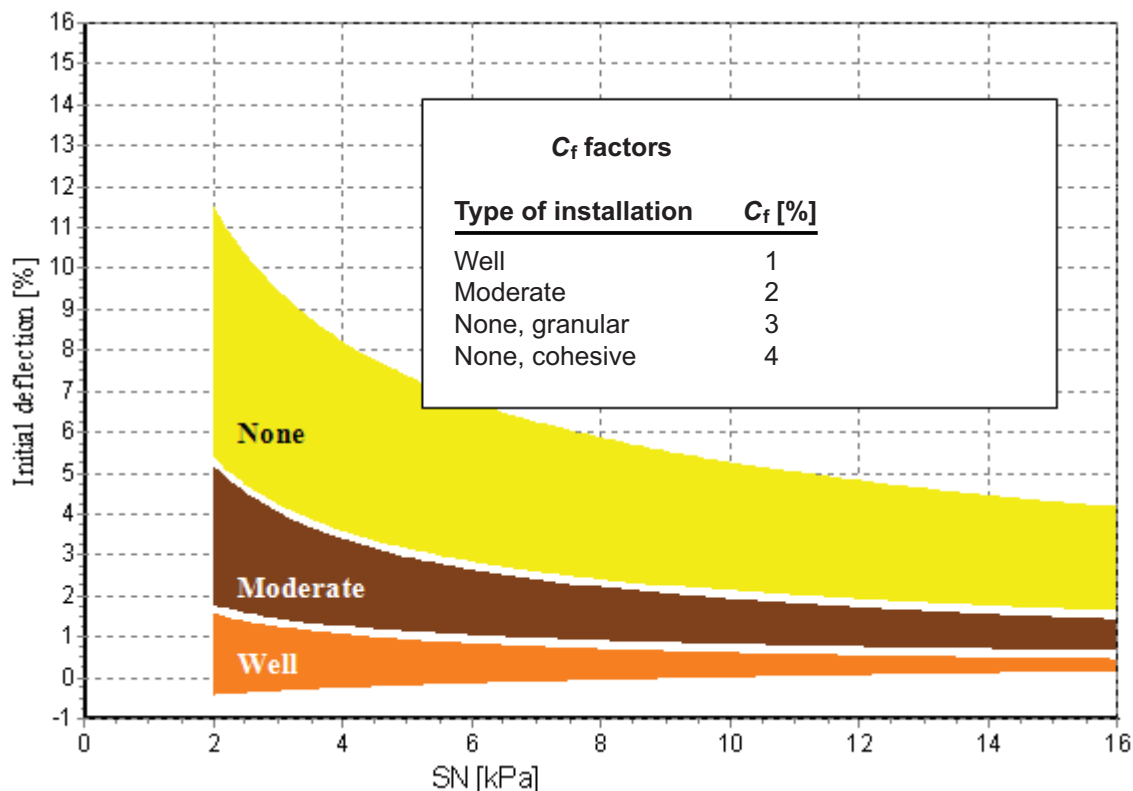


Figure 14 — Pipe deflection immediately after installation, as a function of pipe stiffness (SN) and type of installation

Experimental work over a period of 40 years have shown that pipe deflection increases in the course of time irrespective if the pipe is made out of visco-elastic material or linear elastic material. In the TEPPFA project, it has been explained that this increase is not due to creep of the pipe material but due to settlement of the soil.

In order to determine the final deflections occurring after complete settlement of the soil, the values as listed in [Table 6](#) should be added.

Table 6 — C_f factors to obtain the final deflection

Type of installation	C _f Settlement add-on value [%]
Well	1
Moderate	2
None	4

The final deflection can be calculated as follows:

$$\text{Final deflection} = \text{Initial deflection} + C_f \tag{6}$$

It is important to note that the C_f factor covers the effect of depth of cover, groundwater, and traffic load, as these are all playing an important role in the settlement process.

The pipe ring stiffness SN is determined in accordance with ISO 9969 or can be calculated by

$$SN = \frac{E}{\left[12(1-\nu^2)\right] \times \left(\frac{s}{d}\right)^3} \quad (7)$$

where

- SN is the pipe ring stiffness, in kPa;
- E is the Young's modulus, in MPa;
- ν is the Contraction coefficient;
- s is the Wall thickness, in mm;
- d is the Mean pipe diameter, in mm.

9.3 Installation above ground

9.3.1 Since solvent-cemented joints will sustain axial thrust caused by internal pressure [see item b) of 6.1.3], it is strongly recommended that PVC pipes and PVC-U fittings systems installed above ground or in service ducts constructed below ground are jointed by the solvent cement method. In certain circumstances, the manufacturer's advice should be followed (see Annex A of ISO 1452-2:2009). Other forms of end-load resistant joints as described in item e) of 6.1.3 are also acceptable for inclusion in above-ground installations.

9.3.2 PVC pipes can fracture if the fluids contained within the pipes are allowed to freeze. Measures should be taken to drain and/or isolate sections, which are likely to freeze, or insulation should be provided to protect against frost damage.

9.3.3 The coefficient of linear expansion of PVC is approximately 60×10^{-6} (m/m)/K or 0,06 (mm/m)/K. The following formula is used for calculating dimensional variation:

$$\Delta L = 0,006 L \times \Delta T \quad (8)$$

where

- ΔL is the variation in length, in millimetres;
- L is the initial length, in metres;
- ΔT is the change in temperature of the pipe wall, in degrees Kelvin (or Celsius)

EXAMPLE For a temperature change of 20 K, a PVC pipe 10 m long will have a variation in length of $0,06 \times 10 \times 20 = 12$ mm.

Where ambient temperatures are reasonably constant, the change in pipe wall temperature can be taken as being equal to the change in fluid temperature. Where this is not the case, the pipe manufacturer's advice should be obtained.

The expansion or contraction for temperature changes of 10 K to 45 K and pipe lengths of 1 m to 20 m is shown in [Figure 15](#).

