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Pipes and joints made of oriented unplasticized poly(vinyl chloride) (PVC-O) for the conveyance of water under pressure — Specifications

Tubes et assemblages en poly(chlorure de vinyle) non plastifié orienté (PVC-O) pour le transport de l'eau sous pression — Spécifications

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 16422 was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 2, *Plastics pipes and fittings for water supplies.*

Introduction

Molecular orientation of thermoplastics results in improvement of physical and mechanical properties. Orientation is carried out at temperatures well above the glass transition temperature.

Orientation of PVC-U pipe-material can be induced by different processes.

One is the off-line process, where the thick-walled extruded tube is conditioned in a tubular mould at the desired temperature, and in which means are designed to activate the orientation process in the circumferential and axial directions.

A second option is the in-line process, where the thick-walled tube, directly after the extrusion process, is conditioned in-line at the orientation temperature, and in which means are incorporated to activate the orientation process in the circumferential and axial directions.

After the orientation process, the pipe is cooled down quickly to ambient temperature. The structure of this oriented pipe is stable up to the glass transition temperature (≈ 75 °C), above which the material will have a rubber phase where the pipe will shrink back to its original dimensions after extrusion.

The orientation of the molecules creates a laminar structure in the material of the pipe wall. This structure gives the ability to withstand brittle failure emanating from minor flaws in the material matrix or from scratches at the surface of the pipe wall. PVC-O can therefore be considered as highly resistant to notches and no testing is needed. Because of the morphology of oriented PVC-U pipe-material, there is no risk of long-line rapid crack propagation.

Improved hoop strength and improved resistance to impact also result.

Pipes and joints made of oriented unplasticized poly(vinyl chloride) (PVC-O) for the conveyance of water under pressure — Specifications

1 Scope

This International Standard specifies the general aspects of pipes and joints made of oriented unplasticized poly(vinyl chloride) (PVC-O), for piping systems intended to be used underground or above-ground where not exposed to direct sunlight, for water mains and services, pressurized sewer systems and irrigation systems.

The piping system according to this International Standard is intended for the conveyance of cold water under pressure, for drinking water and for general purposes up to and including 45 °C, and especially in those applications where special performance requirements are needed, such as impact loads and pressure fluctuations, up to pressure ratings of 25 bars[1)].

Joints constructed of other materials shall meet their own relevant standards in addition to the fitness-for-purpose requirements of this International Standard.

2 Normative references

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

ISO 3:1973, *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 1167-1:2006, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 1: General method*

ISO 1628-2, *Plastics — Determination of the viscosity of polymers in dilute solution using capillary viscometers — Part 2: Poly(vinyl chloride) resins*

ISO 2045, *Single sockets for unplasticized poly(vinyl chloride) (PVC-U) and chlorinated poly(vinyl chloride) (PVC-C) pressure pipes with elastic sealing ring type joints — Minimum depths of engagement*

ISO 2507-1, *Thermoplastics pipes and fittings — Vicat softening temperature — Part 1: General test method*

ISO 2507-2, *Thermoplastics pipes and fittings — Vicat softening temperature — Part 2: Test conditions for unplasticized poly(vinyl chloride) (PVC-U) or chlorinated poly(vinyl chloride) (PVC-C) pipes and fittings and for high impact resistance poly(vinyl chloride) (PVC-HI) pipes*

ISO 2531, *Ductile iron pipes, fittings, accessories and their joints for water or gas applications*

1) 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm^2

ISO 3126, *Plastics piping systems — Plastics components — Determination of dimensions*

ISO 3127, *Thermoplastics pipes — Determination of resistance to external blows — Round-the-clock method*

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

ISO 4422-2:1996, *Pipes and fittings made of unplasticized poly(vinyl chloride) (PVC-U) for water supply — Specifications — Part 2: Pipes (with or without integral sockets)*

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

ISO 6259-2:1997, *Thermoplastics pipes — Determination of tensile properties — Part 2: Pipes made of unplasticized poly(vinyl chloride) (PVC-U), chlorinated poly(vinyl chloride) (PVC-C) and high-impact poly(vinyl chloride) (PVC-HI)*

ISO 7686, *Plastics pipes and fittings — Determination of opacity*

ISO 9080:2003, *Plastics piping and ducting systems — Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation*

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

ISO 11922-1:1997, *Thermoplastics pipes for the conveyance of fluids — Dimensions and tolerances — Part 1: Metric series*

ISO 12162, *Thermoplastics materials for pipes and fittings for pressure applications — Classification and designation — Overall service (design) coefficient*

ISO 13783, *Plastics piping systems — Unplasticized poly(vinyl chloride) (PVC-U) end-load-bearing double-socket joints — Test method for leaktightness and strength while subjected to bending and internal pressure*

ISO 13844, *Plastics piping systems — Elastomeric-sealing-ring-type socket joints of unplasticized poly(vinyl chloride) (PVC-U) for use with PVC-U pipes — Test method for leaktightness under negative pressure*

ISO 13845, *Plastics piping systems — Elastomeric-sealing-ring-type socket joints for use with unplasticized poly(vinyl chloride) (PVC-U) pipes — Test method for leaktightness under internal pressure and with angular deflection*

ISO 13846, *Plastics piping systems — End-load-bearing and non-end-load-bearing assemblies and joints for thermoplastics pressure piping — Test method for long-term leaktightness under internal water pressure*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply

3.1
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 It is a convenient round number for reference purposes.

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

3.2
nominal wall thickness
e_n
specified wall thickness, in millimetres

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

3.3
nominal pressure
PN
alphanumeric designation related to the mechanical characteristics of the components of a piping system and used for reference purposes

3.4
hydrostatic pressure
p
internal pressure applied to a piping system

3.5
working pressure
maximum pressure which a piping system can sustain in continuous use under given service conditions without pressure surge

NOTE For thermoplastics piping systems, the value of the nominal pressure is equal to the working pressure at a temperature of 20 °C, expressed in bar.

3.6
hydrostatic stress
σ
stress, expressed in megapascals, induced in the wall of a pipe when it is subjected to internal water pressure

NOTE 1 It is calculated using the following approximate equation:

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

where

p is the applied internal pressure, in bar;

d_n is the nominal outside diameter of the pipe, in millimetres;

e_n is the nominal wall thickness, in millimetres.

NOTE 2 If σ and p are given in the same units, the denominator becomes $2e_n$

3.7
long-term hydrostatic strength for 50 years at 20 °C
σ_{LTHS}
quantity with the unit of stress, i.e. MPa, which can be considered to be a property of the material under consideration

NOTE It 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 for a time of 50 years with internal water pressure.

3.8
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 It is denoted as $\sigma_{LPL} = \sigma_{(T,t,0,975)}$.

NOTE 2 The value of this quantity is determined by the method given in ISO 9080.

3.9
minimum required strength
MRS
required value of σ_{LPL} for a temperature T of 20 °C and a time t of 50 years

NOTE 1 For a particular material, its MRS is established from the value of σ_{LPL} rounded to the next lower value of the R 10 series from ISO 3:1973, when σ_{LPL} is less than 10 MPa, or to the next lower value of the R 20 series when σ_{LPL} is greater than 10 MPa.

NOTE 2 See also ISO 4422-2:1996, Clause 5.

3.10
overall service (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}

3.11
pipe series
S
dimensionless number for pipe designation

NOTE See ISO 4065.

3.12
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 According to ISO 4065, the standard dimension ratio, SDR, and the pipe series S are related, as expressed in the following equation:

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

4 Symbols and abbreviated terms

4.1 Symbols

C overall service (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

K K-value

p internal hydrostatic pressure

p_T test pressure

PN nominal pressure

δ material density

σ hydrostatic stress

σ_s design stress

4.2 Abbreviations

LPL Lower predicted confidence limit

MRS minimum required strength

PFA allowable operating pressure

PVC-U unplasticized poly(vinyl chloride)

S pipe series

SDR standard dimension ratio

5 Material

5.1 General

The material from which the pipes are made shall be PVC-U compound. This compound shall consist substantially of PVC-U resin, to which shall be added only those additives necessary to facilitate the production of pipes and fittings in accordance with this International Standard. All additives shall be uniformly dispersed.

The K value of the PVC-U resin used shall be at least 64, when tested in accordance with ISO 1628-2.

When determined in accordance with ISO 2507-1 and ISO 2507-2, the Vicat softening temperature of the compound shall be not less than 80 °C.

5.2 Rework material

The use of the manufacturer's own reprocessable material, produced during the manufacture and works testing of products and conforming to the material requirements of this International Standard, is permitted. No reprocessable or recyclable material obtained from external sources shall be used.

6 Effect of materials on water quality

When used under the conditions for which they are designed, materials in contact with, or likely to come into contact with, drinking water shall not constitute a toxic hazard, shall not support microbial growth and shall not give rise to any unpleasant taste or odour, cloudiness or discoloration of the water.

Where applicable, pipes and their joints and the sealing rings shall conform to the current national regulations concerning materials in contact with drinking water.

7 Material classification

7.1 MRS value

Oriented pipes made from a defined PVC-U compound and with a well-defined orientation level, in tangential and axial direction, shall be evaluated according to the procedures of Annex A. The minimum required strength (MRS) values shall be classified in accordance with 7.3 and Table 1.

7.2 Overall service (design) coefficient

The overall service (design) coefficient of oriented PVC-U pipes shall be a minimum of 1,6. Alternatively, 1,4 is permitted for MRS 450 and MRS 500, provided that axial contraction of the pipe (due to higher design stress) does not result in pull-out of the joints. In this case, evidence shall be given according to Annex B.

7.3 Design stress

The design stress shall be based on the value of the lower confidence limit σ_{LPL} of the long term hydrostatic strength for the resistance to internal pressure as determined in accordance with ISO 9080. This σ_{LPL} value shall be converted into a minimum required strength (MRS) in accordance with ISO 12162. The MRS shall be divided by an overall service (design) coefficient C to give the design stress σ_s, which is expressed by the following equation.

$$\sigma_s = \frac{\text{MRS}}{C}$$

Table 1 — Material classification

Pipe material classification number		315		355		400		450			500		
MRS	MPa[a]	31,5		35,5		40		45			50		
C		1,6	2	1,6	2	1,6	2	1,4	1,6	2	1,4	1,6	2
σ_s	MPa	20	16	22	18	25	20	32	28	23	36	32	25

[a] Higher MRS classes may be chosen, provided they fall in the R20 range of ISO 3:1973.

8 Classification and selection of pipes

8.1 Classification

Pipes shall be classified to their nominal pressure PN.

The nominal pressure PN, the pipe series S and the design stress, σ_s, are connected by the following relationship.

$$PN \cong \frac{10\sigma_s}{S}$$

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

$$SDR = \frac{d_n}{e_n}$$

$$\sigma_s = \frac{MRS}{C}$$

where

e_n is expressed in millimetres (mm);

PN is expressed in megapascals (MPa);

MRS is expressed in megapascals (MPa);

C is nondimensional.

8.2 Calculation of wall thickness

The relationship between the nominal wall thickness e_n and the nominal outside diameter d_n is specified in ISO 4065. The values for nominal pipe wall thickness e_n for nominal pressure ratings PN, can be calculated by substituting the values for MRS, C, and d_n in the formula

$$e_n = \frac{d_n}{2S_o + 1}$$

where S_o is the calculated preferred value of the nominal S series number of the pipe from 8.1.