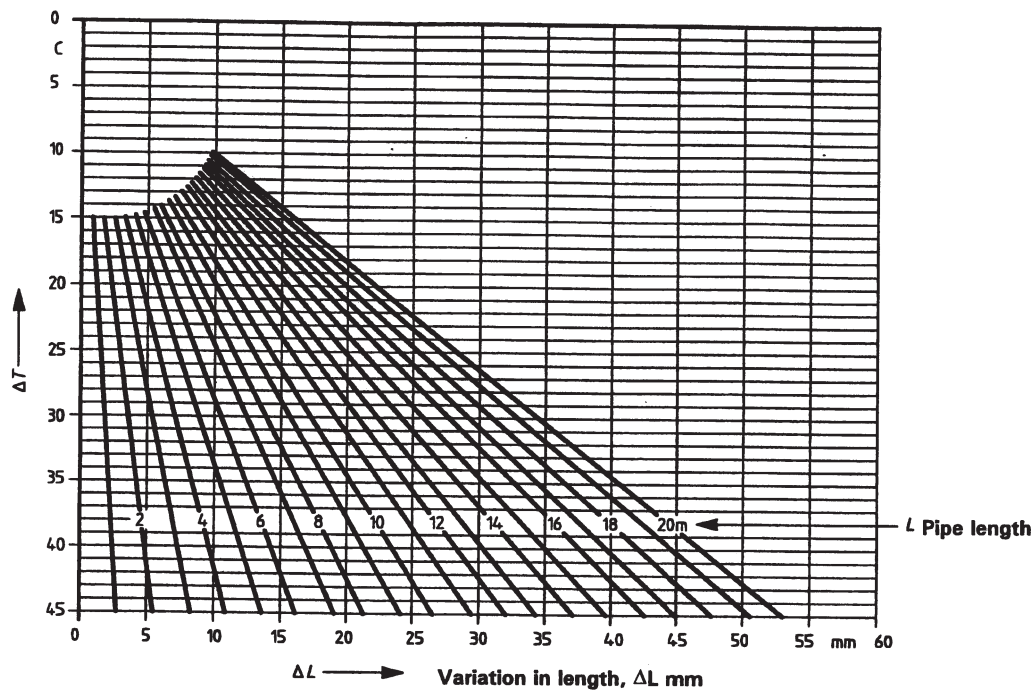


Figure 15 — Thermal expansion/contraction of pipes

The minimum free length, a , of pipe required to accommodate the movement caused by thermal expansion or contraction is shown in [Figure 16](#).

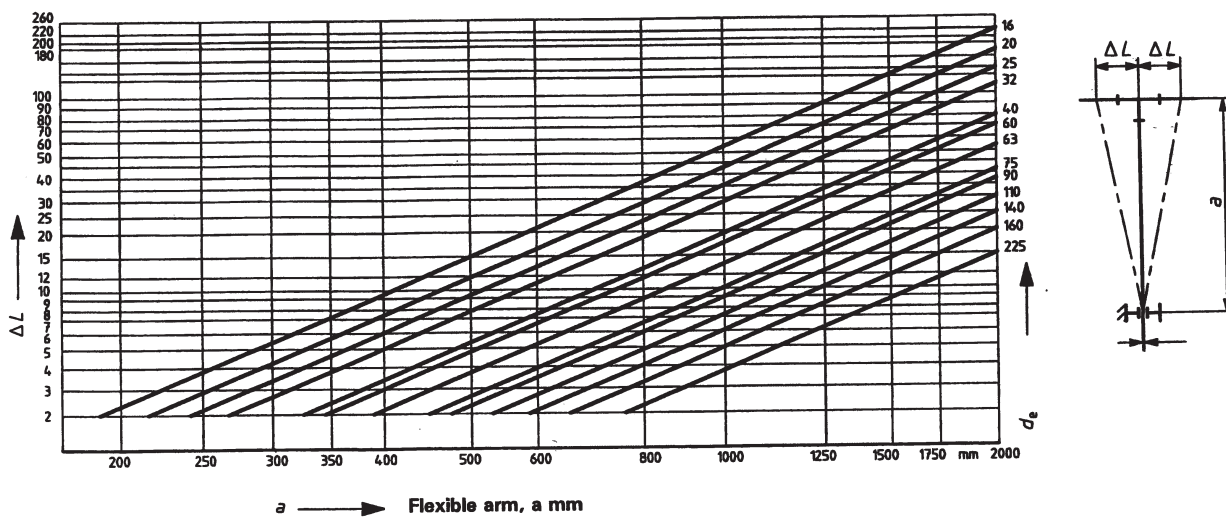
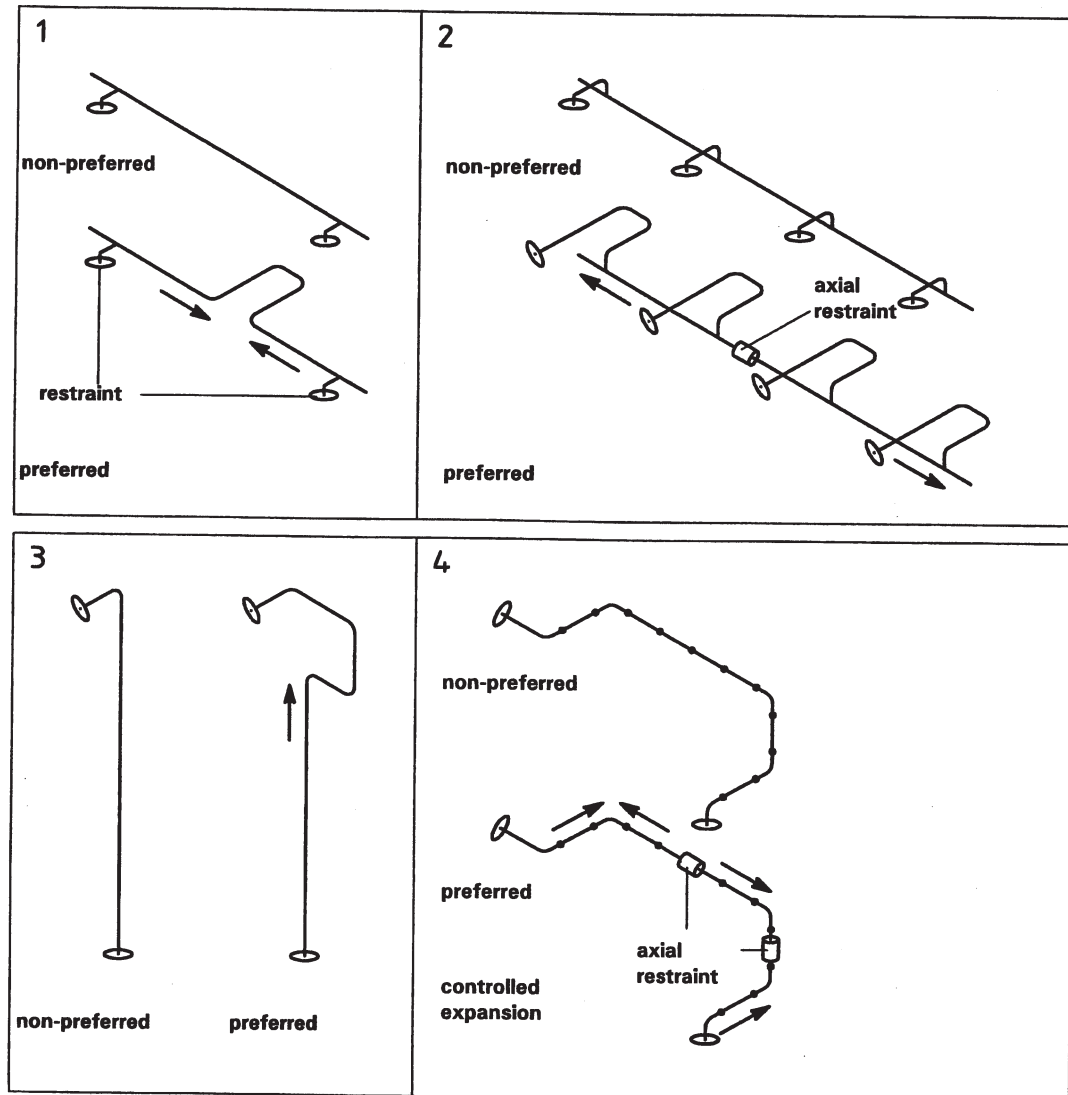


Figure 16 — Minimum free lengths, a , of flexible arm

EXAMPLE For a pipe with expansion of 10 mm and an outside diameter of 50 mm, the length of the arm, a , shall be at least 750 mm.

9.3.4 Pipes should be installed in a way to ensure that the minimum amount of stress is induced in the system from movement caused by expansion or contraction or any forces.

Examples of correct and incorrect arrangements are shown in [Figure 17](#).



Key

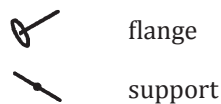


Figure 17 — Examples of correct and incorrect positioning of supports for above-ground installations

9.3.5 As a general rule, PVC pipes should not be restrained in the hoop direction by straps or clamps made from unyielding material. Where such means of securing pipes is to be adopted, a compressible material (e.g. rubber) between the pipe and the clamp is recommended. Numerous methods exist for supporting pipes in the horizontal and vertical planes in above-ground applications. Important features for consideration are the following:

- a) pipes should be free to move in the longitudinal direction unless otherwise fixed for expansion/contraction control;

- b) recommended distances between horizontal or vertical support centre lines for systems operating up to 45 °C, as given in [Table 7](#), should not be exceeded.

Table 7 — Horizontal and vertical pipe supporting centres

Dimensions in millimetres

Outside diameter of pipe d_e	Distance between supporting centres for water at temperatures for						Vertical pipes 20 °C to 45 °C
	Horizontal pipes						
	20 °C	25 °C	30 °C	35 °C	40 °C	45 °C	
16	750	670	600	500	400	–	800
20	850	770	700	600	500	–	900
25	900	820	750	650	550	500	1 000
32	1 000	920	850	750	650	570	1 200
40	1 100	1 050	1 000	900	800	700	1 400
50	1 250	1 200	1 150	1 050	950	820	1 600
63	1 400	1 350	1 300	1 200	1 100	970	1 800
75	1 500	1 450	1 400	1 300	1 200	1 070	2 000
90	1 650	1 600	1 550	1 450	1 350	1 200	2 200
110	1 850	1 800	1 750	1 650	1 550	1 370	2 400
140	2 150	2 100	2 050	1 950	1 850	1 720	2 500
160	2 250	2 200	2 150	2 070	2 000	1 850	2 500
225	2 500	2 450	2 400	2 320	2 250	2 120	2 500

Some typical examples of correct and incorrect methods of supporting PVC pressure pipes and PVC-U fittings are shown in [Figure 18](#).