Values shall be rounded to one decimal place according to the rules of ISO 4065.

NOTE Nominal S numbers and their calculated values are given in ISO 4065 for the R10 series of preferred numbers. For the R20 series required for this International Standard, refer to ISO 3.

The nominal outside diameter and nominal wall thickness for the relevant nominal pressure and material classes are specified in Table 2.

8.3 Determination of the allowable operating pressure, PFA, for temperatures up to 45 °C

The allowable operating pressure, PFA, for temperatures up to 25 °C is equal to the nominal pressure, PN.

To determine the allowable operating pressure, PFA, for temperatures between 25 °C and 45 °C, a supplementary derating factor, f_T, shall be applied to the nominal pressure, PN, as follows:

$$[PFA] = f_T \times [PN]$$

This factor is given in Figure C.1.

8.4 Derating factor related to application of the system

For applications which need additional derating factors, e.g. more safety than included in the overall service (design) coefficient, an additional factor f_A shall be chosen at the design stage.

The allowable operating pressure in continuous use shall be then calculated by

$$[PFA] = f_T \times f_A \times [PN]$$

NOTE [PFA] and [PN] are expressed in the same unit of pressure, preferably in bar.

Table 2 — Nominal outside diameters d_n and nominal wall thickness e_n

Material class	Pressure class PN for design coefficient C = 1,6												
315	6,3		8		10		12,5		16		20		25
355		8		10		12,5		16		20		25	
400	8		10		12,5		16		20		25		
450		10		12,5		16		20		25			
500	10		12,5		16		20		25				
	Pressure class PN for design coefficient C = 1,4												
450	10		12,5		16		20		25				
500		12,5		16		20		25					
	Pressure class PN for design coefficient C = 2,0												
315	5		6,3		8		10		12,5		16		20
355		6,3		8		10		12,5		16		20	
400	6,3		8		10		12,5		16		20		25
450		8		10		12,5		16		20		25	
500	8		10		12,5		16		20		25		
Pipe series S numbers preferred and computed values (ISO 3) and standard dimension ratios (SDR)													
S	32,0	28,0	25,0	22,4	20,0	18,0	16,0	14,0	12,5	11,2	10,0	9,0	8,0
S_{calc}	31,623	28,184	25,119	22,387	19,953	17,783	15,849	14,125	12,589	11,220	10,000	8,9125	7,9433
SDR	65,0	57,0	51,0	45,8	41,0	37,0	33,0	29,0	26,0	23,4	21,0	19,0	17,0
d_n	e_n, mm												
63					1,6	1,8	2,0	2,2	2,5	2,7	3,0	3,4	3,8
75			1,5	1,7	1,9	2,1	2,3	2,6	2,9	3,2	3,6	4,0	4,5
90		1,6	1,8	2,0	2,2	2,5	2,8	3,1	3,5	3,9	4,3	4,8	5,4
110	1,8	2,0	2,2	2,4	2,7	3,1	3,4	3,8	4,2	4,7	5,3	5,9	6,6
125	2,0	2,2	2,5	2,8	3,1	3,5	3,9	4,3	4,8	5,4	6,0	6,7	7,4
140	2,2	2,5	2,8	3,1	3,5	3,9	4,3	4,8	5,4	6,0	6,7	7,5	8,3
160	2,5	2,8	3,2	3,5	4,0	4,4	4,9	5,5	6,2	6,9	7,7	8,5	9,5
180	2,8	3,2	3,6	4,0	4,4	5,0	5,5	6,2	6,9	7,7	8,6	9,6	10,7
200	3,2	3,5	3,9	4,4	4,9	5,5	6,2	6,9	7,7	8,6	9,6	10,7	11,9
225	3,5	4,0	4,4	5,0	5,5	6,2	6,9	7,7	8,6	9,6	10,8	12,0	13,4
250	3,9	4,4	4,9	5,5	6,2	6,9	7,7	8,6	9,6	10,7	11,9	13,3	14,8
280	4,4	4,9	5,5	6,2	6,9	7,7	8,6	9,6	10,7	12,0	13,4	14,9	16,6
315	4,9	5,5	6,2	6,9	7,7	8,7	9,7	10,8	12,1	13,5	15,0	16,8	18,7
355	5,6	6,2	7,0	7,8	8,7	9,8	10,9	12,2	13,6	15,2	16,9	18,9	21,1
400	6,3	7,0	7,9	8,8	9,8	11,0	12,3	13,7	15,3	17,1	19,1	21,3	23,7
450	7,0	7,9	8,8	9,9	11,0	12,4	13,8	15,4	17,2	19,2	21,5	23,9	26,7
500	7,8	8,8	9,8	11,0	12,3	13,7	15,3	17,1	19,1	21,4	23,9	26,6	29,7
560	8,8	9,8	11,0	12,3	13,7	15,4	17,2	19,2	21,4	23,9	26,7	29,8	33,2
630	9,9	11,0	12,3	13,8	15,4	17,3	19,3	21,6	24,1	26,9	30,0	33,5	37,4

9 General requirements for pipes

9.1 Appearance

When viewed without magnification, the internal and external surfaces of the pipe shall be smooth, clean and free from scoring, cavities and other surface defects which would prevent conformity with this International Standard. The material shall not contain visible impurities. The ends of the pipe shall be cut cleanly and square to the axis of the pipe.

9.2 Opacity

If a pipe is required to be opaque for use in above ground applications, the wall of the pipe shall not transmit more than 0,2 % of visible light falling on it when tested in accordance with ISO 7686.

10 Geometrical characteristics for pipes

10.1 Measurement

The dimensions of pipes shall be measured in accordance with ISO 3126.