Examples of good and bad pipe supports

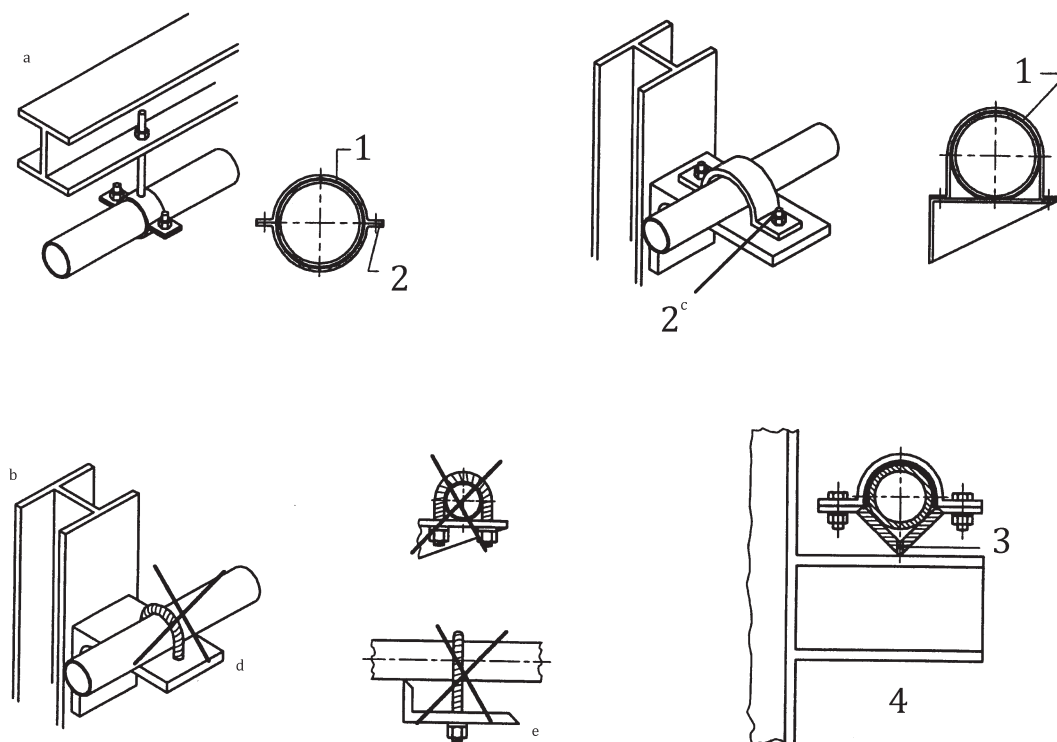


Figure 18 — Examples of correct and incorrect pipe support details for installation above ground

9.3.6 PVC pipes should be installed at a sufficient distance from hot objects to prevent damage by radiant heat.

9.3.7 All control devices (such as valves) should be correctly supported so that the pipe is not subjected to any operational torsional strain. In addition, the support provided should be sufficiently robust to prevent bending and direct stresses being induced by the weight of the device.

9.3.8 PVC pipes and fittings installed above ground should be protected from direct sunlight. Optionally, the pipes and fittings can be painted with acrylic based paint (PVA) in order to create sufficient protection.

9.4 Installation in ducts

9.4.1 Where possible, pipes with end-load-bearing joints should be used for installation inside inaccessible ducts. In addition, centring rings should be fitted to the pipe to provide optimum support and facilitate the withdrawal of the pipe in the event of rupture (see Figure 19 for typical detail). For large diameter pipes or where the duct is large compared to the pipe but not large enough to be accessible, other methods of securing the pipe can be necessary (see Figure 20). The opening between the pipe and the ducting system should be sealed at the ends.

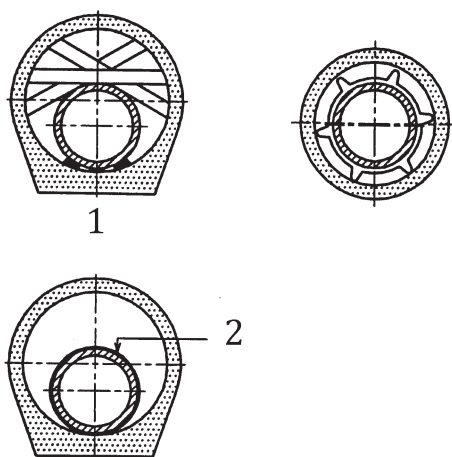


Figure 19 — Typical details of pipes installed in small ducts

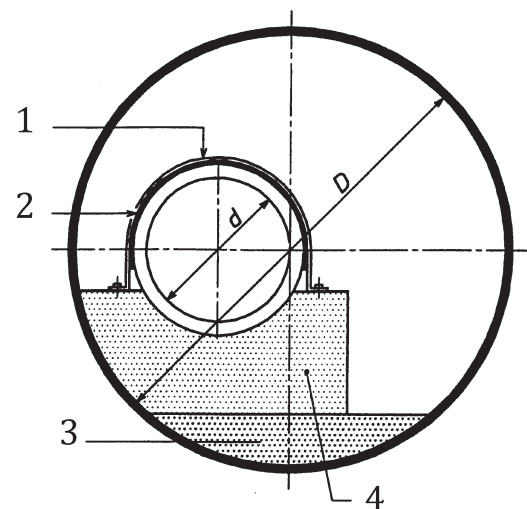


Figure 20 — Typical details of pipes installed in large ducts

NOTE Lateral forces can cause the end caps to turn and be displaced.

9.4.1 Installation of pipes in large accessible ducts should be as described in [9.3](#)

10 Commissioning by site pressure testing

10.1 General

Pressure tests should never be carried out using compressed air as the testing medium.

10.2 Preparation for test

10.2.1 Pipe systems should be hydraulically tested in lengths appropriate to the diameter and site conditions. Pipelines longer than 800 m can require testing in sections. Preferably, the length selected for test is between 300 m and 500 m.

10.2.2 Preferably, the test should be carried out between blank flanges. The ends of the pipeline to be tested can be adapted by the use of appropriate flanged sockets or bolted flange adaptors. The blank ends or special test unit (see Figure B.18) should be drilled and tapped as necessary to accommodate the necessary inlet and outlet connections. The ends of the main pipeline, and all branch connections, should be strutted and anchored so as to adequately withstand the thrusts from the test pressures. Testing against closed valves is not recommended unless there is no alternative.

10.2.3 Anchoring systems are usually formed by mass concrete, temporary piles, timber baulks, or sheet steel, depending upon the pressures involved and the available earth resistance. Typical test-end layouts are illustrated in Figure 21. The anchor jacks or struts should be of adequate strength and properly aligned.