It is recommended that pipes be supplied in one or more of the following lengths: 6 m, 10 m, 12 m, where these lengths do not include the depth of any socket(s).

10.2 Outside diameters and wall thicknesses

The nominal outside diameter of pipes in accordance with ISO 161-1, and the corresponding wall thickness, shall be selected from Table 2 as appropriate for size, nominal pressure and pipe material class.

The tolerances on mean outside diameters shall be in accordance with ISO 11922-1:1997, grade C.

The tolerances on the mean wall thickness shall be specified by the manufacturer; otherwise, they shall be in accordance with ISO 11922-1:1997, grade W.

NOTE Due to the additional processing step of the orientation of the material, the spread on mean wall thickness of the PVC-O pipe could be increased.

The tolerances on out-of-roundness shall be in accordance with ISO 11922-1:1997, grade M.

For PN 25, nominal diameters from ISO 2531 may also be used.

10.3 Pipes with integral sockets

The minimum depth of engagement of integral sockets with elastomeric sealing ring type joints shall conform to ISO 2045.

Attention is drawn to the fact that the depths of engagement required by ISO 2045 could be insufficient for PVC-O pipes under certain circumstances. It is recommended that the suitability of depth of engagement be verified. In Annex B example is given of calculation of depth of engagement.

NOTE There is no minimum wall thickness requirement for sealing ring type sockets. It is considered as being more relevant to verify the strength of the sockets as being at least the same as the strength of the pipe in accordance with 11.1.2.

Although this International Standard covers only pipes and joints of PVC-O materials, the requirements of depth of engagement are relevant to couplers of other materials that can be employed with PVC-O pipes. Shorter depths of engagement may be suitable where restricted to 6 m and shorter lengths.

10.4 Plain ends

Pipes with plain end(s) to be used with elastomeric sealing ring type joints shall have a chamfer conforming to Figure 1 with 12° < α < 15°.

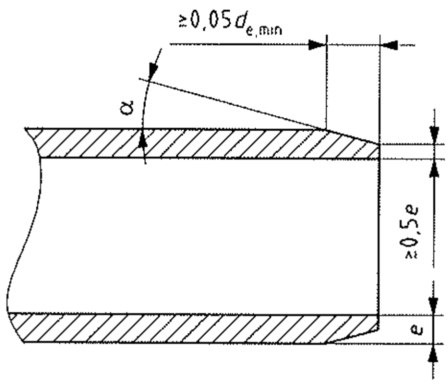


Figure 1 — Spigot end for pipes with elastomeric sealing ring

11 Mechanical characteristics of pipes

11.1 Resistance to hydrostatic pressure

11.1.1 Pipes

Resistance to hydrostatic pressure shall be verified using the induced stresses derived from the analysis of the test data in accordance with ISO 9080. For a period of 10 h at 20 °C and at the time of 1 000 h at 20 °C, the 99,5 % LPL value shall be taken as the minimum stress level.

For a period of 1 000 h at 60 °C, the 99,5 % LPL value established from analysis of test data at 60 °C in accordance with ISO 9080 can be taken as the minimum stress level. In case of a lack of data, alternatively, a value of 0,625 times the MRS value shall be taken as the minimum stress level.

When tested using either end cap type A or type B in accordance with ISO 1167-1:2006, and using the combinations of test temperatures and induced stresses so derived, the pipe shall not fail in less than the times stated above.

See Annex A for the procedure to establish 20 °C test stress values for testing under provisional qualification.

11.1.2 Pipes with integral socket

When tested in accordance with ISO 1167, using the test procedure as given in 11.1.1, integral sealing ring sockets formed on pipes shall not fail in less than the time according to 11.1.1. The length of the pipe section shall meet the requirements or specification given in 11.1.1. Failure shall not occur in either pipe or socket sections. Data obtained is valid for pipe specified in 11.1.1.

11.1.3 Pressure testing

Pressure testing shall be conducted in accordance with ISO 1167-1 with the following provisions.

a) End fittings: testing may be conducted using either end cap type A or type B, including for reference purposes. However, the same type of end caps shall be used for both acceptance and quality tests.

b) Number of specimens: one specimen shall constitute a test. In the event of a test failure, three more specimens may be selected from the same batch and tested, and shall pass.

c) Conditioning times: testing may proceed directly following the conditioning times stated in ISO 1167-1.

d) Socket tests: when testing integral sockets or couplings in accordance with 11.1.2, the pipe spigot inserted into the socket may be of different material or heavier gauge than the specimen under test. The sealing ring may be restrained from blow-out by adhesive or mechanical means, provided such means do not materially reduce the stress on the pressurized portion of the socket.

11.2 Resistance to external blows at 0 °C

Pipes shall be tested at 0 °C in accordance with ISO 3127, and shall have a true impact rate (TIR) of not more than 10 % when using masses given in Table 3. The radius of the striker nose shall be R = 12,5 mm.

Table 3 — Classified striker mass and drop height conditions for the falling-weight impact test

Nominal size DN	Total mass kg
63	4
75	5
90	5
110	6,3
125	6,3
140	8
160	8
180	10
200	10
⩾ 225	12,5

Drop height is 2 m.

NOTE 1 Masses are based on experience of pipe material classes 450 and 500. Masses for other pipe material classes are still under study.

NOTE 2 Impact characteristics can change over time. These values are applicable only at the time of manufacture.

11.3 Ring stiffness

The ring stiffness of pipes conforming to this International Standard may be determined in accordance with ISO 9969.

Pipes of stiffness less than 4 kN/m^2 might not be suitable where high vacuum or external pressure could be developed, and could need special installation techniques where installed below ground.

The calculated nominal stiffness of the pipes is given in Annex D.

12 Physical characteristics — Tensile strength

When determined in accordance with ISO 6259-2, the pipes shall have a minimum tensile strength of 48 MPa.