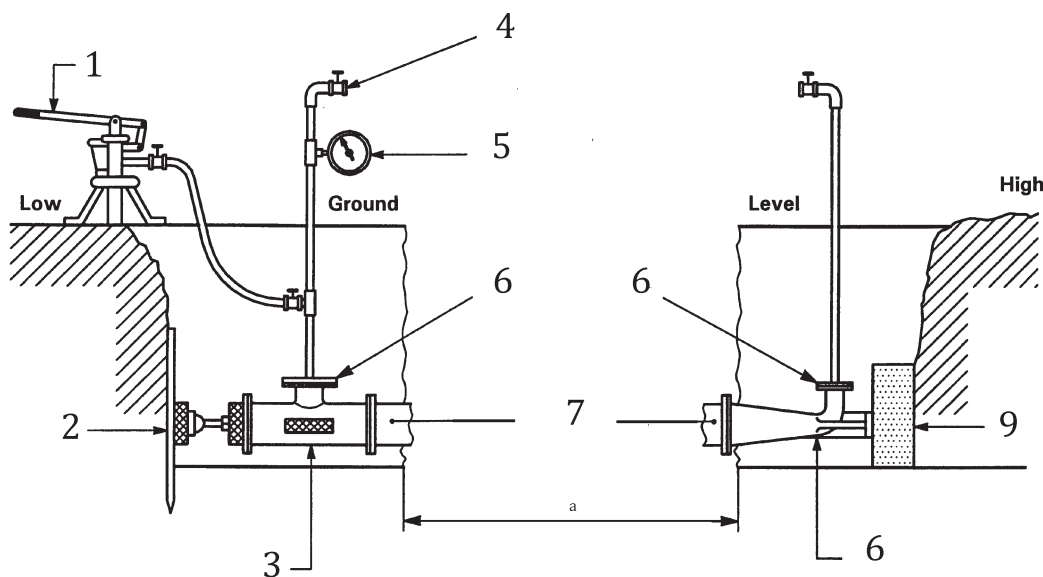


Figure 21 — Typical layout details for test ends

10.2.4 Testing should not take place until any concrete used for anchorage has matured and attained its required strength. Solvent-welded joints should be allowed to harden for a minimum of 24 h before being subjected to test conditions.

10.2.5 Site conditions will usually dictate whether all joints can be left exposed. Whenever practicable, joints should be exposed throughout the test period. It is important to provide sufficient compacted surround and backfill, over the main barrel of the pipe, to prevent displacement and to maintain stable temperatures during the test period.

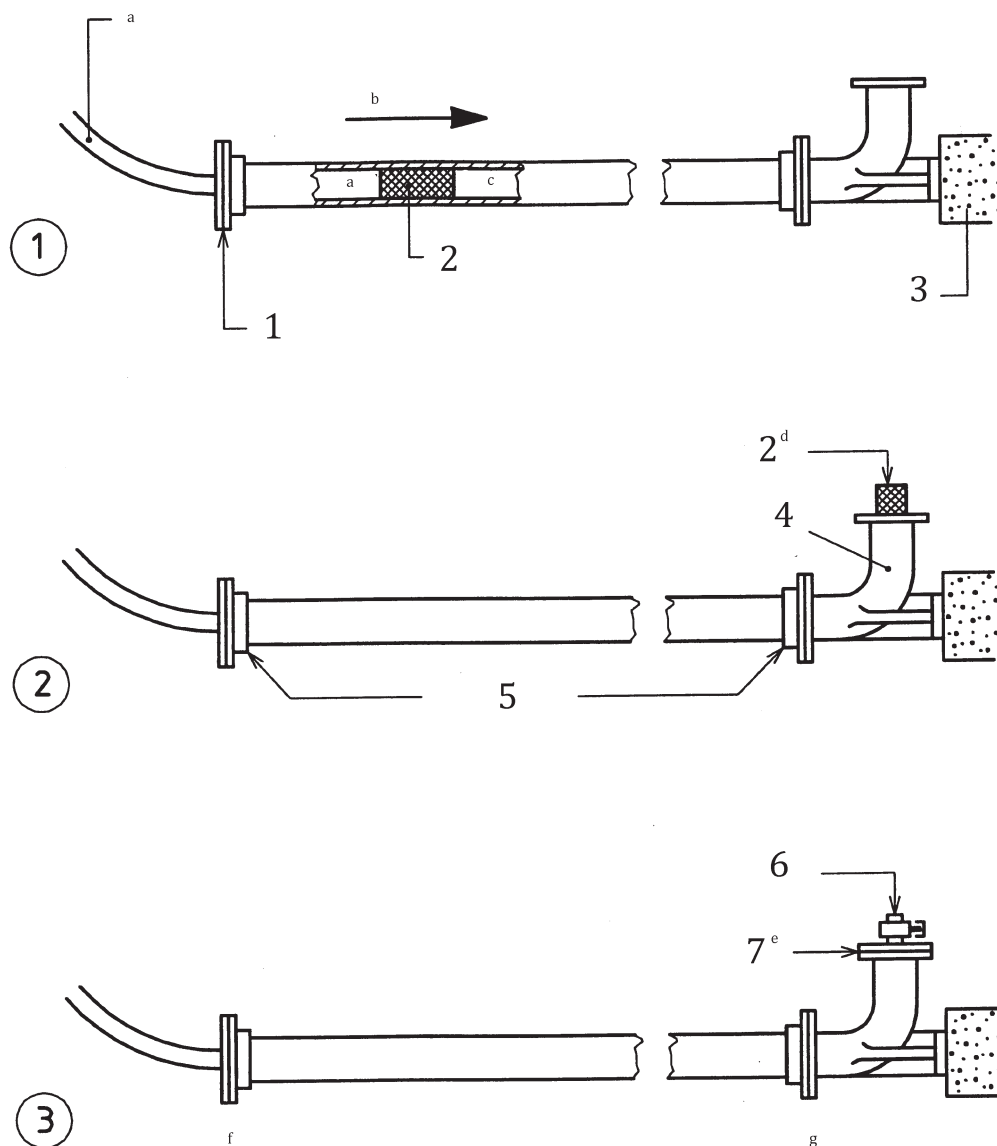
10.2.6 Wherever possible, the test position should be located at the lowest point of the pipeline profile to encourage the expulsion of air as the pipe is being filled. This position will usually register the maximum pressure head and enable easier control over the release of any test water. Adequate air release mechanisms should be sited at all high points along the pipeline.