Test samples shall be prepared in accordance with ISO 6259-2:1997, 5.2.1, by machining.

13 Mechanical characteristics of assemblies, including joints

13.1 Assemblies with non-end-load-bearing joints

The following types of assemblies with non-end-load-bearing joints shall fulfil the fitness for purpose requirements given in 13.2 to 13.5 and Tables 4, 5 and 6, as applicable:

a) integrally socketed PVC-O pipe to pipe assemblies with elastomeric ring seal joints conforming to this International Standard;

b) metal fitting and PVC-O pipe assemblies with elastomeric ring seal joints;

c) metal valve and PVC-O pipe assemblies with elastomeric ring seal joints;

d) mechanical joint assemblies with PVC-O pipes.

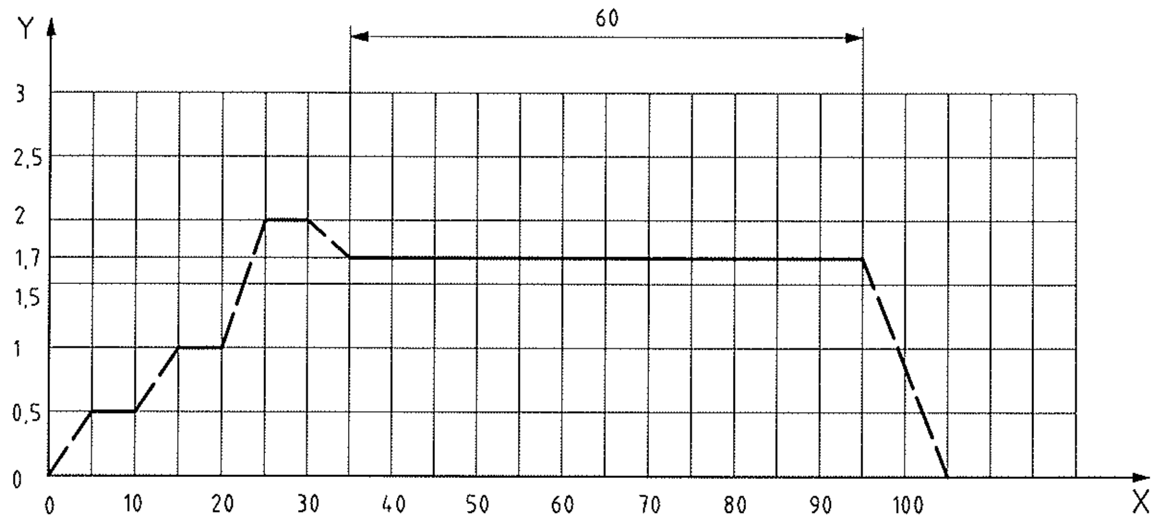
13.2 Short-term pressure test for leaktightness of assemblies

13.2.1 Test procedure

When an assembly with one or more elastomeric sealing ring type joints is tested using a hydrostatic pressure and angular deflection in accordance with ISO 13845, and the test conditions given in Table 4, the assembly shall conform to the requirement given in Table 4.

Table 4 — Test conditions and requirement for short-term assembly test

Test temperature °C	Test pressure bar	Test time	Test requirement
$T \pm 2$ where T is any temperature between 17 °C and 23 °C	Pressure calculated in accordance with Figure 2 and 13.2.2	One cycle in accordance with Figure 2	No leakage at any point of the jointing areas throughout the whole test cycle
NOTE The pressure changes from one pressure level to the next shall take place within the periods indicated, but need not take place at strictly linear rates.			



Key

X time, min

Y factor f

Figure 2 — Hydrostatic pressure test regime

13.2.2 Test pressure

The test pressures p_T shall be calculated by multiplying the factor f indicated in Figure 2 by the nominal pressure PN, i.e. by using the following equation:

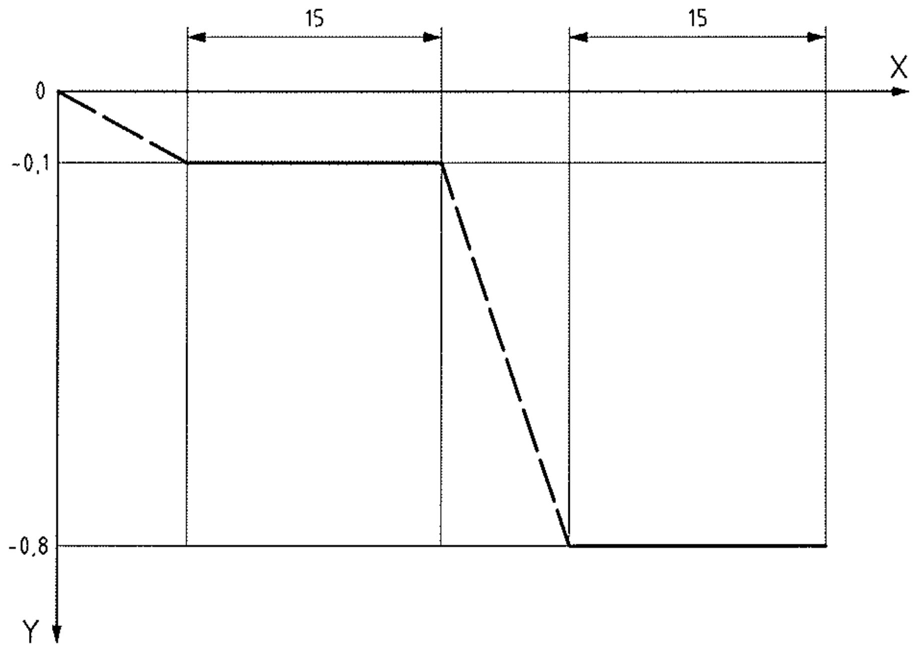
$$p_T = f \times PN$$

13.3 Short-term negative pressure test for leaktightness of assemblies

When an assembly with one or more elastomeric sealing ring type joints is tested using a negative pressure and angular deflection/deformation in accordance with ISO 13844 and the test conditions given in Table 5, the assembly shall conform to the requirement given in Table 5.

Table 5 — Test conditions and requirement for short-term negative-pressure assembly test

Test temperature °C	Test pressure bar	Test time	Test requirement
$T \pm 2$ where T is any temperature between 17 °C and 23 °C	Pressure calculated in accordance with Figure 3	One cycle in accordance with Figure 3	The change in negative pressure shall be not more than 0,005 MPa during each 15 min test period shown in Figure 3
NOTE The pressure changes from one pressure level to the next need not take place at strictly linear rates.			



Key

X time, min

Y pressure, bar

Figure 3 — Negative-pressure test regime

13.4 Long-term pressure test for leaktightness

When an assembly with one or more joints selected from elastomeric sealing ring type sockets and other end-load-bearing and non-end-load-bearing joints for oriented PVC-U components for a piping system is tested in accordance with ISO 13846, using the test conditions given in Table 6 for the test temperatures of 20 °C and 60 °C, the assembly shall conform to the requirement given in Table 6.

Table 6 — Test requirement for the long-term pressure testing of assembled joints

Test temperature °C	Test pressure[a] bar	Test time	Test requirement
20	1,4 PN	1 000	No leakage at any point of the jointing areas for at least the test time
40	1,1 PN	1 000	

[a] The PN rating used in this calculation is the PN rating of the fitting or, if pipe with an integral joint is being tested, the PN rating of the pipe. See Annex E for an explanation of the values.

13.5 End-load-bearing joints — Pressure and bending test for leaktightness and strength

When end-load-bearing joints having one or more sockets (see note) and fitted with one or more elastomeric sealing rings together with one or more locking rings to withstand the longitudinal forces resulting from the application of internal hydraulic pressure are tested in accordance with ISO 13783 at a single ambient temperature of ($T \pm 2$)°C (where T is any temperature between 17 °C and 23 °C), the joint shall remain leaktight throughout the whole of the test period.

NOTE Such joints are usually, but not necessarily, in the form of double sockets.

14 Elastomeric sealing rings

Elastomeric sealing rings used for joining components shall conform to both of the following requirements:

a) the rings shall conform to the material requirements specified in ISO 4633;

b) the rings shall be free from chemical agents (e.g. plasticizers) that could have a detrimental effect on the pipes or fittings, or on the quality of the water.

15 Marking

Pipes shall be permanently marked at intervals not greater than 1 m.

The markings shall include at least the following information:

a) the manufacturer's name or trade mark;

b) the pipe material and material classification, e.g. PVC-O 400;

c) the nominal outside diameter d_n and nominal wall thickness e_n, e.g. 160 × 3,1;

d) reference to this International Standard, i.e. ISO 16422;

e) the nominal pressure PN;

f) the C-factor, i.e. C = 1,4, C = 1,6 or C = 2,0;

g) production site;

h) production date or code.

Annex A
(normative)

Establishment of the minimum required strength (MRS)

A.1 General

The minimum required strength of materials for the purpose of this International Standard shall be evaluated according to the procedures of ISO 9080:2003 and ISO 12162, subject to the following provisions.

A.2 Test conditions of ISO 9080:2003, 4.1

In the case of dispute, pipe samples shall be of the smallest diameter produced commercially by the manufacturing process and plant in question.

A.3 Full qualification

In accordance with ISO 9080:2003, 4.2, tests at a single temperature of 20 °C shall be deemed sufficient, provided it is demonstrated that no "knee" exists.

This condition shall be considered satisfied if no knee is identified by analysis according to ISO 9080:2003, Annex B, of a series of minimum 10 observations at a single elevated temperature. The observations shall span 3 log decades of time and at least two observations shall be in excess of the minimum time required according to ISO 9080:2003, Clause 5, for valid extrapolation at 20 °C to 50 years[2]. Unfailed points may be used, provided they reduce the absolute value of the slope of the predicted regression line.

A.4 Provisional qualification

Prior to establishment of qualification under E.2, a product may be considered provisionally qualified for commercial purposes if compliance with the requirements of 11.1.1 are demonstrated. For this purpose, induced test stresses, to be applied for 10 h and 1 000 h at 20 °C, shall be derived as follows.

A test data series of minimum eight observations at 20 °C shall be analysed by simple linear regression using stress as the independent variable. The stress levels on this line at the 10 h and 1 000 h ordinates, less 5 %[3], shall be taken as the required induced test stresses.

The observations shall have the following failure time distribution

10 h ordinate	failure time:	$3 < t_1 < 30$	4 points minimum
1 000 h ordinate	failure time:	$300 < t_2$	4 points minimum

Unfailed points may be used, provided they increase the computed test stresses.

A provisional qualification may be issued under this International Standard after commencement of the longest term test required for full qualification, and shall have a validity period of 18 months, non-renewable.

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2) For example, for tests at 60 °C, two test times shall exceed 4 383 h (extrapolation factor = 100).

3) It is not possible to form a reliable estimate of the 99,5 % LPL from analysis of limited data. Based on examination of live data, the 5 % offset is a reasonable estimate of the position of the 97,5 % LPL, and as such can be expected to be a conservative estimate of the 99,5 % LPL test point values derived from the final 30 point analysis.