10.2.7 Test ends should be designed to enable the measured filling and subsequent emptying of the pipeline. Blank flanges, test pipes, or end caps should have the relevant tappings to accommodate the necessary pressure gauges and related equipment. An air bleed should also be incorporated at each end of the test section.

10.2.8 The pressurizing equipment, whether hand or mechanically operated, should be adequately sized and sufficiently robust, with connections of suitable design to positively impose and maintain the required test pressures. All seals and any non-return valve mechanisms should be checked prior to the test.

Duplicate isolating valves on the pressure injection line are recommended. Where mechanical pressure gauges are used (e.g. Bourdon type), these should be of sufficient size to enable easy reading and be capable of resolving to an accuracy of $\pm 0,2$ bar. Automatic pressure recording equipment is recommended to be used.

10.2.9 Before filling the pipeline, all line valves and air venting systems should be checked open. On the larger mains, automatic air/vacuum release valves should have been installed at all high points of the pipeline profile and these will operate normally during charging. Every endeavour should be made to remove all air from the main. Introduction of a firm foam swab ahead of the water column will prove helpful in some cases. This procedure is shown diagrammatically in [Figure 22](#).



Key

- 1 blank flange or test pipe tapped to suit pump connection
- 2 foam swab
- 3 temporary thrust block
- 4 cast iron duckfoot bend
- 5 flange adaptors
- 6 air release cock
- 7 blank flange
- a Water.
- b Flow.
- c Air.
- d Emerging from bend.
- e Boiled in place.
- f Low point.
- g High point.

Figure 22 — Filling behind a foam swab

10.2.10 When the system is to be used for potable water, then the test medium should be potable water. It is important to charge any pipeline slowly, the rate of fill being governed by the facilities available for the air to discharge at an equal volumetric rate. After ensuring the pipeline is fully charged, all air vents should be closed. Automatic air valves will self-seal under pressure but their action and seating should be checked as part of the test.

10.2.11 During the filling and pressurizing process, a number of minor movements can be expected in the pipeline between anchorage points because of one or more of the following:

- a) additional weight of the pipe as it fills, causing slight adjustment in the soil/pipe interface;
- b) minor dimensional changes and a tendency of the pipeline to straighten under pressurization;
- c) thermal movement due to temperature differences at the water/pipe/soil interfaces.

10.2.12 The whole pipeline should therefore be left under a nominal or service pressure to stabilize for a period of time. A minimum of 2 h to 3 h should be allowed for even the smallest pipeline.

10.3 Test pressures

10.3.1 The hydrostatic (proof) test should conform to the following conditions:

- a) be carried out at ambient temperature;
- b) be applied for at least 1 h but not more than 24 h;
- c) not exceed 1,25 times the maximum rated pressure of the lowest rated component.

Recommendation c) is interpreted in a variety of ways. Test pressure requirements range from the severe 1,25 times pipe nominal pressure PN to the more lenient 1,25 times the actual operating pressure. The actual operating pressure is the continuous pressure, which is sustained in the system without surge.

For the purposes of ISO 1452, the recommended test pressure is selected as follows:

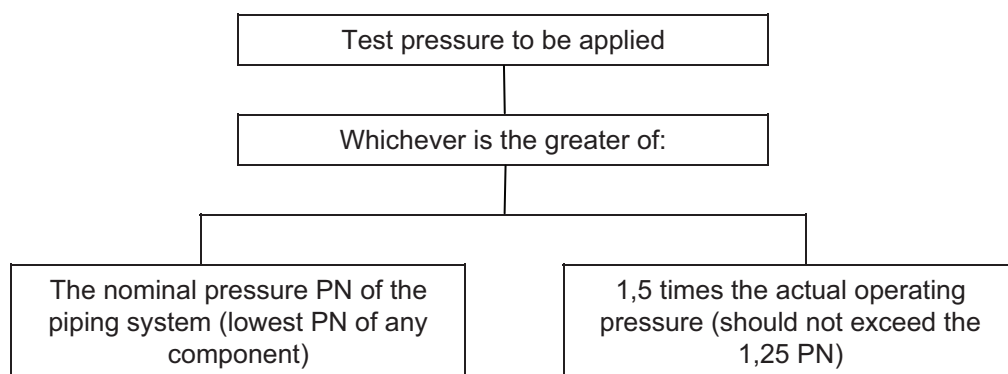


Figure 23

10.4 Applying the test

10.4.1 After sufficient time has been allowed for the main to stabilize, the pressure test can then be steadily applied. Pressurizing can be either by hand or motorized pump. Pressure gauges should be observed throughout and the rate of pressure increase recorded.

10.4.2 The pressure should be increased until the specified test pressure is reached at the lowest part of the section. The pressure is maintained at this level, by additional pumping if necessary, for a period of

1 h. All valves are then closed and the pressurising unit disconnected. No further water should be allowed to enter the section under test for a further period of 1 h.

10.4.3 During the test period, a visual examination of all joints and connections of the section under test should be carried out.

10.5 Interpretation of results

10.5.1 If there has been a decrease in pressure during this period, the original test pressure is re-established by injecting a measured quantity of water into the test section.

10.5.2 The test can be considered satisfactory if

- a) there is no decrease in pressure (it is even possible for there to be a slight rise due to changes in temperature or material reversion) and
- b) the measured quantity of water required to reinstate the pressure to the original test pressure is less than a "permissible maximum".

NOTE The "permissible maximum" value and the method of calculation vary considerably from country to country. Users' requirements should therefore be obtained and applied as appropriate.

The volume of water added is an allowance made to compensate for the natural expansion/movement of the pipe and flexible joints under pressure and for the inevitable entrapment of small amounts of air within the test length. In bubble form, this air compresses and can pass in and out of the solution at test pressures.

10.5.3 On completion of any test, the residual pressure should be released slowly and in a carefully controlled manner.

WARNING — The rapid decompression of any entrained air can cause surge conditions, which are potentially dangerous both to the pipeline and to personnel.