Annex B
(informative)

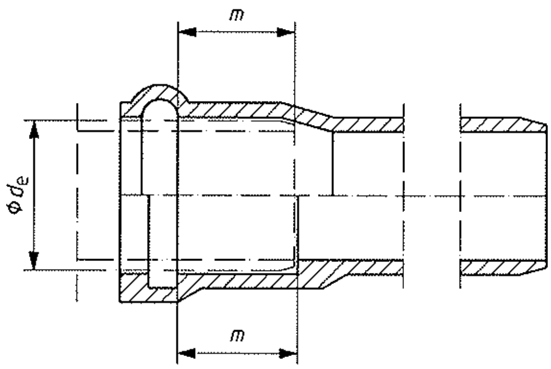
Minimum depth of engagement of sockets

B.1 General

The minimum depth of engagement of integral sockets with elastomeric sealing ring type joints is given in ISO 2045.

Attention is drawn to the fact that the depths of engagement required by ISO 2045 could be insufficient for PVC-O pipes according to ISO 16422 under certain circumstances, particularly pipes of length greater than 6 m, and could result in "pull out" and leakage under adverse conditions. Primarily, this is due to the higher strain levels developed at the higher operating stresses invoked in PVC-O pipes, compared with the PVC-U pipes for which ISO 2045 was developed.

The potential for pull-out also exists with short-socketed fittings of PVC or other materials used in conjunction with PVC-O pipes.



Key

m depth of engagement

d_e external diameter of pipe

Figure B.1 — Depth of engagement

B.2 Calculation of depth of engagement

B.2.1 Depth of engagement, m, is calculated by

$$m = m_p + m_t + m_a + m_c + m_s$$

where m is the sum of B.2.2 to B.2.6.

B.2.2 Poisson contraction — shortening of length when pressurized:

$$m_p = \frac{L \times \mu \times \sigma}{E_c}$$

where

- L is the length of pipe in metres;
- μ is the Poisson ratio (0,45);
- σ is the hydrostatic stress in the circumferential direction in MPa;
- E_c is the elastic modulus in the circumferential direction (2,0 GPa)

σ is usually taken as the long-term operating stress at working pressure, or the design stress σ_s for the pipe material, and E_c as the long-term creep modulus.

EXAMPLE For an MRS 500 pipe C = 1,6 and σ_s = 32 MPa, then $m_p = 6 \times 0{,}45 \times 32/2{,}0 = 43$ mm.

For buried pipelines, resistance to contraction is offered by the soil and the full Poisson contraction is unlikely to be realized. However, an unrestrained above-ground pipeline may be subject to the full contraction. A worst-case situation arises during field testing of lines not yet back-filled, where a test pressure margin of 25 % could be applied.

EXAMPLE With a short-term modulus of 4,0 GPa, then $m_p = 6 \times 0{,}45 \times 32 \times 1{,}25/4{,}0 = 27$ mm.

B.2.3 Temperature contraction — shortening due to drop in temperature:

$$m_t = L \times \alpha \times \Delta T \times 10^3$$

where

- L is the length of pipe, in metres;
- α is the coefficient of linear expansion (7×10^{-5}) °C^{-1};
- ΔT is the temperature differential, in degrees Celsius.

This can occur, for example, during construction as a result of filling the pipeline with water. Again, for buried pipelines, soil friction will reduce the range of movement, but above ground lines could realize the full contraction. Some specifications also require an expansion gap to be allowed between the spigot and the back of the socket to accommodate a possible rise in temperature.

EXAMPLE A total ΔT of 50 °C gives $m_t = 6 \times 7 \times 10^{-5} \times 50 \times 10^3 = 21$ mm.

B.2.4 Angular deflection — retraction of one side of the spigot due to angular deflection of the spigot within the socket:

$$m_a = \frac{d_e \times \pi \times \theta}{180}$$

where θ is the maximum angle of deflection of spigot within socket degrees.

Most parallel joints are capable of spigot/socket deflection of less than 1°.

EXAMPLE For a DN 315 joint, this gives $m_a = 315 \times \pi/180 = 5$ mm.

Deflection joints can have greater capability and require proportionately more allowance.

B.2.5 Chamfer length — length of chamfer c, in millimetres, shall be included in the available depth of engagement, as per the manufacturer's specification.

EXAMPLE for DN 315: $m_c = c = 25$ mm.

B.2.6 Safety allowance S — for construction error m_s.

EXAMPLE m_s = S = 20 mm.