10.5.4 All defects revealed by the test should be rectified and the procedure repeated until a satisfactory result is obtained.

11 Contaminated soil

11.1 PVC pipes are resistant to all normal soil conditions and do not require any corrosion protection.

11.2 Care should be taken to ensure that the backfill materials are not polluted by chemicals such as aromatic hydrocarbons. Where the existing ground is contaminated with such pollutants, the polluted ground should be replaced by unpolluted ground material. Otherwise, the PVC pipes, PVC-U fittings, and valves should be protected. It is recommended not to use unprotected PVC pipes and PVC-U fittings in polluted ground material.

11.3 Anti-corrosion tape or similar protective materials applied to metal connecting pieces should be of a type which does not damage the PVC pipes or PVC-U fittings if they come into contact with the pipeline.

In case of doubts, advice can be sought from the pipe manufacturer.

12 Corrosion protection of metal parts

PVC does not conduct electricity and thus cannot be used for earthing; neither can these pipes be thawed by electrical means using the pipe as a conductor. If a network exists of metal pipes with a cathodic

protection system and part of the network is replaced with PVC pipes, electrical continuity shall be maintained by bridging the PVC pipes.

13 Pressure surge

In operating conditions where surge pressures will occur, suitable precautions should be taken. In such circumstances, a surge analysis should be undertaken to establish the magnitude and frequency of surge pressure transients.

Pressures greatly in excess of normal sustained operating pressures can be generated when fluid velocities change rapidly. The magnitude of pressure surge largely depends on the rate of change of velocity and the modulus of the pipe line material.

Typical operating conditions, which can give rise to surge pressure, include the following:

- a) rapid closure of single action valves;
- b) oscillating float valves (i.e. no stilling chamber);
- c) pump shut down;
- d) pockets of entrapped air ([Clause 10](#) on site pressure testing).

Good pipeline design will always analyse for surge conditions regardless of the pipeline material to be used.

Where surge pressures are anticipated, the design should include such control features as surge towers, flywheels to pumps, and slow operating valves to reduce the surge magnitude.

It is not recommended to use pipes with nominal ring stiffness $SN < \text{kN/m}^2$ when surge can occur and/or poor soil conditions ([Table A.1](#) groups 6 and 7) installation practices are intended to be used.

14 Usage at lower temperature

PVC-U fittings can be sensitive to very rapid changes in temperature, for example, due to the introduction of chilled water, brine, or ethylene glycol solution into a pipe system at room temperature. Since PVC is an excellent insulator, such action sets up steep thermal gradients through the wall, resulting in extreme internal stresses that can lead to rupture. Operating systems should be designed to ensure that such temperature changes occur at moderate rates. Where rapid changes cannot be avoided, consideration should be given to the use of metallic fittings.

This phenomenon is observed primarily with fittings, having thicker walls and complex geometry, and does not occur in pipes.

15 Fatigue

Fatigue is associated with a large number of repetitive events. Many materials will fail at a lower stress when subjected to cyclic or repetitive loads than when under static loads. This type of failure is known as (cyclic) fatigue. For thermoplastic pipe materials, fatigue is only relevant where a large number of cycles are expected, greater than 25 000 during the life of the system. Such circumstances are rare in water supply systems.

For systems where frequent cycling cannot be avoided, various design methods have been proposed*, based on experimental data. One such involves an assessment of the magnitude of the pressure

fluctuation, the loading frequency, and the intended service life. A Fatigue Cycle Factor, f_c , is obtained from [Table 8](#), and the required pressure rating, P , of the pipe is calculated as

$$P = \frac{P_c}{f_c} \quad (9)$$

where

P_c is the maximum pressure in the system related to the pressure cycle;

f_c is the Fatigue Cycle Factor;

P is the required rating of pressure.

An appropriate PN can be selected accordingly. More detail can be found in the references listed in [Table 8](#). For fittings, complex stress patterns can complicate selection. The manufacturer's advice should be sought.

Table 8 — Fatigue Cycle Factors

Total Life Cycles	Approx. No. Cycles / day for 100y life	Fatigue Cycle Factors, f_c	
		PVC-U	PVC-O
26 400	1	1	1
100 000	3	1	0,75
200 000	5,5	0,81	0,66
500 000	14	0,62	0,56
1 000 000	27	0,50	0,49
2 500 000	82	0,38	0,41
5 000 000	137	0,38	0,41
10 000 000	274	0,38	0,41

NOTE Sources are References [7] and [8].

16 Repairs

Various methods can be used for repairing leaks or damage to sections of PVC piping. The recommended procedure is to replace the damaged section using a new straight length of pipe, pre-fabricated element, or fitting. Where leakage occurs in a solvent-cemented joint, re-cementing should never be attempted.

Sliding sleeves (repair couplers) which include elastomeric sealing rings, are available, without a central stop, e.g. as shown in Figure 3 c). These are especially made for repair work and slid onto the spigot ends so that the required position is obtained for a leak-tight joint.

Many forms of mechanical fittings for repair work are available, for example, PVC-U repair coupling with elastomeric rings compressed axially by threaded end caps and bolted gland fittings are in various materials such as ductile iron, stainless steel, or FRP. These fittings are used where a section shall be cut out of the line and a replacement inserted. Repairs of small damaged sections can be performed without cut-out and can be effected by use of bolted clamp fittings. These devices are used where possible to effect repair of small leaks without disruption to service.

Care shall be exercised in the use of all bolted fittings to observe the manufacturer's recommendations with regard to tightening torque and to ensure uniform progressive tightening of bolts. Over-tightening or uneven tightening can lead to local buckling of the pipe wall, especially for small diameter (<DN 200) and low stiffness (<SN 10) pipes. Proper lubrication of the gaskets according to manufacturer's instructions is very important.

For low stiffness pipe repairs, recommended devices are available such as rigid clamp fittings and flexible band clamps. Rigid clamp fittings should preferably have a positive stop to prevent over-tightening. Flexible band clamps are not recommended for small bore low stiffness pipes, and for larger pipes, two-part (or more) devices are preferred. Note that flexible clamps should not be used for connecting pipes or for large ruptures.