B.2.7 Example — the above allowances for a 6 m DN 315 pipe total

$$m = m_p + m_t + m_a + m_c + m_s = 114 \text{ mm}$$

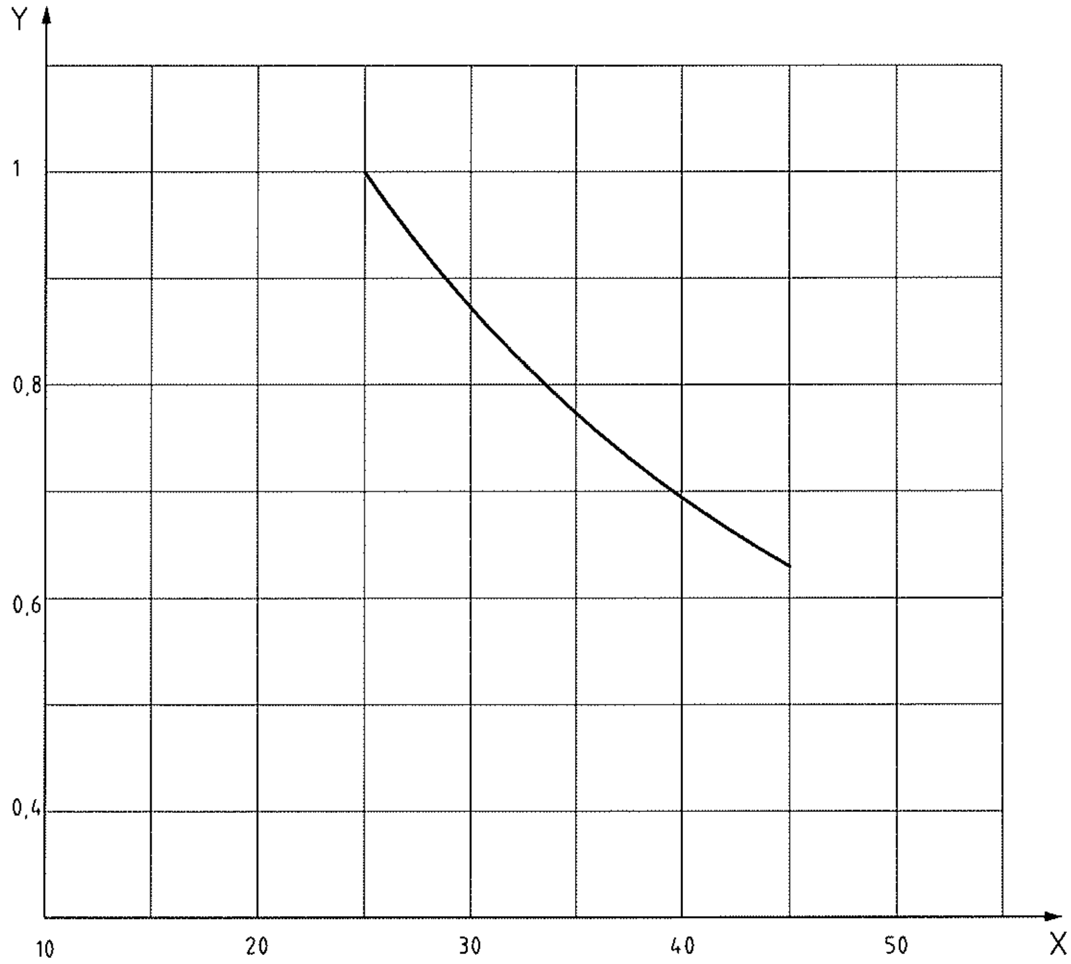
The standard engagement length according to ISO 2045 is 118 mm.

Where full Poisson contraction may occur, this joint would be inadequate for a 12 m pipe length.

Annex C
(normative)

Temperature derating factor

Temperature derating information given in Figure C.1 may be used as a guide unless real figures from manufacturers are available.



Key

X temperature, °C

Y derating factor, f_T

Figure C.1 — Derating factor f_T as a function of operating temperature

Annex D
(informative)

Ring stiffness of pipes

D.1 Calculation of initial ring stiffness

For design purposes, the calculated initial ring stiffness of the pipes can be derived from Table D.1.

Table D.1 — Initial ring stiffness of pipes

Pipe material class	Theoretical minimum stiffness kN/m²				
	PN				
	10	12,5	16	20	25
315	4,6	8,9	18,7	36,5	71,2
355	3,9	7,6	16,0	31,3	61,1
400	2,7	5,2	10,9	21,3	41,7
450	1,9	3,7	7,8	15,2	29,7
500	1,3	2,5	5,2	10,2	19,9

This value has been calculated from the formula

$$S_{\text{calc}} = \frac{E \times I}{(d_{\text{n}} - e_{\text{n}})^3} = \frac{E}{96\,(\text{S})^3}$$

where

S_{calc} is the calculated initial ring stiffness in kN/m²;

E is Young's modulus:

— for pipe class 315, $E = 3{,}5 \times 10^6$ kN/m²;

— for pipe class 355 and higher, $E = 4 \times 10^6$ kN/m²;

I is the moment of inertia = $1/12 e_{\text{n}}^3$, in cubic millimetres per metre (mm³/m).

NOTE The stiffness values are calculated on the basis of minimum wall thickness at any point $e_{\text{y,min}} = e_{\text{n}}$ (see 3.2). Since the stiffness is a function of the mean wall thickness, it is statistically not possible for these values to be realized in practice, and the real stiffness will be significantly greater. For a tolerance of 15 % of wall (grade T), the mean could reasonably be expected to be around 5 % over minimum, and the stiffness correspondingly 16 % higher than the above results.

D.2 Negative pressure capability of pipes

Pipes may be subject to unstable buckling under negative pressure conditions due to vacuum and/or external or groundwater pressure, if unsupported by soil or other lateral stiffening devices.

Table D.2 — Negative pressure capabilities of pipes

Pipe material class	P_{cr} kPa				
	PN				
	10	12,5	16	20	25
315	137	268	562	1 097	2 143
355	118	230	482	942	1 840
400	80	157	329	642	1 254
450	57	112	234	457	893
500	38	75	157	306	598

These values have been calculated from the formula

$$P_{cr} = \frac{24\ S_{calc}}{(1-\upsilon^2)}$$

where

P_{cr} is the unsupported critical buckling pressure, in kilopascals (kPa);

υ is Poisson's ratio, which can be assumed to have a value of 0,45.

NOTE The critical buckling pressure can likewise be expected to be around 16 % higher than these values in practice. No other design coefficient is incorporated.

When pipes are buried with cover exceeding two diameters, lateral soil support will increase buckling pressures significantly. Users should refer to appropriate engineering texts for advisory material.

Annex E
(informative)

Explanation of calculated pressures for long-term leak-tightness testing

For details of the calculation of the factors, see ISO 4422-5:1997, Annex A, for σ_s = 12,5 MPa.

It is considered that for PVC-O pipes these factors are the worst case. Where a manufacturer has made available stress/strain data, the actual factors may be derived from this information in accordance with the method given in ISO 4422-5:1997, Annex A.

Bibliography

[1] ISO 4422-5:1997, *Pipes and fittings made of unplasticized poly(vinyl chloride) (PVC-U) for water supply — Specifications — Part 5: Fitness for purpose of the system*