It is most important to understand that the various fittings each have their own applications and limitations. They are not equivalent. In all cases, follow the manufacturer's instructions.

17 Pipeline detection

PVC pipelines, once buried, cannot be traced by electromagnetic means. To facilitate their tracing, or simply to limit the possibility of damage from excavating machinery after the pipeline is laid and backfilled, it is recommended that suitable marker tapes are placed vertically above the crown of the pipe at a distance between 350 mm and 500 mm below the finished surface level of the ground, depending upon environmental circumstances. Some tapes contain elements, which can be traced by remote means.

Annex A (informative)

Classification of soils

A.1 Soil group

In this Annex, taken from CEN/TR 1046, various types of soil are considered, namely non-cohesive, mixed grained, fine grained, and organic. Each of these has subgroups, which, for granular material, are based on particle size and granulation and, for cohesive material, are based on levels of plasticity.

Table A.1 — Soil groups

Soil type	Soil group				
	#	Typical name	Symbol ^a	Distinguishing characteristics	Example(s)
Non-cohesive, coarse-grained granular, predominantly gravel sized	1	Single-sized gravel	[GU]	Steep grading curve, predominance of one grain size	Crushed rock, river and beach gravel, morainic gravel
Non-cohesive, coarse-grained granular, predominantly sand sized	2	Well-graded gravels, gravel-sand mixtures	[GW]	Continuously sloping grading curve, several grain sizes	scoria, vulcanic ash
		Poorly graded gravel-sand mixtures	[GP]	Step-like grading curve, one or more absent grain sizes	
		Single-sized sands	[SU]	Steep grading curve, predominance of one grain size	Dune and drift sand, valley sand, basin sand
		Well-graded sands, sand-gravel mixtures	[SW]	Continuously sloping grading curve, several grain sizes	Morainic sand, terrace sand, beach sand
		Poorly graded sand-gravel mixtures	[SP]	Step-like grading curve, one or more absent grain sizes	

^a The symbols used are taken from the British Standard BS 5930.

Table A.1 (continued)

Soil type	#	Typical name	Soil group		Example(s)	
			Symbol ^a	Distinguishing characteristics		
Mixed grained soil with low fine fraction and some cohesion	3	Silty gravel-sand mixtures	[GWM] [GPM] [SWM] [SPM]	Gravel being the predominant fraction, particle size ≤0,06 mm (5 % to 15 %)	Morainic gravel, weathered material, hillside debris, glacial till	
		Clayey gravel-sand mixtures	[GWC] [GPC] [SWC] [SPC]			
		Silty sands	[SWM] [SPM]	Sand being the predominant fraction, particle size ≤0,06 mm (5 % to 15 %)		
		Clayey sands	[SWC] [SPC]			
Mixed grained soil with high fine fraction and moderate cohesion	4	Very silty gravel-sand mixtures	[GML] [GMI] [SMH] [SMV] [SME]	Well- or poorly graded gravel resp. sand being the predominant fraction (portion of silt resp. clay 15 % to [35] 40 %)	Morainic gravel, weathered material, hillside debris, glacial till	
		Very clayey gravel-sand mixtures	[GCL] [SCL] [SCH] [SCV] [SCE]			
		Very silty resp. clayey sand	[SML] [SCH] [SCV] [SCE]			
		Silty or clayey fine sand	[SWM] [SPM] [SWC] [SPC]	Particle size <0,2 mm (portion of silt resp. clay 5 % to [35] 40 %), low plasticity, low dry strength		Loess, leucstrine clay
		Silt of low plasticity	[MLS] [MIS]			

^a The symbols used are taken from the British Standard BS 5930.

Table A.1 (continued)

Soil type	#	Typical name	Soil group		Example(s)
			Symbol ^a	Distinguishing characteristics	
Fine-grained cohesive soils	5	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands	[ML]	Low stability, rapid reaction, nil to slight plasticity	Loess, loam
		Inorganic clay, distinctly plastic clay	[CL]	Medium to very high stability, no to slow reaction, low to medium plasticity	Alluvial marl, clay
Organic	6	Mixed grained soils with admixtures of humus or chalk	[OK]	Admixtures of plant or non-plant type, decay smell, light weight, large porosity	Top soils, chalky sand, tuff sand
		Organic silt and organic silt clay	[OL]	Medium stability, slow to very quick reaction, low to medium plasticity	Sea chalk, top soil
		Organic clay, clay with organic admixtures	[OH]	High stability, nil reaction, medium to high plasticity	Mud, loam
	7	Peat, other highly organic soil	[Pt]	Decomposed peats, fibrous, brown to black coloured	Peat
		Muds	[F]	Sludges deposited under water, often interspersed with sand/clay/chalk, very soft	Muds

^a The symbols used are taken from the British Standard BS 5930.

Where a soil is a mixture of types, then whichever is the predominant one present can be used for the classification.

A.2 Consolidation class terminology

Frequently, the density or degree of consolidation is indicated for a soil. This can be in the form of words or numbers. [Table A.2](#) gives the approximate relationship for the various descriptions used.

Table A.2 — Consolidation class terminology

Description	Degree of consolidation			
	≤ 80	81 to 90	91 to 94	95 to 100
% Standard Proctor ^a	0 to 10	11 to 30	31 to 50	> 50
Expected degrees of consolidation achieved by the compaction classes in this standard	NOT (N)			
	MODERATE (M)			
			WELL (W)	
Granular soil	loose	medium dense	dense	very dense
Cohesive and organic soil	soft	Firm	stiff	hard
^a Determined in accordance with DIN 18127 NOTE Table A.2 is meant to be an aid for interpretation of descriptions used in various sources into the terms used for the degrees of consolidation in this standard.				

Where detailed information of the undisturbed native soil is not available, then it is usually assumed that it has a consolidation equivalent to between 91 % and 97 % Standard Proctor Density (D_{Pr}).

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